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BLOCKCHAIN: APPLICATIONS, EFFECTS AND CHALLENGES IN  
SUPPLY CHAINS

Master of Science Thesis

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## ABSTRACT

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Nowadays, effectively manage the supply chain has become even more complex than ever, resulting in inefficient processes, higher costs, low quality and poor customer service. Within this context, the interdependence amongst supply chain partners is growing, requiring new levels of adaptation in order to achieve long-term mutual benefit. Despite the importance of the integration and coordination throughout the supply chain to obtain its effective management, there is still far from achieve. In the last years, a large number of technologies have arisen to facilitate the digitalization of current supply chains, helping to break the existing barriers and enabling a more integrated ecosystem while enhancing the supply chain visibility. One of the technologies with more potential to improve and transform current supply chain management by its intrinsic features is the blockchain, which can increase the efficiency and transparency of supply chains.

The main objective of this research is to examine the potential use cases of blockchain technology in supply chains and its impacts in supply chain management. Moreover, the main challenges that companies are currently facing to introduce this technology are also discussed. In order to form a comprehensive picture of current supply chain digitalization issues and better understand the blockchain technology, a literature review was undertaken. Subsequently, a theoretical framework is formulated with the aim to explore the applications of blockchain to improve supply chain management. Through multiple study cases, the framework is tested with an explanatory approach, providing also a base to identify the main effects and challenges in its implementation in supply chains.

As a result of this study, the feasibility of blockchain technology to support several proposed supply chain processes is proved. The main effects observed in the study cases analyzed show the ability of blockchain to overcome the currently main issues in supply chain management, enabling to reduce cost, enhance supply chain efficiency and increase customer value. However, the innovative characteristic of the blockchain technology makes more difficult its adoption. In fact, there are multiple technical and regulatory issues that must to be overcome to reach a broadly implementation of blockchain technology within supply chains.

## **PREFACE**

This thesis aims to give a broader insight of the potential applications of blockchain technology into supply chains. In a field that is still in an early adoption stage, the effects shown as result of the first tested pilots and the main challenges faced by companies to implement this technology into their businesses are of special importance to boost its widely adoption. This project provide me an excellent opportunity as industrial engineer student to discover a new disruptive technology that has the potential to radically transform the way supply chains are conceived in today's business world.

I would like to thank my thesis supervisor Professor Heikki Liimatainen, from Tampere University of Technology, for his great advices and feedback during the master thesis development. Moreover, I would also like to thank my friends, particularly the Erasmus ones, who have been there for me throughout my all experience in Finland.

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Tampere, 16.5.2018

Isabel Vegas Villalmanzo

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## LIST OF SYMBOLS AND ABBREVIATIONS

%	Percent sign
&	Ampersand
\$	Dollar sign
M	Millions
APS	Advance planning and scheduling
BC4A	Blockchain for Aviation
BiTA	Blockchain in Transport Alliance
B2B	Business to business
B/L	Bill of landing
CPFR	Collaborative planning, forecasting and replenishment
CMR	Contrat de Transport International de Marchandises par la Route
DNA	Digital Network Architecture
DSN	Digital supply network
DSCSA	Drug Supply Chain Security Act
eBL	Electronic bill of landing
EDI	Electronic data interchange
eIDAS	Electronic Identification and Signature
EPCIS	Electronic Product Code Information Services
GDPR	General Data Protection Regulation
GDSN	Global Data Synchronisation Network
GTIN	Global Trade Item Number
GSIN	Global Shipment Identification Number
ID	Identification Number
IPNLF	International Pole and Line Foundation
IoT	Internet of Things
IS	Information system
IT	Information technology
KPI	Key Performance Indicator
L/C	Letter of credit
MRO	Maintenance, repair and operations
M2M	Machine-to-machine
NFC	Near Field Communication
NGO	Non-governmental organization
OEM	Original Equipment Manufacturer
P2P	Peer-to-peer
PoC	Prof-of-Concept
POS	Point-of-sale
PoW	Proof-of-Work
PSD2	Payment Services Directive 2
QR	Quick Response
RFID	Radio frequency identification device
R&D	Research and Development
SC	Supply chain
SCOR	Supply chain operation reference
SCM	Supply chain management
SRM	Supplier relationship management

SMS	Safety Management System
SSCC	Serial Shipper Container Code
TMS	Transportation management system
TRU	Traceable resource unit
T&T	Track and trace
US	United States
VMI	Vendor managed inventory
WMS	Warehouse management system
WSN	Wireless Sensor Networks
3D	Three Dimensions



# 1. INTRODUCTION

## 1.1 Research background

In today's business world, effectively manage the supply chain has become even more complex than ever due to several factors such as globalization, shorter product life cycles, outsourced manufacturing, longer supply chains and tighter product margins among others (Hidjaja, 2018). These challenges are disrupting current businesses and the relationships between supply chain partners, which can result in supply chain inefficiencies, higher costs, low quality and poor customer service.

Nowadays, the customers' expectations are continuously increasing and varying, which leads in shorter product life cycles and more change in the market demands. This situation is adding pressure to manufacturers, who need to constantly working on adding more value to their offering and service responsiveness, at the same time prices must be competitive (bossard.com, 2018). This means that companies have to redesign and optimize their value chains in order to stay competitive and flexible to meet market demands (Berrios, 2014). Due to these claims, the globalization of the supply chains appears as a business strategy to achieve a competitive advantage by lower costs even if the delivery times take longer (Leung, 2018). This approach is based on the reallocation of manufacturing to low cost countries in an effort to reduce direct and overhead costs and to minimize taxes (Berrios, 2014). Moreover, the globalization brings considerations that represent a challenge in supply chain management, such as lack of transparency, breakdowns in product flow, quality issues or environmental and social considerations (Harrison, et al., 2008).

Within this context, the interdependence amongst supply chain partners is growing, requiring new levels of adaptation in order to achieve long-term mutual benefit. Despite the importance of the integration and coordination throughout the supply chain to obtain its effective management, there is still far from achieve (Harrison, et al., 2008). The transparency of information upstream and downstream is one of the main problems current supply chains face. The lack of mutual trust between supply chain members makes them to be reluctant to share required sensitive information, which directly affects the responsiveness and processes efficiency throughout the supply chain. In addition, in most of the cases the information is not still appropriately communicate and shared among parties by current systems due to paper-based processes, information siloes instead of having common information systems, outdated information, reconciliation processes, etc. These inefficiencies in communication and data sharing not only make it more error prone, but also facilitate the counterfeit and fraud along the whole supply chain.

