DLT-based sustainable business models for the shipping industry

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Acknowledgement
The authors thank Dr. Carsten Sørensen of London School of Economics and Political Science, for referring us to the research work of Dr. Thomas Jensen on TradeLens, as well as thoughtful discussions on the topic of information infrastructures.

No external funding has been received for the development of this research.

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Structured Abstract

Purpose

This paper explores how distributed ledger technology (DLT), aka blockchain, might function as the technological basis for sustainable business models (SBM) in the shipping industry. More specifically, it examines the role that DLT can have in generating circular economies for information resources as well as inter-firm collaboration inside shipping.

Design/methodology/approach

We present a conceptual model depicting the relationship between DLT and sustainable shipping, and conduct an exploratory case study about a DLT-based information platform for global supply chains, using content analysis technique.

Main findings

Our preliminary assessment finds that DLT, by allowing increased information circularity and associative behaviours between supply-chain actors, undergirds SBM and drives sustainable practices in the shipping industry.

Originality/value
The research extends previous literature on DLT technology and its impact on the circular economy, associative business models, and inter-firm coordination in general. It does so under the context of maritime shipping, extending both maritime literature and DLT/blockchain technology research, presenting a case study on a real-life deployment of DLT technology in the context of maritime shipping.

Keywords: Sustainable business models, sustainable shipping, distributed ledger technology, information circularity, associative behaviours, TradeLens.

1. Introduction

Ever since the Brundtland Report defined sustainability as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’ (WCED, 1987), the topic has been increasingly present in academic research and policy discussions. Concepts like the triple bottom line (Elkington, 1998) —where the performance of an organization or industry is not only measured in economic terms, but also according to its social and environmental impact—, have entered the jargon of scholars, politicians, and executives. Throughout the last decade, the focus on climate change, socially inclusive economic growth, and corporate social responsibility has only increased. Environmental, social and governance (ESG) criteria are now taken on account for investments and asset valuations (Gregory et al., 2020); and recently, 181 US CEOs, including some of the biggest global corporations, declared that the purpose of a corporation could no longer be limited to benefit its shareholders, but that it had also to generate value to all stakeholders, including customers, employees, the environment and the whole of society (Business Roundtable, 2019).

Given its significance for the global economy, the shipping industry has been anything but alien to this increased focus on sustainability, with a surging number of publications on sustainable shipping (Shin et al, 2018). At the same time, the concept of sustainable business models (SBM) has gained ground in strategic management studies. In parallel, the shipping industry has also given heightened attention to digitalisation. Among emerging technologies related to digitalisation of business processes, distributed ledger technology (DLT), better known as blockchain (we use the terms interchangeable throughout this paper), has promised to bring about unprecedented levels of efficiency, coordination, and transparency.

While these three areas —sustainable shipping, sustainable business models and distributed ledger technology— have been researched in maritime and transportation studies, few papers have explored their interrelationship. On the one hand, how does DLT might have an impact on sustainable practices and business models has indeed been studied (Bai and Sarkis, 2020; Lund et al., 2019; Upadhyay et al., 2021); but despite its importance for global value chains — 80% of all trade in goods is done by sea (UNCTAD, 2020)— there is a gap in the literature on this topic inside the maritime context. On the other hand, there are already numerous studies on DLT use cases in the maritime shipping industry, but with some exceptions (Clott et al., 2020), their focus is not on sustainability.

To address this gap, this paper adopts an interdisciplinary perspective. It delves on concepts like “circular economy” from sustainability research and applies them in the context of information flows in the shipping industry and maritime supply chains. As a result, it proposes an original concept: information circularity, locating it inside a conceptual framework that purports to explore how DLT technology might positively influence sustainability practices and business models in the shipping industry.

The research question that this paper aims to answer can be expressed as follows:

RQ: What impact does DLT has on the adoption of SBM, as well as sustainable practices, in the shipping industry?

The relevance of the RQ to be addressed is derived from the increasing need of understanding the drivers of sustainable practices and business models and the role that certain technologies, like DLT, might play in different contexts. Sustainable economies are the result of efforts and improvements in different dimensions, one of which is the availability of new technologies (Linnér and Wibeck, 2021). The RQ's value and purpose is therefore to explore and shed light on how a specific technology (DLT) might drive sustainability in a specific context (maritime shipping).

Accordingly, this paper adopts a bottom-up exploratory approach. Instead of trying to provide a general explanation on how technology drives sustainability, it looks to provide insights on concrete real case applications. In particular, how DLT technology would impact the adoption of SBM in the shipping industry and, in turn, sustainable shipping practices. To this end, we elaborate a conceptual model based on previous literature, and then conduct an initial assessment by conducting an exploratory case study about a real-life DLT-based information platform in the shipping industry: TradeLens.

The remainder of the paper is organised as follows. Section 2 provides a background on the several theoretical dimensions of the research. Section 3 presents the research methodology. In Section 4, we develop our conceptual model. Section 5 presents an exploratory case study on TradeLens, a DLT-based shipping information platform. In Section 6, we discuss the case and assess the conceptual model provided. Section 7 concludes by presenting the contributions, managerial implications, limitations and suggestions for further research.

2. Theoretical Background

To address the research question, this paper delves into theoretical constructs from the literature on information resource management (Cleveland, 1982; Eaton and Bawden, 1991; Ward and Carter, 2019), sustainable shipping management (Lirn et al., 2014; Yuen et al., 2019; Tran et al., 2020), sustainable business models (Geissdoerfer et al., 2017; Lüdeke-Freund et al., 2017; Gallo et al., 2018), and distributed ledger technology (Kouhizadeh et al., 2019; Saberi et al., 2019; Yang, 2019).