In the last years, a large number of technologies have arisen to facilitate the digitalization of current supply chains, such as Internet of Things, Big Data, or robotics. The digitalization helps to breaking the existing barriers in supply chains, and enables a more integrated ecosystem while enhancing the supply chain visibility. In addition, it also helps to improve the efficiency of certain supply chain processes, boosting the competitive advantage in that supply chain. One of the technologies with more potential to improve and transform current supply chain management by its intrinsic features is the blockchain, which can increase the efficiency and transparency of supply chains.

## 1.2 Purpose of the study and research questions

Given the existing challenges that supply chains face in today's business environment, this paper aims to explore the application of blockchain technology in current supply chains in order to enhance supply chain management.

Despite the vast amount of literature and reports about the supply chain management and slightly more limited about the blockchain technology. There is a need for a clearer picture of the potential use cases of this technology in supply chains and its impacts in supply chain management. Moreover, it would be of interest explore the main challenges that companies are currently facing when they implement the blockchain technology to support supply chain processes.

Thereby, the main objective of this paper is...

*... to develop a framework for introduce the different potential applications of blockchain technology in supply chain management, as well as analyze current applications within this framework and identify the main effects and challenges in its implementation in supply chains.*

This research problem can be expressed in a form of the following research questions:

- Why should blockchains be implemented in supply chains?
- Which are the applications of blockchain technology in supply chains?
- Which are the effects of blockchain technology implementation in supply chains?
- Which are the challenges in the implementation the blockchain technology in supply chains?

## 1.3 Scope and limitations

To keep the focus only on relevant applications of blockchain for this study and due to length limitations, future envisioned applications that are not possible to implement nowadays will not be discussed.

## **1.4 Structure of the thesis**

This paper is structured in eight parts. The first chapter gives briefly a background information to familiarize with the topic and explains the main objectives of this paper. The second chapter reviews existing research methodologies and introduces the chosen one, as well as the research process undertaken in this master thesis. The third chapter refers to theoretical background related to supply chain management, its digitalization and an introduction on the basics of blockchain technology. A framework of the different potential applications of blockchain technology in supply chain management is also introduced. In the fourth chapter, the multiple cases under study are presented and summarized. The fifth chapter analyses how the different study cases fit within the framework presented, and how those potential applications of blockchain technology have been implemented. The sixth chapter aims to give a general insight of the possible effects of the implementation of blockchain technology in supply chains, and how it affects to supply chain management. The seventh chapter addresses the main challenges companies face when they implement the blockchain technology in their current processes. In addition, the main concerns of different industry leaders in regards with the introduction of this technology in their supply chains are exposed. Finally, the eighth chapter summarizes and discusses key results of the thesis.

## 2. RESEARCH METHODOLOGY

Research is a process undertaken in order to find out things in a systematic way with the objective of increasing the existing knowledge or obtaining new one. In this approach, the “systematic” refers to the research is based on logical relationships and not just beliefs, while “to find out things” suggests having a clear purpose, such as the answer to a question or number of questions, with the objective of advancing knowledge (Saunders, et al., 2009).

Focusing the research in the business and managerial area, the use of knowledge from a range of disciplines enables management research to gain new insights that cannot be obtained through all of these disciplines separately. In addition, the business and management research not only needs to provide findings that advance knowledge and understanding, it also needs to address business issues and practical managerial problems. Thereby, the research can act as a blueprint for managerial practices, highlighting the focus on moving from ideas to practice (Saunders, et al., 2009).

At the same time, the research methodology refers to the theory of how research should be undertaken (Saunders, et al., 2009). The methodology defines the methods for conducting the research and explains the logic behind the use of every particular method, approach or technique. Moreover, methodology explains why researchers choose one tools over others and enable the comparison of research results by the researcher and others (Ponomarjovs, 2013).

In this section, the main approaches and methods for business and managerial research are reviewed. The context and purposes of a research serve as a trigger for analyse the different existing research designs, as well as, the tools to achieve validity and reliability in the study. Finally, this leads in the actual selected research strategy, which includes the research philosophy, methodology and data gathering methods and how they have been used in this study (Ponomarjovs, 2013).

### 2.1 Research purpose and importance

In business and managerial research, the purpose and context of a research project can differ considerably. Within the boundaries of advancing knowledge, addressing business issues and solving managerial problems, the researchers are usually aimed at new theory building or verification of already existing theories (Saunders, et al., 2009; Ponomarjovs, 2013).

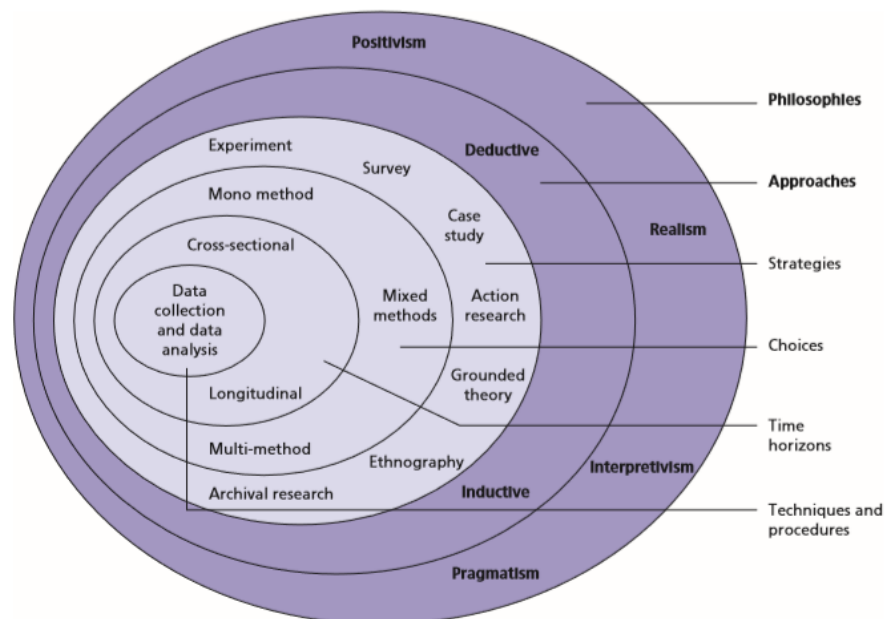
To some extent, this thesis is aimed to solve current managerial problems by building a new theory and trying to verify it. The purpose of this thesis is to create a framework with

the objective of use the blockchain technology to overcome supply chain management issues. Afterwards, multiple study cases are employed to verify the suggested framework, evaluating how companies are starting to introduce this technology in their supply chains and the effects and challenges they perceive in its implementation.

The importance of this research goal lies on the fact that is an applied study, aiming to improve the understanding of how this technology can result as the solution of current problems in supply chains. The limited knowledge about this topic implies the necessity of conducting studies to obtain findings of practical relevance and value to managers in organizations (Saunders, et al., 2009). The outcomes of this study are believed to provide an insight of the potential applications of this technology in supply chains and how it can suppose a tool to improve current supply chain management.

## 2.2 Research philosophy and approach

According to Saunders et al. (2009), the research process can be illustrated as an onion (see Figure 1). The different layers of the research onion describe a more detailed stage in the research process, providing an effective progression through which a research methodology can be designed.



*Figure 1: The research onion (Saunders, et al., 2009).*

In the outermost layer is the research philosophy adopted. It contains important assumptions about the way in which the researcher views the world, which underpin the research strategy and the methods chosen in a research. In the following table, some of the most important research philosophies are introduced (Saunders, et al., 2009).

	<b>Positivism</b>	<b>Realism</b>	<b>Interpretivism</b>	<b>Pragmatism</b>
<b>Ontology:</b> <i>the researcher's view of the nature of reality or being</i>	External, objective and independent of social actors	Is objective. Exists independently of human thoughts and beliefs or knowledge of their existence (realist), but is interpreted through social conditioning (critical realist)	Socially constructed, subjective, may change, multiple	External, multiple, view chosen to best enable answering of research question
<b>Epistemology:</b> <i>the researcher's view regarding what constitutes acceptable knowledge</i>	Only observable phenomena can provide credible data, facts. Focus on causality and law like generalisations, reducing phenomena to simplest elements	Observable phenomena provide credible data, facts. Insufficient data means inaccuracies in sensations (direct realism). Alternatively, phenomena create sensations which are open to misinterpretation (critical realism). Focus on explaining within a context or contexts	Subjective meanings and social phenomena. Focus upon the details of situation, a reality behind these details, subjective meanings motivating actions	Either or both observable phenomena and subjective meanings can provide acceptable knowledge dependent upon the research question. Focus on practical applied research, integrating different perspectives to help interpret the data
<b>Axiology:</b> <i>the researcher's view of the role of values in research</i>	Research is undertaken in a value-free way, the researcher is independent of the data and maintains an objective stance	Research is value laden; the researcher is biased by world views, cultural experiences and upbringing. These will impact on the research	Research is value bound, the researcher is part of what is being researched, cannot be separated and so will be subjective	Values play a large role in interpreting results, the researcher adopting both objective and subjective points of view
<b>Data collection techniques most often used</b>	Highly structured, large samples, measurement, quantitative, but can use qualitative	Methods chosen must fit the subject matter, quantitative or qualitative	Small samples, in-depth investigations, qualitative	Mixed or multiple method designs, quantitative and qualitative

**Table 1: Comparison of four research philosophies in management research (Saunders, et al., 2009)**

Moreover, it is useful to determine the research approach because it influences the research in terms of logic, generalizability, use of data and theory. The main approaches used in business research are deductive and inductive. The deductive approach is based on the development of a theory and hypothesis (or hypotheses) and the design of a research strategy to test the hypothesis. On the other hand, the inductive approach is related to the collection of data and the development of a theory as a result of the data analysis (Saunders, et al., 2009).

### 2.3 Research design

The research design is related with the general plan of how to answer the research questions. In the process of research design, it is necessary to establish the research strategy, research choices and time horizons (Saunders, et al., 2009).

The election of a certain research strategy must be guided by the research question(s) and objectives, the extent of existing knowledge, the amount of time and other available resources. Hereafter, the main research strategies commonly employed in business and management research are briefly introduced (Saunders, et al., 2009):

- Experiment

The purpose of an experiment is to study causal links. In other words, when a change in one independent variable produces a change in another dependent variable. More complex experiments also consider the size of the change and the relative importance of two or more independent variables (Saunders, et al., 2009).

- Survey

Surveys are questionnaires administered to a sample in a standardised way, which allow easy comparison. The surveys are widely used to answer who, what, where, how much and how many questions. Moreover, they allow collecting a large amount of data from a sizeable population in a highly economical way (Saunders, et al., 2009).

- Case study

According to Saunders et al. (2009), the case study is the empirical investigation of a particular contemporary phenomenon within its real context using multiple sources of evidence.

- Action research

The action research purposes that the only way to improve understanding is by taking action and learning from the experience. From this perspective, an action is undertaken in order to gain understanding of things by changing them, and studying and reflexing about the consequences of the action before taking again a new action (Fisher, et al., 2004).

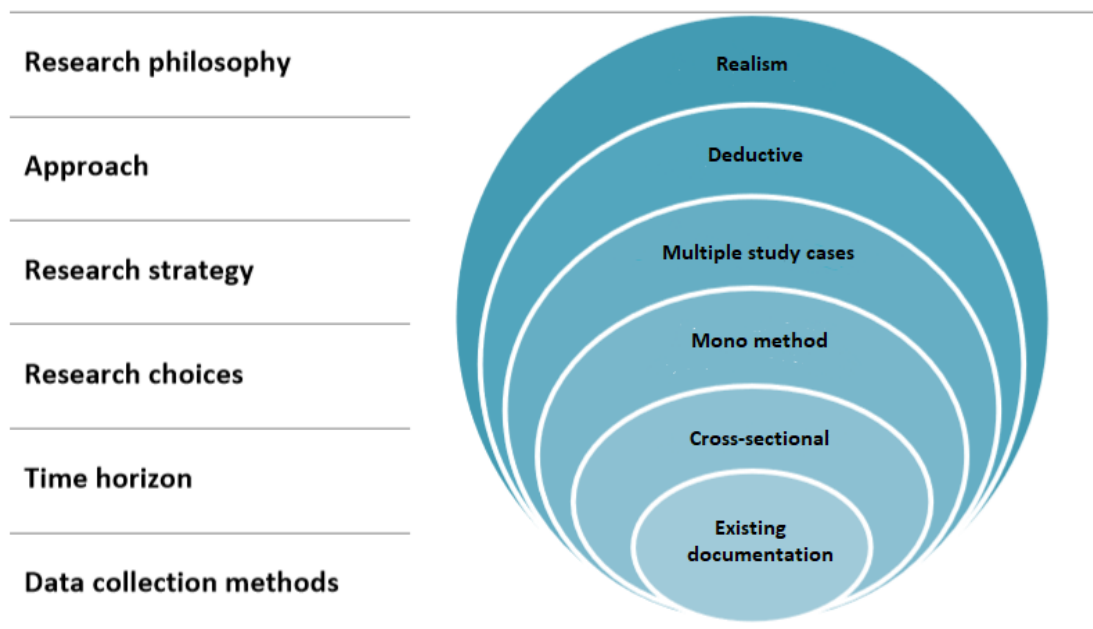
Once the research strategy is defined, it is advisable to determinate the research choice by choosing to combine or not different quantitative and qualitative techniques and procedures for data collection and subsequent analysis. Each research method for data collection has its own associated procedures to data analysis. Hereunder, the major research methods are listed (Saunders, et al., 2009).