Reflecting the interdisciplinary approach of this study, this section is divided into several topics. These topics provide the theoretical bases upon which the conceptual model is then developed in Section 4.

2.1. Information as a resource

Whether or not information could be truly considered as a resource, was a debated topic in the 1980's and 1990's. A whole sub-field in management science, information resource management (IRM), developed from the general concept of "information economy", which characterised information as a commodity (Cooper, 1983; Repo, 1989). IRM prescribed that resource management principles and techniques proper of different types of resources like property, energy or money, should be equally applicable to manage information. Other authors pointed out the crucial differences between information and other kind of assets, most prominently the fact that information was expandable, did not decreased with its use, and could be shared but not exchanged (Cleveland, 1982; Eaton and Bawden, 1991).

Above these divergences, IRM's central tenet that —like other resources— information (whether or not a commodity) needs to be acquired, stored, processed and distributed is generally acknowledged by the management literature (Lewis et al., 1995; Ward and Carter, 2019). Stated more technically; information follows a resource-like life cycle, which includes collection, transmission, processing, storage, dissemination, use and disposal (Burk and Horton, 1988).

For maritime shipping and supply chains, information acquires a special relevance as a resource for sound decision making. Choosing the most efficient type of hinterland transportation mode (Zuidwijk and Veenstra, 2015) or the optimal container yard stowage and order-picking (Gharehgozli et al., 2016; Conca et al., 2018), depends on real-time information about relevant facts such as a vessel's ETA. In turn, determining the optimal vessel's ETA for a port call (and therefore its sailing speed) depends on information about port congestion levels (Meng and Wang, 2014). While complex algorithm-based schedule design can cope (up to a point) with these uncertainties (Wang and Meng, 2012a, 2012b), an increase in information would traduce in higher efficiencies and easier decision making.

Therefore, information (or, more precisely, accurate, relevant and timely information) constitutes an input for decision making and business processes. Even if different than other resources like financial capital or raw materials, it shares with them a basic life cycle: it is obtained, it is used as an input for a process, and afterwards consumed. The later deserves some additional commentary.

That information is consumed does not mean that it decreases or is depleted with usage, like financial or physical resources. The fact that a vessel with 50 containers is to arrive at time t1 will be known well after t1. In fact, after the vessel has arrived, t1 will be determined with full certainty and precision, and the information will not be lost after the fact. Nonetheless, the value of this information at t0 is significantly superior than at t1+n: knowing with a 90% probability degree that a vessel's ETA is between 01:25h and 01:45h of the next day, is far more valuable than knowing with 100% certainty that a vessel's ATA was 01:37h last week. In general, after the set of decisions and procedures for which information constitutes an input has been executed, the latter's value (not its amount) significantly decreases. It is in this sense that information can be said to be consumed as a resource.

2.2. Sustainable shipping

Literature on sustainable shipping has focused on the benefits of sustainable shipping for performance, under the above-mentioned triple bottom approach of economic, environmental, and social value (Lirn et al., 2014, Shin and Thai, 2016). Recent studies have analysed how sustainable shipping should be achieved by maritime firms, identifying a set of critical factors and resources for sustainable shipping management (SSM) (Yuen et al., 2019; Tran et al., 2020).

The theoretical lenses generally used to analyse SSM are the resource-based view (RBV) from strategic management, the relational view (RV) and the knowledge-based view (KBV). In line with these approaches, intra-firm resources, inter-firm resources, and organizational learning, are identified as drivers of sustainable shipping (Yuen et al, 2019). The RV, in particular, focuses on specific elements of intra-firm interactions that contribute to sustainability: contractual governance, interfirm relationship management, information sharing, and complementary resources and capabilities.

This "inter-firm" element —as opposed to the "intra-firm" aspect focused by the RBV— is gaining ground as the key basis for sustainable shipping. While a firm's internal resources and management directly contribute to sustainable shipping practices, it is at the inter-firm network level that sustainability is properly achieved (or failed to be achieved). Planning and decision making at the strategic, tactical and operational levels is required for greener shipping (Lu et al., 2016), entailing in turn joint decision making between shipping actors, e.g.: liner shipping companies and port operators (Meng and Wang, 2014). Furthermore, external sustainable collaboration at the inter-firm network level is positively correlated with intra-firm sustainable management and performance (Yuen et al, 2019; Wu et al., 2020).

2.3. Sustainable business models

The theoretical construct of a sustainable business model (SBM) has emerged in the last years as an offspring of the literature on business model innovation and sustainability. Some scholars consider research on SBM as a field in its own right, calling for an integrative research agenda (Lüdeke-Freund et al., 2017). One of the central tenets behind the construct of SBM is derived from the sociological concept of "embeddedness" (Granovetter, 1985). It is realised that business models' basic elements (value creation, value delivery and value appropriation) are embedded in wider economic, environmental and social contexts (Upward and Jones, 2016). This embeddedness is reflected in the search for business models that are more concerned with environmental and societal well-being, and the surge of new theoretical constructs related to sustainability.

One of these emerging constructs is the notion of a "circular economy". Defined as a 'regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops' (Geissdoerfer et al., 2017, 766), the concept has gained notability in research and policy discussions, most prominently in China (Yuan et al, 2006; Sarkis and Zhu, 2008) and the European Union (European Commission, 2015). The core idea is that a value chain should strive for circularity, where value aggregating processes do not follow a linear path of make-use-dispose, but instead a circular cycle where outputs can be turned into inputs for further processes. More specifically, the ReSOLVE model deconstructs circularity into 6 strategies: regenerate, share, optimise, loop, virtualise, and exchange (Ellen MacArthur Foundation, 2015). Circularity, therefore, is a core building block of a sustainable business model.

Another business block of an SBM has to do with the "coordination" and "inter-firm" perspective based on the above-mentioned relational view. It is understood that true sustainable development is only possible through collaborative actions between actors and organizations at the network level, rather than at the individual firm level. Gallo et al. (2018) thus propose the construct of an associative sustainable business model as a sub-category of SBM, defining it as 'those business models deeply grounded in associative behaviours and partnerships to create value in the triple bottom line' (Gallo et al., 2018, p. 906).

2.4. Distributed ledger technology

Distributed ledger technology (DLT), most commonly known as blockchain technology, has caught the attention of businesses, governments and academics alike. It has generated massive expectations, many of them based on misunderstandings on what the technology is really about. Nonetheless, a second "slope of enlightenment" (to use the terminology of the Gartner cycle), where the true potential of DLT will manifest beyond the cryptocurrency frenzy, is predicted to be around the corner (Kietzmann and Archer-Brown, 2019).

At its core, DLT is a distributed database controlled by multiple nodes on a network, where certain events are registered in such a way that they cannot be modified or tampered with, and where any new event most be congruent with the last state of the system (Drescher, 2017). Bitcoin, the original DLT's use case, provides a good practical example of this: if the state of the Bitcoin ledger at time t is that public key A has 100 BTC and public key B has 50 BTC, an event that modifies the system such that at time t+1 A has 50 BTC and B has 100 BTC is valid, while an event where A would have 80 BTC and B also have 80 BTC is not.

This functionality is not limited to registering crypto-currency transactions, but allows for the automatic execution of pre-defined processes in the form of smart contracts (SC). SC have been defined as automatable and enforceable agreements (Clack, 2018), into which business logic or heuristic can be embedded. Thus, standardized business processes, even if they involve several untrusting parties, could be automated and more efficiently executed (Weber et al, 2016).

The business impact of DLT is expected to span several industries, but most specially finance (Guo and Liang, 2016) and supply chain (Dujak and Sajter, 2019). In the specific context of maritime shipping, DLT is expected to streamline processes that are currently delayed due to paperwork problems, such as container movements, custom clearance, reducing document forges and fraud, as well as enabling tracking and tracing systems (Yang, 2019).

The technology has also been hailed as a sustainability enabler. Kouhizadeh et al. (2019) consider that DLT contributes to the circular economy by enhancing resource regeneration and closed loop processes. Moreover, due to its reliability and immutability, DLT would substantially increase transparency, traceability and security along the supply chain, allowing to confirm and verify that processes conform to sustainability standards (Saberi et al., 2019).

3. Research Method

This study follows the exploratory research methodology through a case study. Both exploratory research and case studies have been considered appropriate for the analysis of contemporary phenomena, where empirical data from which to derive statistical inferences is not available (Yin, 2009; Sreejesh et al., 2014). Moreover, the research follows the critical realism approach, which sustains that there is an external, causally driven reality, independent of our empirical perceptions; not to be reduced neither to the observable or measurable (positivism), nor to the outcome of socially constructed meanings (interpretivism). Critical realism provides a sound epistemological basis for case studies in general (Easton, 2010), and for information systems research in particular (Mingers et al., 2013).

The subject of the case study is TradeLens, a DLT-based information infrastructure platform for the shipping industry. The choice of TradeLens was based on the fact that, in contrast with other blockchain related initiatives in shipping, it is already a functioning platform capturing real-life data.

Given the exploratory nature of the research, and its early stage, data gathering is limited to documentary sources. The first source is provided by a previous case study about TradeLens, conducted by Jensen et al. (2019). This case study is particularly relevant, as one of the authors, working under an industrial PhD framework, was able to immerse himself for several years into the conception and development of TradeLens, gaining first-hand experience on the discussions and perspectives that led to the platform in its current form. The second source is TradeLens Documentation, published at its website (TradeLens, 2020). This comprises detailed descriptions of the platform's functionality, business model, architecture, and technological basis. A final source was an interview with an IBM global trade business development executive about TradeLens, conducted by a website dedicated to blockchain news and knowledge (Unblocked Events, 2019).

The data gathered about the case study subject is discussed in Section 6, as a way of evaluating the propositions that build the conceptual model presented in Section 4. The evaluation is done through content analysis, a technique for analysing text-based sources, with the objective of providing new insights, increase a researcher's understanding of particular phenomena, or inform practical actions (Weber, 1990; Krippendorff, 2019). Each of the propositions presented is evaluated against a validation scale with four possible scores: not valid (-), low validity (+), medium validity (++), and high validity (+++). It is important to point out that, at this early stage of the research, the evaluation is preliminary and does not intend to derive definite conclusions, but rather to increase the understanding of the subject of study and provide insights for a subsequent research stage. Moreover, while it would be desirable to compare the case of TradeLens with other DLT solutions in the shipping industry, the truth is that TradeLens is currently the only applied solution that is properly operational (Quarmby, 2021).

4. Conceptual model

In line with the exploratory nature of this research, this section presents a series of theoretical explorations conducing to propositions, and the depiction of a conceptual model based on them. This conceptual model offers a theoretical answer to the research question, and provides a basis to discuss the results of the case study.

4.1. Information flows and circularity

Integrating the view of information as a resource and the concept of circularity, prompts to enquiry in which sense, if any, could information flows be said to be circular. The following analysis explores the issue in the context of supply chain and shipping processes.

The notion of circularity, as observed in the theoretical background, rests on the idea of resource processing that does not follow the linear path of make-use-dispose, but rather creates a loop where the output of a value aggregating process can be re-used as the input of other value aggregating processes.