- Questionnaires
- Panels, including focus groups
- Observation, including participant observation
- Existing documentation
- Databases

Finally, other issue to take into account in the research design is the time horizon of the study, which is independent of the research strategy or the choice of method chosen. If the research is based on the study of a particular phenomenon (or phenomena) at a particular time, then is a cross-sectional study. If the study of the phenomenon is running over a period of time, it is called longitudinal study (Saunders, et al., 2009).

## 2.4 Chosen research strategy

The purpose of this research will serve as the starting point to select the most suitable research strategy. After the review of the different research methodologies and methods, and taking all the time into account the validity and reliability, the research strategy of this master thesis has been selected (see Figure 2).



*Figure 2: Chosen research strategy (Tirkkonen, 2015)*

The philosophy behind the research tries to be critical realism because the researcher recognise the role of subjectivity and the existence of knowledge that is not easily accessible because is hidden for a common view (Fisher, et al., 2004). The results of the research are independents, but will be biased by the background of the researcher and social conditioning.

In order to response appropriately the research questions purposed, a deductive research approach will be employed. A deductive research is the most convenient to answer the research questions purposed due to the main idea of this thesis is to clarify the potential of blockchain technology in supply chains by creating a framework. Thereby, to discover this reality, a theoretical framework will be developed, supposing the deductive hypothesis of the research. This framework will be based on a literature review, focusing on



topics related to how to get an effective supply chain management and the basics of blockchain technology.

On the other hand, the deductive hypothesis will be tested by analysing multiple study cases with an explanatory approach. This strategy has been chosen against the others due to the ability to collect and analyse the data within the context of phenomenon and the ability to capture complexities of real-life situations so that the phenomenon can be studied in greater levels of depth (Saunders, et al., 2009). Moreover, the scarcity of information about this topic has influenced the decision of employ multiple study cases. More than one study cases are used with the objective to obtain greater levels of depth about how companies are starting to introduce this technology in their supply chains and the effects and challenges they perceive in its implementation. These study cases will be analysed in a particular time, meaning a cross-sectional time horizon in the research.

The information used in the research was gathered employing different existing materials. For the development of the theoretical framework, the literature review was based on books, business journals, brochures of companies and white papers. Firstly, the information search was carried out in the electronic library of the Universidad Politécnica de Madrid using keywords, such as blockchain or supply chain management. Subsequently, more information was collected by doing an internet search employing the same keywords. In regards with the study cases, the information related with them was gathered in a similar way, mainly based on mass media reports, brochures, white papers or companies' press releases.

After the main searches, a large set of suitable material to answer the research questions was found, so a selection criteria was necessary to ensure the research validity and reliability. The criteria established includes the methodology employed, accuracy, currency, objective, nature and dependability of the materials. According to the methodology used in the research, the material selected should be reliable, valid and generalizable to the problem at hand. For that purpose, the accuracy must to be assessed by comparing data from different sources. The currency of the material directly affects to the results, so it is necessary check the publication date or the time lag between collection and publication of the information sources to ensure the most updated research results. On the other hand, the goals of the research will determine the relevance of the data, helping to filter the set of materials. The nature of the data is also used as selection criteria. The content of the data is assessed according to the quality of discussions and depth of analyses. Finally, the dependability of the data, which is based on the expertise, credibility, reputation and trustworthiness of the source, is evaluated by the originality of the source, trying to avoid acquired ones (Kumar, 2015).

## **2.5 Validity and reliability**

The attributes of validity and reliability are important for the credibility of the research findings. The reliability refers to the extent to which the data collection techniques or analysis procedures yield consistent findings, while the validity is a measure of test's ability to measure phenomena it claims to measure (Saunders, et al., 2009; Ponomarjovs, 2013). In regards with the validity, there are two different kinds: internal and external validities. Internal validity refers to the accuracy of results, whereas external validity refers to generalizability and transferability of research results (Ponomarjovs, 2013).

In order to ensure validity and reliability in the research, both of them are emphasised during the research design. To ensure internal validity several sources of information for each study case are employed. On the other hand, the external validity is kept as the result of the study can easily applied to other companies. Moreover, this study is reliable as most of the sources of information come from directly from the companies under study.

### 3. THEORETICAL BACKGROUND

Every organization delivers products to its customers in order to serve their needs (Waters, 2007). For that purpose, they need to look outside the individual organization and consider how to reach an effective flow of materials and information to meet the requirement of the customers (Christopher, 2005). Thereby, individual businesses no longer compete as solely entities, instead of that they are part of supply chains (Lambert & Cooper, 2000).

The supply chain (SC) is a network of partners who collectively convert a basic commodity (upstream) into a finished product (downstream) that is valued by end-customers, and who manage returns at each stage. Each partner in a SC is responsible directly for a process that adds value to a product (Harrison, et al., 2008). It encompasses all the activities related with the flow of information and materials from the raw material stage through to the end user (Ballou, 2004).

The objective of every SC is to achieve the highest possible return on investment over time (Ballou, 2004). It demands a sustainable competitiveness of the SC as a whole by meeting end-customer demand through supplying what is needed in the form it is needed, when it is needed, at a competitive cost (Harrison, et al., 2008). In order to reach these goals is required an effective supply chain management (SCM).

In this section, the main currently SCM challenges are discussed, as well as how the digitalization of certain SC processes can help to enhance efficiency and minimize risks across the whole SC. Among all the existing technologies to digitalize the SC, the blockchain has a huge potential to solve SCM issues and transform current SCs. Finally, a framework about the potential applications of the blockchain technology in the SCs is introduced.

#### 3.1 An effective Supply Chain Management

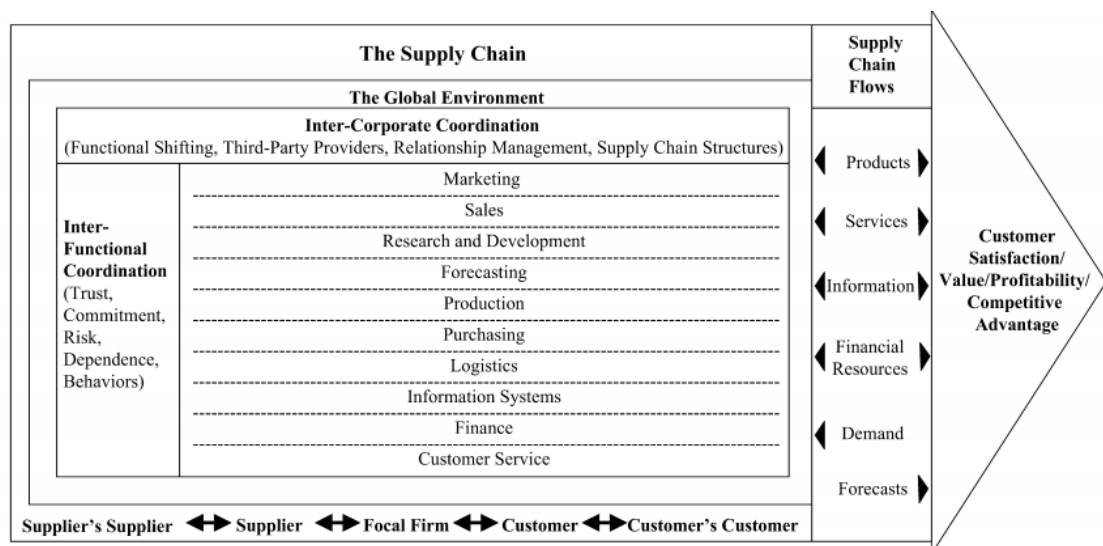
The literature reveals a lack of consensus regarding the meaning of the term SCM, but it has evolve merging in a unified body of literature with a common goal of competitiveness and increased efficiency. The definition of SCM that is adopted in this document is the proposed by Simchi-Levi, et al. (2008):