Information, as a resource, can be the input or the output/by-product of business processes. The construct 'business process' is to be understood in terms of its physical, financial and informational dimensions. Thus, the delivery of a container by a truck is a physical business process that generates GPS data as a by-product. This by-product data can be then transformed, through data analytics, into information which would be the input for business decisions about optimal times for port picking-up scheduling (Wasesa et al., 2017). In the same way, the request for a transportation service by a shipper is a business process that generates information about transportation demand as a by-product, which in turn can be the resource for a decision regarding capacity allocation and transport mode use by a logistic operator (Hofman, 2016). Whether as a by-product/output or as resource/input, information flows between actors in supply-chain and shipping processes, as shown in Figure 1.

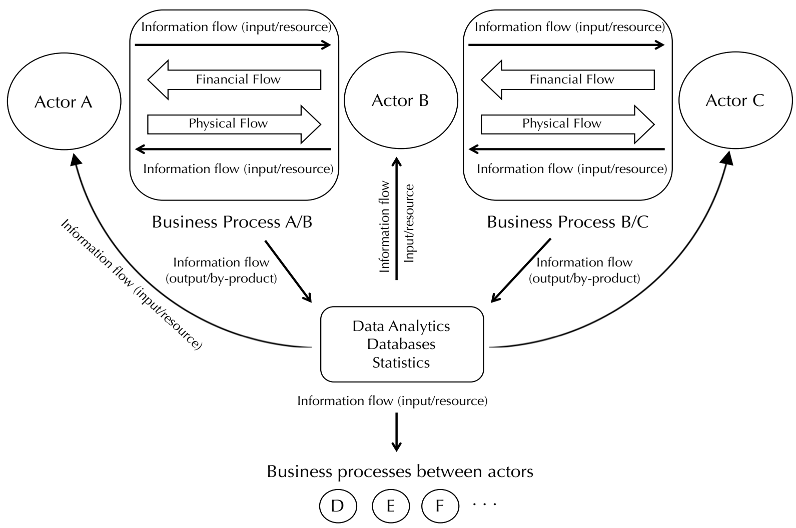

Figure 1 – Information as input/output of business processes

When information that is generated as an output of a business process between A and B can be reused as an input of a successive (or parallel) business process between B and C, then information as a resource can be said to follow a circular path. In the same way, information/data outputs that are gathered into a database platform, can be acted upon and become the input of business processes between actors not involved in the originating ones. Such a path generates new value from information that had been previously consumed or generated as an output by the original actors.

For information flows to follow the circular path so described, information sharing is an essential requirement. A data infrastructure that facilitates information sharing would therefore enhance information circularities. This prompts to question whether DLT could be such a data infrastructure, and how would that impact sustainability.

4.2. Conceptual model propositions

The key functionality of a DLT database, whether an open (permissionless) or restricted (permissioned) one, is that it provides a single source of truth for multiple actors in a business network. As parties interact, data and information can be registered in a distributed ledger, as long as it can be represented in code. The ledger, in turn, can be used and acted upon as an input source by any actor with access rights, regardless of its involvement in the interaction that generated it in the first place. A DLT platform, therefore, constitutes a transparent and reliable depository of output information from business processes, and a source of input information for new business processes. This double role undergirds circular information flows among the parties in a network, becoming especially valuable for supply-chain and shipping, where multiple parties can use the same information as input for their decisions.

The first proposition of the conceptual model is thus expressed in the following way:

> P_1: DLT enhances information resource circularity by providing a depository of output information from business processes, and a source of input information for new business processes.

To some degree, in all industries, decision making has to be taken in coordination with other actors. In the supply chain and shipping industry, however, inter-firm coordination acquires a more prominent role as a basis of efficiency. This is due to the multitude of actors that take part in a single process (e.g. the transportation of a containerized cargo), and the cause-effect relations between steps in the process. Interfirm collaboration in the form of information sharing, constitutes in this manner an essential element of the value creation and value delivery dimensions of firms business models. Moreover, collaboration and associative behaviours between firms require that information inputs are reliable, secure, and accessible to all the parties that collaborate.

DLT provides a secure and reliable database that serves as a unique input for coordination decisions, guaranteeing at the same time that all the parties involved in the collaborative action have access to it. Furthermore, because business logic can be embedded into DLT-based smart contracts (e.g. as pre-defined workflows), parties can automate at least part of these coordination decisions or processes. The second proposition can thus be expressed as follows:

> P_2: DLT positively impacts inter-firm collaboration and associative behaviours.

As observed by the literature referred in the theoretical background, both circularity and associative behaviours constitute elements that underpin sustainable value creation, delivery and appropriation. In the particular case of information as a resource, information circularity and information sharing (which is in itself an associative behaviour) drive the adoption of sustainable shipping business models by increasing a coordinated creation, delivery and appropriation of value extracted from information as an input. Propositions 3 and 4 express that functionality:

> *P_3:* Information circularity drives the adoption of sustainable shipping business models by enhancing coordinated value creation, delivery and appropriation.

> *P_4:* Information sharing, as an associative behaviour, drives the adoption of sustainable shipping business models by enhancing coordinated value creation, delivery and appropriation.

Finally, the "inter-firm" dimension of sustainable shipping management observed through the theoretical lenses provided by the relational view (RV), as a basis for sustainable shipping, benefits from SBM that are based on information circularities and information sharing. In plainer terms, sustainable shipping practices, like planning and operations that strive for efficient physical flows with the lowest environmental footprint, find a solid basis in sustainable business models where information loops and is shared at the inter-firm level. The fifth proposition is thus stated in the following way:

> *P_5*: A sustainable shipping business model based in information circularity and associative behaviours, provides a solid basis for sustainable shipping practices.

4.3. Conceptual model depiction

Figure 2 portrays the conceptual model expressed in the above stated propositions. The model depicts the influence of DLT on information circularity and associative behaviours, which in turn constitute building blocks of sustainable shipping business models. Finally, a sustainable business model is a solid basis for sustainable shipping practices.

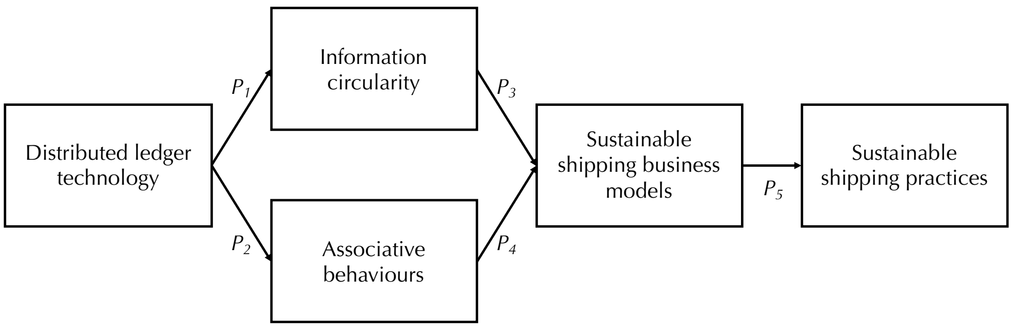

Figure 2 – Conceptual model depiction

5. Case Study: TradeLens

TradeLens (TL) is an information infrastructure platform developed by a joint venture between IBM and Maersk, formally launched on December 11, 2018 as a Maersk's subsidiary, with IBM as technology supplier (Jensen et al., 2019). During both its development and operational phases, TL has caught considerable attention from pundits among the shipping and technology industries, as one of the first few real-economy use cases of blockchain. As the time of this writing, the platform claims to have more than 15 million shipping events tracked, close to 4.5 million documents published, and more than 2.7 million containers processed (TradeLens, 2020). While blockchain constitutes a core component of TL's technology basis, it is not its unique or more important one (cloud computing is arguably the central element in the platform's architecture). However, the role that DLT (blockchain) plays in the overall system's functionality, visualised in conjunction with TL's architecture and business model, provides an insightful example of how DLT might contribute to sustainable business models for the shipping industry and global trade. This section, therefore, presents a brief exploratory case study into TL as a way of analysing the conceptual model in Section 3 against a real-life use case.

As Jensen et al (2019) observe, TL's value proposition evolved from two initiatives: the information pipeline initiative and the paperless trade initiative. In order to break down information silos between global shipping actors (shippers, carriers, 3PLs, custom and port authorities, etc.), TL provides an infrastructure platform where information can be exchanged in a secure and transparent way. This is the main value provided by the information pipeline initiative. The paperless trade initiative, on the other hand, addresses the inefficiency problem generated by paper documents. Despite considerable digitalisation of industries like media, retail, or travel/tourism, the shipping industry continues to rely on physical documents (BLs, packing lists, etc.); a circumstance that generates information flow delays which, in turn, affect physical and financial flows. To address these inefficiencies, TL aims to standardise and digitise trade related documents, enabling relevant supply chain actors to exchange and access them through a platform that guarantees traceability and immutability, thanks to blockchain technology.

The architecture of TL reflects a business model where collaboration and open innovation are at its core. The general structure is divided into 3 components: ecosystem, platform, and marketplace. The ecosystem comprises all the global supply chain actors that interact through the platform. The platform is where information and documents flow between the ecosystem actors. And the marketplace, built on top of the platform, allows applications to be developed by third parties, thus fostering open innovation and value co-creation. Figure 3 shows TL's general architecture.

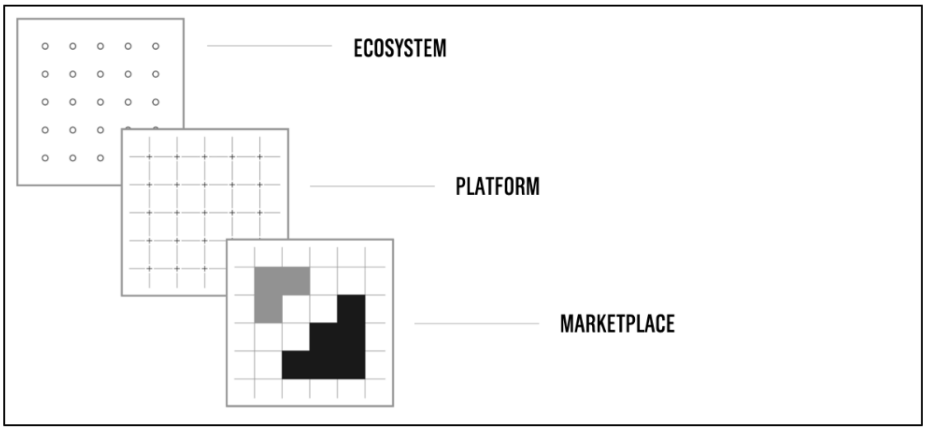

Figure 3 – TradeLens General Architecture

Source: TradeLens (2020)

The platform has a layered structure where a blockchain network lies at the bottom, supporting the platform services (which are cloud-based) and the platform API. Shipping actors access the platform (and interact with each other) through APIs, through TL's proprietary application (TradeLens Core) or through third party apps. Information is stored at the platform in different persistence layers like object storage, document databases, relational databases, or the DLT-based database provided by Hyperledger Fabric. Which layer supports the information depends on the latter's type and how it is accessed (TradeLens, 2020). Figure 4 shows the Platform's architecture.