*Supply chain management is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimized systemwide cost while satisfying service level requirements.*

This definition takes into consideration that every function (marketing, logistics, production, etc.) in each facility and the logistics interaction among them has an impact on cost, and plays a key role on making the product according customer's requirements. It is also required taking into account the suppliers' suppliers and the customers' customers because they impact on the supply chain performance (Simchi-Levi, et al., 2008).

This approach is focused in managing the supply chain as system, integrating the processes of supply chain partners (Simchi-Levi, et al., 2008). So, SCM is based on a systematic, strategic coordination of the traditional business functions and tactics across these business functions and across business within the SC, for the purpose of improving the long-term performance of the individual companies and the SC as a whole (Ballou, 2004).

The scope of this model of SCM is illustrated in the Figure 1, where the SC is pictured as a pipeline. The SCM is about coordination of different directional flows (product, information, forecast, etc.) across different functions in each organization (marketing, sales, logistics, production, etc.) and across companies along the SC. The inter-fuctional coordination includes trust, commitment, risk and dependence on the viability of internal funtional sharing, while inter-corporate coordination is about functional shifting within the SC, the role of different third-party providers, relationship management between companies and viability of different SC structures. Without an appropriate inter and intra-coordination, the SCM cannot achieve its full potential ( Mentzer, et al., 2001).



*Figure 3: Model of Supply Chain Management (Ballou, 2004).*

In this context, the information exchange technologies and IT systems are key to achieve both inter and intra-coordination through the SC, and ultimately are important enablers of effective SCM. The information flow is the connecting link that binds the different SC

processes all together, and which help to coordinate the different internal functional processes. Moreover, the information shared among SC partners help to reduce uncertainty by being aware of other partners' activities (Harrison, et al., 2008).

This model also shown the importance of the end-customer, who is responsible to initiate the whole process by buying finished products. This behaviour causes materials, information and cash to flow through the supply chain (Harrison, et al., 2008). Thus, the customer focus in SCM is key to create a unique and individualized sources of customer value, leading to customer satisfaction ( Mentzer, et al., 2001).

Furthermore, this model help to focus on the ultimate goals of SCM – improve efficiency and effectiveness in a strategic context to obtain competitive advantage that ultimately bring profitability. In other words, the main objectives of SCM are enhance customer value and satisfaction, which in turn leads to enhance competitive advantage for the SC, as well as each member firm. This, in the end, improves the profitability of the SC and all its members ( Mentzer, et al., 2001).

Hereafter, the key issues and trade-offs associated with a successfully SCM, previously commented, are deeply discussed.

### **3.1.1 Customer value and satisfaction**

In currently customer-driven markets, the perceived value to customers of the entire relationship with a company is the most critical factor (Simchi-Levi, et al., 2008). The consciousness of customers towards value is determinant during the purchase decision process, wherein customers increasingly are demanding products with more value added, but at lower costs (Waters, 2007).

This customer centric perspective requires linking customer value to SC strategy by taking the end user as the organization's point of departure (Christopher, 2005). Being one of the basic functions of SCM the ability to respond to customer requirements. In order to undertake it, SCM contribute by creating availability and selection in the offer to the customers to cover their wants and needs. The price and the service level are also essential parts of the customer value, as well as the value-added services and the relationships and experiences with the firm (Simchi-Levi, et al., 2008).

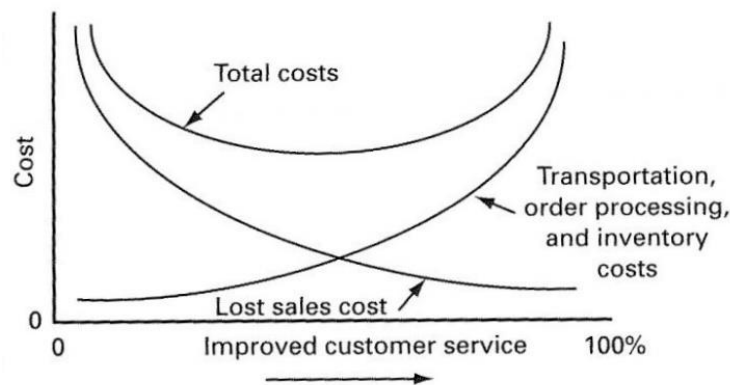
Customers value many aspects of the total offering of a firm, primarily place value against product quality, order cycle lead-time, cost and service levels (Emmett & Crocker, 2007). Nevertheless, these elements do not have the same relative importance for the customers, some factors in customer service are more important than others in value adding to them. Therefore, companies must to understand first, which the core areas are that customer value the most for a certain offering, and focus on leverage and boost them.

Because the customer value is based on perceptions, it requires metrics allowing for identify the company's advantages as well as opportunities for SC improvement. Typical measures include service level, customer satisfaction and SC performance metrics (Simchi-Levi, et al., 2008).

- **Service level**

The whole purpose of the SCM is to provide customers with the level and quality of service that they require, thereby the service level measure is used to quantify a company's market conformance or the ability to satisfy customer's delivery date (Christopher, 2005; Simchi-Levi, et al., 2008). In this sense, when defining the market-driven SC strategy the aim is to achieve "service excellence" in a cost-effective way. The cost-customer service trade-off is in evidence at setting the proper customer service level (Christopher, 2005).

To meet with higher customer service levels required by the customers, the activity levels are increased, incurring in costs that increase in a rising rate, as is shown in Figure 4. If customer service level is improved, fewer customers are lost due to out-of-stock situations, slow or unreliable deliveries, and inaccurate order filling. The cost of less lost sales decreases with enhanced service level. In contrast, the cost of maintaining the level of service rises because of improved service means that more must to be paid for transportation, order processing and inventory (Ballou, 2004).