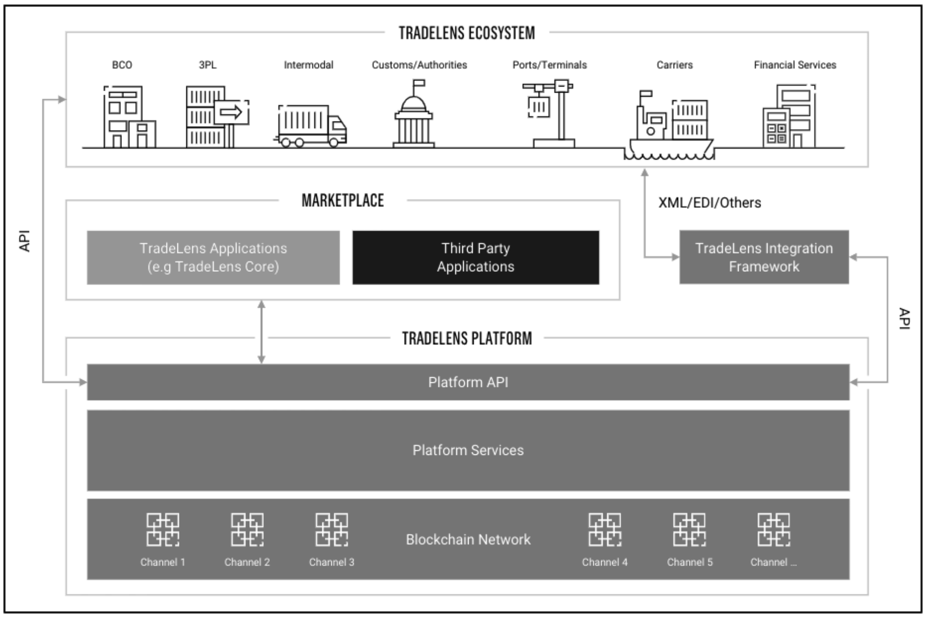

Figure 4 – TradeLens Platform Architecture

Source: TradeLens (2020)

A central element of TL's functionality is the *event* model (related with the information pipeline initiative). More than 120 shipping events are supported, under a data model with two classes: consignment events and transport equipment events. Consignment events relate to cargo shipments, while transport equipment ones relate to containers, reflecting the two levels of containerized information flows, container level and cargo level (Van Baalen et al., 2009). A consignment can involve multiple transport equipment (containers) or vice versa. An event represents a significant logistic milestone that has to occur in order for the cargo to get from origin to destination, including both the cargo level (e.g. booking) or transport equipment (e.g. load, departure, arrival, etc.). Events can involve a document. Here TL provides another classification (related with the paperless trade initiative) regarding two document types: structured and unstructured. Structured documents are generated from a JSON schema (template), while unstructured documents are based on pdf or image files. Unstructured documents might be a representation of a paper document or not.

The accessibility of information about events and/or documents is defined by the platform through a permission matrix. The *type* of data that can be accessed will depend on the role played by an actor in the overall shipping process. Thus, only actors involved in a specific shipment can have access to data over that shipment, and the type of data they can access depends on the role they play. For instance, an *export* customs broker has access to data about booking confirmation and shipping instructions, while an *import* customs broker has not; and the latter has access to data on arrival order and delivery notice, while the former has not. The permission matrix aims to ensure that *'no commercially sensitive information is available to competitors or other unauthorized parties'* (TradeLens, 2020).

What role does blockchain play in TL's overall system? As stated in TradeLens Documentation, *'blockchain is used to address trust challenges, provide a shared view of the truth, and provide an immutable audit trail'* (TradeLens, 2020); or, as expressed by the Head of Business Development for IBM Blockchain Global Trade Applications, Richard Stockley, in its interview: *'a common view of the most up-to-date information, as well as an auditable record of the changes that have occurred. This is where blockchain shines'* (Unblocked Events, 2019). Thus, data registered at the blockchain layer is tamper proof, verifiable, recoverable and auditable. The blockchain component is based on IBM Blockchain Platform, in turn based on Hyperledger Fabric. The latter has been described as a modular and extensible distributed operating system for permissioned blockchains (Androulaki et al., 2018). One of the key characteristics of Fabric is that it partitions the blockchain network into channels that comprise a determined set of nodes, with consensus taking place inside the channel and not (generally) across channels. This feature is reflected in TL's blockchain layer, where information on events is accessible only by peers (or "Trust Anchors") included in a particular channel, which generally corresponds to a specific carrier. As mentioned, not all data is registered at the blockchain layer, but only that which creates trust challenges and requires auditability. All other data resides on persistence layers like document and relational databases, under a traditional cloud-based system.

Even though that TL's documentation does not expressly mention the term "smart contract", it dedicates a section to what denominates "Actionable Doc Flows". These are pre-defined processes following a specific sequence of steps, where some of them are automatically handled by the TradeLens platform. Currently, only one Actionable Doc Flow is available (in Beta version): a doc flow from Shipping Instructions to a SeaWay bill of lading. Figure 5 presents a simplified version of it.