**Figure 4: Trade-off in setting the customer service level (Ballou, 2004)**

In order to set the optimal customer service level, an analysis of the total costs is needed. Through it, the conflicts among different activities of a firm are displayed. Thus, the different activities can be managed and balanced for the purpose of optimize collectively. As is shown in Figure 2, the best trade-off occurs in a point below the 100% customer service (perfect customer service), where that service level maximizes the firm's profit contribution (Ballou, 2004).

Afterwards, the customer service has to be effectively assessed to improve it continuously. For that purpose, tailored customer service measures are needed, focusing in

the more valued aspects for the customers. Total order-cycle time and its variability are one of the best measures due to encompass multiple variables key to the customers. In addition, customer service level can be also measured with SC performance metrics related with: order entry, order documentation accuracy, transportation, inventory and product availability, etc. (Ballou, 2004).

With the help of these measures, an inappropriate customer service and SC performance can be detected and managed. Competitive forces, policy revisions or just arbitrary service goals different from those originally set can lead in SC strategy reformulation (Ballou, 2004). However, not always is necessary exactly meet the customers' expectations, most of them accept a relatively wide range of performance in any given service factor (Waters, 2007).

- **Customer satisfaction**

The customer satisfaction is what customers think about the quality of product/service of the company and the value gotten for the money (Harrison, et al., 2008). Measuring the customer satisfaction is usually done by surveys that provide feedback about sales department and personnel performance. Unfortunately, these are not a very reliable source of information because the surveys are easily manipulated and misleading (Simchi-Levi, et al., 2008).

The subjective attitude of customer satisfaction is based on the value perception for a service/product, which is key to the behaviour of customer loyalty. The customer loyalty is how long a customer is retained, which helps to generate long-term revenue streams and provide cost savings in comparison with attract new customers. In addition, the loyal customers tend to buy more than new ones, increasing spending over time and may be willing to pay premium prices (Harrison, et al., 2008).

The customer loyalty metric is widely use due to be easier to measure than customer satisfaction. It can be conducted by analysing customer repurchase patterns or internal databases focusing on, for instance, customer retention or customer asset accumulation (Simchi-Levi, et al., 2008).

By the measurement and comparison of customer loyalty metrics with the strategically established goals for them, companies can adjust them to increase the value added to customers. Changes in service quality, product quality or price deliver a higher perceived value, which ultimately leads into customer loyalty (Harrison, et al., 2008).

- **SC performance measures**

The SC performance is an important provider of customer value, especially the customer service (Simchi-Levi, et al., 2008). Typically, these measures are wrongly

based on internal performance, such as how reliably and fast the organization delivered against planned timetable. This approach misses the customer-focus orientation due to these measures might not be aligned with customers' needs, failing in tracking responsiveness to customers. Therefore, it is necessary to ask customers for their desired delivery window and measure performance against that customer-defined measure of success (Waters, 2007).

Furthermore, a standardization in the SC performance measures is required due to reach a common language among the multiple partners in the SC. For that reason, the Supply-Chain Council purposed the Supply Chain Operation Reference (SCOR) model (Simchi-Levi, et al., 2008). A model in which the focus firm is placed in the context of the SC, helping companies to understand their SC performance and opportunities for SC improvement (Harrison, et al., 2008).

The SCOR model is based on a set of metrics for SC performance, which help to analyse the current state of the processes, operational performance and goals of a company. These measures are evaluated against best-practice information of industry benchmarks, such as average and best-in-class (Simchi-Levi, et al., 2008).

The previously mentioned metrics of customer value captured are recorded in company's information systems. Firstly, the data captured and collected, both internally and externally, must to be transformed into information that can be portraying in a useful manner for decision-making (Ballou, 2004). But, the accuracy and reliability of the data gathered together with its enough abundance of availability are important points to use this information effectively and have the opportunity to improve the SC performance (Simchi-Levi, et al., 2008). On the other hand, the different measures recollected do not have only to be comparable with existing internal metrics, but also should they be compatible with SC partners' ones in order to appropriately assist in the decision-making process.

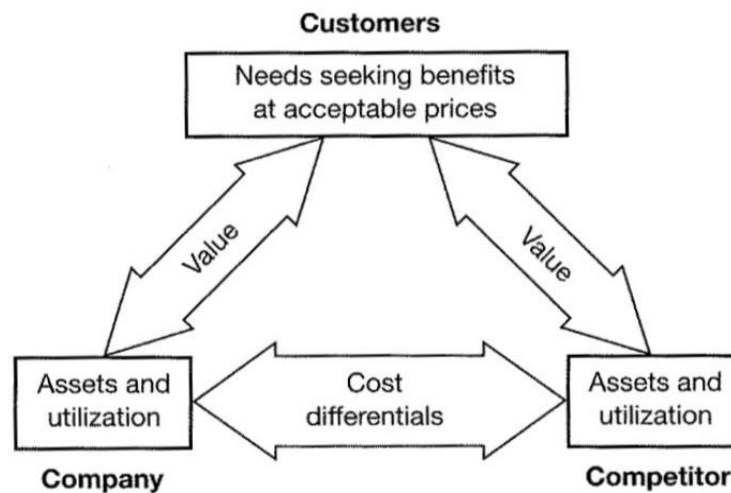
### **3.1.2 Competitive advantage**

An efficient SCM can provide a sustainable source of competitive advantage, by providing the customers the increasingly value added that they continuously demand (Waters, 2007). Therefore, through better SCM than the competitors, companies can reach a position of enduring superiority in terms of customer preference (Christopher, 2005).

Some authors defend that the source of competitive advantage is found around the triangular linkage of the company, customers and its competitors, as is shown in the Figure 5. The company has to find the ability to differentiate itself from its competitor and operate at a lower cost. Ideally, the most successful company in an industry tends to be the lowest cost producer or/and the supplier providing with the greatest perceived differentiate values. In other words, it has a cost advantage, which gives a lower cost profile, or a value

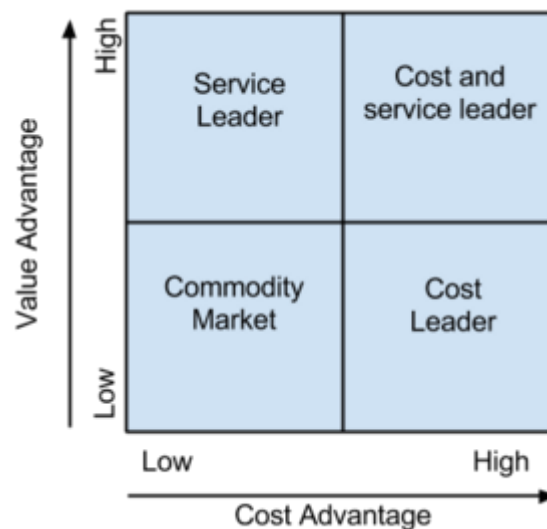


advantage that allows competitive offerings, or a combination of both (Christopher, 2005).