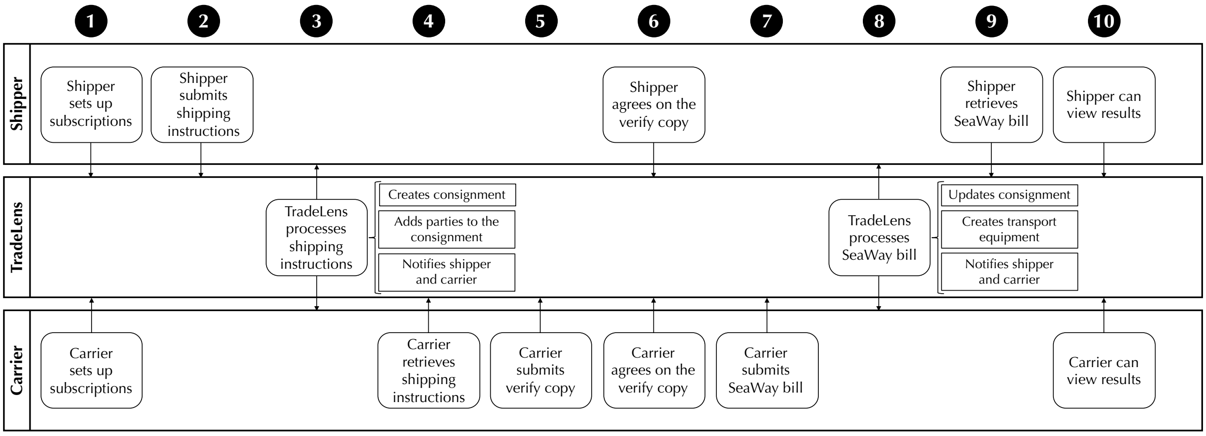

Figure 5 – Actionable Doc Flow

Steps 3 and 8 are automatically processed by TL through code execution. In this sense, it could be argued that an Actionable Doc Flow is a (rather basic) smart contract between the shipper and the carrier, using TL as a tool.

In the end, the fundamental contribution made by blockchain to TL's platform and overall ecosystem is to provide a secure basis for information flows among shipping actors, enhancing trust between them. These information flows concern pre-defined shipping events upon which logistic decisions are to be taken in relation to a shipping process. The result is (or so it is claimed) a streamlined, transparent and secure global supply chain (Van Kralingen, 2020).

6. Discussion

The content analysis was performed over the documentary sources about TradeLens, in order to evaluate the coherence between the conceptual model and the findings of the use case. The following discussion, therefore, assess to which extent the conceptual model's propositions are reflected in TradeLens's structure, architecture, design and vision.

The core functionality of TL is facilitating information flows between the actors involved in the transportation of a cargo, from origin to destiny. When assessing the role played by blockchain technology, TL's documentation expressly asserts that the blockchain layer aims to address trust issues, provide a shared view of the truth as well as an immutable audit trail. Moreover, the data registered into the blockchain layer is structured in a series of pre-defined events that represent steps in the transport process. Information about these events is accessible by the relevant actors, according to the role they fulfil in the transportation network. Every event, as a logistical milestone, generates data that it is usually relevant for future events. This is so because many events are causally dependent on precedent ones.

To use the terminology presented in the conceptual model: the execution of a specific event in the logistic chain utilizes information about previous events as one of its inputs, and generates as an output information that, in turn, is the input of successive events. Because this information is traditionally dispersed and siloed between the many logistic actors, and is also paper-based for the most part, the possibility of it being re-used by actors other than those directly involved in the event that generates it is limited.

By registering events data into an immutable and shared source of truth, by means of a DLT (blockchain) database, TL extends the utilization of information on certain events as a resource or input for successive events by all the parties for whom it might be relevant. Thus, the positive impact of DLT technology on information circularities *(P_1)* is clearly reflected in TL's design and vision. Indeed, TL's blockchain based database works as both a depository and a source of information that is input and/or output of logistic events.

It is important to observe that this circularity does not take place exclusively at the blockchain layer. Information about events registered at the blockchain layer can function as input for decision making not directly related with specific logistic events (e.g. resource planning or the choice of a specific transportation mode or company). Also, nothing precludes for some information residing at TL's Platform Service layer to function as input for decision making by different actors.

By providing a single depository and source of event's information, as well as automating (up to a point) certain business processes between actors involved in the transportation chain, TL enhances the collaboration and coordination between them. While the first example of a smart contract-based coordination (the Actionable Doc Flows) is still basic, the availability of structured information registered at the DLT layer (and also at the Platform Service layer) provides a basis for more sophisticated coordination.

On the other hand, TL's architecture, where an ecosystem of apps is to be built on top of the Platform, including third-party applications, is a catalyst for collaboration among shipping actors. Interaction with the Platform Service layer by means of these apps is done through APIs. The key role played by DLT in this case is to feed trusted information across all the layers, so that, for instance, a third-party app may provide functionalities that use information stored at the blockchain layer. In the end, by enabling the digitisation and automation of cross-organizational shipping processes, TL positively impacts collaboration and associative behaviours between shipping actors *(P_2)*.

The first two propositions aim to capture a direct relation between DLT technology and two phenomena: information circularity and associative behaviours. TL's technical profile (architecture, structure, design) can thus serve as a basis for assessing their validity. In contrast, the following ones *(P_3 and P_4)*, express a relation between the former two phenomena and a mostly theoretical construct: a sustainable business model (SBM); and the final proposition *(P_5)* states a relation between two theoretical constructs, SBM and sustainable shipping. For this reason, the content analysis regarding the final 3 propositions focuses on statements about TL's vision and purpose, rather than its technical aspects.

In TL's website, an introductory video is available, where it is stated that TL enables transparency, efficiency and collaboration across the global supply-chain. The inter-firm cross collaboration element is stressed in several materials available in the website. In particular, the Solution Brief highlights, as TL's main objectives, the following ones: connecting the shipping ecosystem, drive true information sharing, fostering collaboration and trust, and spurring innovation (TradeLens, 2020).