*Figure 5: Competitive advantage and the "Three CS" (Christopher, 2005)*

The challenge to SCM is to identify and establish the appropriate SC strategies to be both a cost and service leader company, moving the organization to the right top corner of the matrix in Figure 6.



*Figure 6 : Supply chain and competitive advantage (Christopher, 2005)*

In order to leverage opportunities to gain value advantage, companies have to consider introduce better customer service by increasing reliability, responsiveness, resilience and tailored services. On the other hand, better capacity utilization, inventory reduction or synchronous supply are necessary to reach a better cost advantage (Christopher, 2005). All these strategies require better information sharing among the different SC partners,

which helps to avoid the bullwhip effect and replacing inventory with information (Simchi-Levi, et al., 2008).

### **3.1.3 Profitability**

The difference between the revenue generated from the customer and the overall cost across the SC is the SC profitability (Chopra & Meindl, 2007). One of the main goals of SCM is maximize the SC profitability by efficiently response to customers while total systemwide cost are minimized, in other words, global optimization (Simchi-Levi, et al., 2008). Hence, SC profitability might be used as a measure of SC success (Chopra & Meindl, 2007).

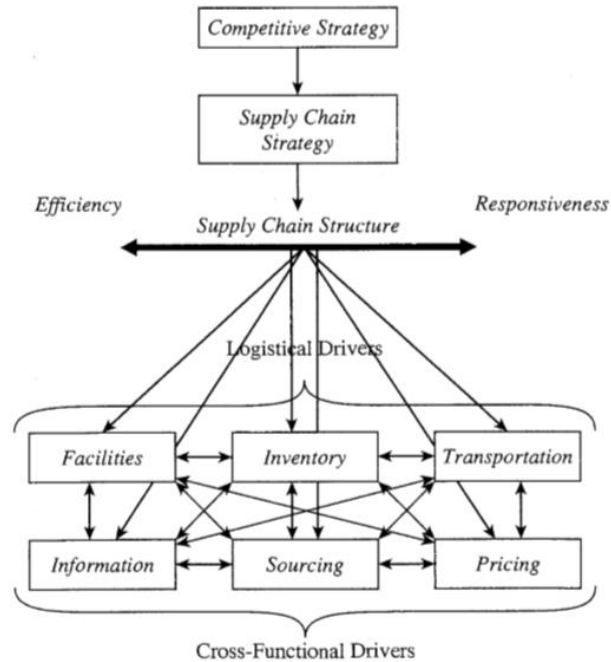
Designing, planning and operating a SC where the total systemwide costs are minimized while the service level are adequate is highly challenging. SC partners have to replace traditional strategies focus on maximize its own profit to those that are the best for the entire SC. Thus, all the members of a SC share risk and the potential benefit (Simchi-Levi, et al., 2008). In addition, all functional areas across all members of the SC has to strategically focus on maximize SC profit. Consequently, all functional strategies have to be developed to support both each other and the competitive strategy of global optimization (Chopra & Meindl, 2007).

In order to enhance company's profitability, and ultimately SC profitability, a company can improve SC performance in terms of responsiveness and efficiency. Therefore, cost are minimized or/and more value added is created to the end-customer offering, making them willing to pay more (Chopra & Meindl, 2007).

According to Chopra & Mendel (2007), the logistical drivers – facilities, inventory, and transportation – and the three cross-functional drivers – information, sourcing, and pricing – can designate the SC performance. These drivers interact with each other, determining the SC's performance in terms of responsiveness and efficiency, as is shown in Figure 7. As a result, the configuration or structure of these drivers establish the strategic fit achieved across the SC.

The information driver is potentially the most important driver to SC performance due to it directly affects each one of the other drivers. The information consists on the data and analysis concerning facilities, inventory, transportation, costs, prices and customers throughout the SC (Chopra & Meindl, 2007). Information represents management with the opportunity to make SCs more responsive and more efficient by better customer demand forecast and improved coordination of manufacturing and distribution system strategies (Simchi-Levi, et al., 2008).

The main goal of SCM is to reach a balance between responsiveness and efficiency, which is aligned with SC strategy to maintain competitive advantage. For this reason, the logistics and cross-functional drivers need to be configured to attain the performance level the SC strategy dictates to maximize the supply chain profits (Chopra & Meindl, 2007).



*Figure 7 : Supply chain decision-making framework (Chopra & Meindl, 2007)*

### 3.1.4 Integration and coordination

The integration and coordination intra and inter-organizations in a SC is not a direct goal in SCM, but is a basic requirement to attain an efficient and successful SCM (Mentzer, et al., 2001). Individual companies cannot longer compete against other isolate companies, but rather as SC against SC (Waters, 2007). In this way, if each stage of a SC works only towards its own objectives and interests instead of the whole system's, an overall reduction in SC profitability appears because of changes in one activity inevitably affects others. A performance improvement in a company, which is misaligned to SC strategy, can only push costs and inefficiencies to other parts of the chain (Waters, 2007). A lack of integration affects negatively to the SC's ability to match effectively demand and supply, leading in customer dissatisfaction and higher costs (Chopra & Meindl, 2007).

Generally, an improved integration, both upstream and downstream, leads to an improved performance of the whole SC. For that purpose is necessary support the coordination between SC partners by establishing a common governance of material and information flows (Harrison, et al., 2008). This means that companies can only obtain the best results by considering all aspects of information and material movement in a single and coordinated flow through the SC, meaning that all the related activities are merged into a single integrated function (Waters, 2007).

Despite the vast opportunities in a coordinated and integrated information flow throughout the whole SC, most SC partners are still reluctant to share sensitive information. The lack of trust among partners, because of the risk of deliberate misrepresentation of information or indirectly give advantage to competitors among others, results in significant duplication efforts and the reduction of the amount of information available. The integration of the information flow can only be achieved with a common IT system based on trust, in which available data is up to date and shared among SC partners in a for your information basis and in a common standardized format (Simchi-Levi, et al., 2008).

In practice, internal integration is the starting point for a broader integration across the SC. With an internal cross-functional alignment around SCM, companies demonstrate higher performance in terms of meeting customer needs, which enhance customer perception of the organization. Despite the potential performance improvement by internal integration, the inter-company or external integration could present even higher benefits (Harrison, et al., 2008).

The external integration can increase responsiveness in SC by integrating critical processes across the SC, such as material replenishment, new product development or payments. This approach is based on collaborative planning and strategic development with the key upstream partners. Furthermore, the synchronous production, which consists on linking the upstream production schedules with downstream demand, is another approach that can be used to improve material flow and reduce inventories while enhancing responsiveness in the whole SC. In this case, the transparency and share of the systemwide information are key to make possible the synchronisation of the work. Some widely use techniques of synchronous production are collaborative planning, forecasting and replenishment (CPFR), quick response or vendor managed inventory (VMI) (Harrison, et al., 2008).