Though it is not expressly mentioned, the corollary of these objectives is the emergence of new business models, were value creation, delivery and appropriation take place increasingly at the inter-firm level, something that will take a change of paradigms and mentality in the shipping industry. IBM's Richard Stockley puts it this way: *'The biggest inhibitors to the full realisation of technology generally –and blockchain specifically– is our own reptilian brains and the organisational structures we are anchored to. The challenge is to see that platforms allow a new way for enterprises to collaborate and differentiate'* (Unblocked Events, 2019).

The language used by TradeLens points toward new business models, though the sustainability element is barely mentioned. Nonetheless, the stress on two key aspects of SBM (information sharing and cross-collaboration) is clear, as well as the role played by DLT. Propositions P_3 and P_4 are thus moderately validated in TL's vision and objectives.

P_5 expresses a positive relationship between SBM and sustainable shipping, as SBM would provide a solid basis for sustainable shipping practices. Among those practices, information sharing, sound contractual governances, interfirm relationship management, and the development of complementary resources and capabilities, are identified (Yuen et al., 2019).

TradeLens's vision to provide a platform where actors in the shipping ecosystem can access and share information in a secure and transparent way, as well as develop cooperative behaviours, would constitute, if successfully adopted by the industry, a solid basis for sustainable shipping practices. Information sharing in itself would boost sustainability, for instance, when transport disruptions take place, because corrective inter-firm actions can be taken more quickly, saving resources and decreasing environmental footprint. Moreover, having a single source of information supports the development of complementary resources and capabilities. Finally, the possibility of developing pre-defined process flows like the Actionable Doc Flows (whether or not are those considered a true smart contract), would enhance interfirm relationship management and even provide a basis for contractual governance.

These practices, in turn, are supported by two building blocks of an SBM, reflected in TL: information resource circularity and associative behaviours. P_5 can thus be at least moderately validated by TL case study.

Based on the foregoing assessment, Table 1 summarizes the result of the conceptual model propositions' validation.

Table 1 – Conceptual model proposition's evaluation

Nº	Proposition	Validity
P_1	DLT enhances information resource circularity by providing a depository of output information from business processes, and a source of input information for new business processes.	+ + +
P_2	DLT positively impacts inter-firm collaboration and associative behaviours.	+ + +
P_3	Information circularity drives the adoption of sustainable shipping business models by enhancing coordinated value creation, delivery and appropriation.	+ +
P_4	Information sharing, as an associative behaviour, drives the adoption of sustainable shipping business models by enhancing coordinated value creation, delivery and appropriation.	+ +
P_5	A sustainable shipping business model based in information circularity and associative behaviours, provides a solid basis for sustainable shipping practices.	+ +

Note: not valid (-), low validity (+), medium validity (++), high validity (+++).

7. Conclusion

7.1. Theoretical contributions and managerial implications

This paper presents a conceptual model that sketches the impact that distributed ledger technology (DLT) can have on sustainable shipping business models and practices. The model's theoretical base is grounded on the conception of information as a resource, provided by information resource management (IRM) theory. From this foundation, the paper presents the construct of information circularity, whereby information that is generated as output or by-product of business processes, is then re-utilised as a resource for subsequent or parallel business processes. This theoretical construct contributes to the IRM literature, as well as sustainability research, specifically on the concept of circular economies.

The research extends previous literature on blockchain technology and its impact on the circular economy, associative business models, and inter-firm coordination in general. It does so under the context of maritime shipping, extending both maritime literature and blockchain technology research. Moreover, the paper presents a case study on a real-life deployment of blockchain technology in the context of maritime shipping. The theoretical lenses provided by IRM bring a new perspective about the functionality of DLT/blockchain; if data and information are treated as resources for business processes, it is more clearly understood how blockchain bolsters new business models by enhancing information flows between actors engaged in complementary processes along the supply chain.

The theoretical perspective presented, contrasted with the exploratory case study on TradeLens, offers a series of managerial implications, both for maritime shipping firms and regulatory bodies. Given the surge of DLT-based information infrastructures like TradeLens, shipping firms need to carefully analyse how they will take advantage of the new information flow dynamics that these platforms shall be enabling. Firms that are more effective in identifying and taking advantage of information flows interdependencies with the help of DLT-based tools, will gain competitive advantages and improve their sustainability performance ratings. On the other hand, the construct of information resource circularity offers a novel perspective to government and other regulatory bodies, which may enrich their discussions on sustainability policies, measures, standards and incentives. Moreover, they might gain new insights on the beneficial role that blockchain technology can play for circular economies and sustainability in the specific area of maritime shipping.

7.2. Limitations and future research

Finally, it is important to point out some limitations of this paper, as well as potential avenues for future research. Two main limitations constrict the validity and generalisability of this research: one deriving from the research itself and the other from the subject of study. The case study research is currently in an early stage, where data sources are limited to documented material; furthermore, the content analysis assessment carries with it a significant dose of subjectivity. In a subsequent stage of the case study, the authors intend to incorporate semi-structured interviews with key stakeholders in TradeLens, as well as a survey conducted on platform users.

The subject of the case study, DLT in the shipping industry, is still novel, with only a single real-life use case. This circumstance limits data triangulation with other use cases. However, as new blockchain based platforms become operational —like Singapore-based Global eTrade Services (GeTS)—, the subject will broaden significantly, allowing new research opportunities, and the conduction of multi-case studies (Benbasat et al., 1987).

Among these potential research avenues, cross-sectional and longitudinal case studies on different shipping information infrastructures, whether DLT-based or not, can be conducted. Issues like the impact of governance structure on adoption, or the inclusion of sustainability issues in their core mission can be analysed. On a more concrete level, specific input-output shipping information interdependencies, their impact on sustainability, and the utility of digital tools as sustainability performance enhancers, can be researched in more depth.

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