As a result, successfully internal and external integration can provide the following benefits (Waters, 2007):

- Common objectives for all members of the SC
- Increasing transparency by sharing information along the SC
- Easier planning
- Faster and more flexible responses to customer demands
- Lower stock levels
- Less duplication of effort, information, stocks, etc.
- Improved efficiency and productivity
- Less uncertainty, errors and delays
- Waste elimination – elimination of non-value added activities for customers

## 3.2 Digital Transformation of Supply Chains

The ability to handle impressive amounts of data quickly and accurately by cheap computer power has transformed the way SCM is conducted over the last 30 years (Rushton, et al., 2007). The SC has become increasingly more information-dependent, making data, information and knowledge critical assets for SCM (Waters, 2007; Copacino, 1997).

The information systems (IS) are key to manage those assets, requiring continuously more demanding capabilities to obtain a superior SC performance and gain competitive advantage. Through information technology (IT), which consist on telecommunication, networking and data processing technologies, data can be collected, analyzed to generate meaningful information and exchange and share with SC partners (Waters, 2007).

In 1990s, the Enterprise Resource Planning (ERP) database supposed an important development for many major companies (Rushton, et al., 2007). These systems allow capturing data from the whole business, integrating multiple databases that previously existed and worked as isolated siloes (Anon., 2015). As a result, the ERP systems combined with an appropriate SCM enabled a tremendous improvement in data availability and accuracy, and increasing the recognition of the need for better planning and integration among SC components (Anon., 2015; Rushton, et al., 2007). Nevertheless, the installation and implementation of those ERP systems supposed a widespread change and challenge within the organization, modifying the way in which individuals work as well as in terms of organizational structure (Rushton, et al., 2007).

Afterwards, the advance planning and scheduling (APS) systems appeared as SCM tools to support decisions and operational planning in a SC. Thus, APS tools use real-time information (i.e. demand data or/and forecast), linked with production capacities and run rates, inventory holding levels and locations, supplier lead times, etc. to help to determine operational production and inventory requirements (Rushton, et al., 2007). The APS systems are embedded in ERP systems, as well as other functional IS (transaction support systems), such as barcoding technology in a point-of-sale (POS), warehouse management systems (WMS), supplier relationship management (SRM) systems, transportation management systems (TMS), etc. (Waters, 2007; Rushton, et al., 2007).

Previous SC information systems integrate IT internally, facilitating the data, information and communication in an organization, that is to say, across dispersed functional departments and locations. Using local area information and client-server technologies to implement an organization-wide information and communication framework (Waters, 2007).

However, an extranet system to share and exchange information with the SC partners is also required (Waters, 2007). Traditionally, electronic data interchange (EDI) is a widely

adopted computer-to-computer inter-firm exchange of structured data for automatic processing, enabling standardized electronic business message to replace paper-based processes (Harrison, et al., 2008; Rushton, et al., 2007). The deployment of EDI increases productivity, cost savings, accurately billing and improved traceability and expenditure. Moreover, it helps upstream partners to access timely to accurate information from markets and customers, whereas downstream partners can provide better customer services by responding better to market changes and demands (Waters, 2007). Other technologies that enable an integrated SC are the radio frequency identification devices (RFIDs), barcodes, scanning technology or automatic order generation and processing (Rushton, et al., 2007).

The ITs above contribute to develop shared SC processes, allowing each SC partner to focus on their core business values and permitting them to benefit from each other. These ITs achieve integration and visibility throughout the SC, enabling synchronous production approaches like VMI or CPFR (Waters, 2007; Harrison, et al., 2008).

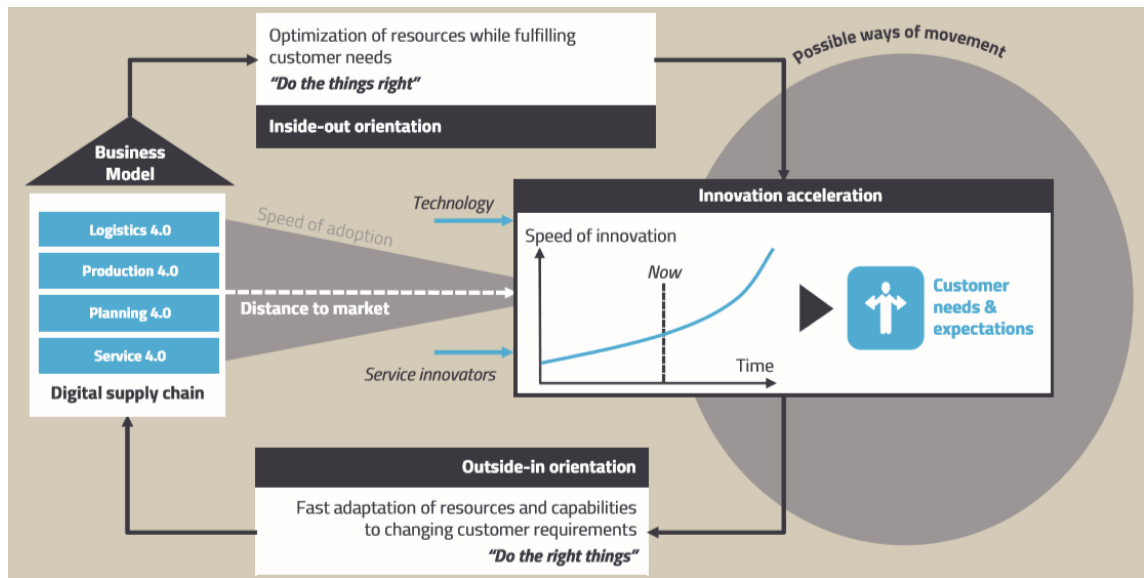
Despite the widely use of the inter-organizations systems abovementioned, they can be incompatible with each other, while they imply high development and installation costs. Technologies based on internet offer a platform-independent communications that can be used as a cross-company interface, facilitating the access to new markets and new business opportunities as e-commerce and e-business (Harrison, et al., 2008).

Reducing the gap between the market expectations and the SC performance, which is the gap between demand and supply at every point in the system, is a never-ending game in SCM (Barkawi, 2018). Nowadays, in a globalized and widely connected to the internet world, traditional SC are evolving towards a connected, smart, and highly efficient SC ecosystem. The digitalization enables a more integrated SC, offering a greater degree of resiliency and responsiveness to provide most efficient and transparent service delivery to customers and to solve current challenges in SCM (PWC, 2016).

The rising technical maturity and the increasing use of standards and platform technologies are boosting the digitalization adoption and implementation, shaping the digital supply chain ecosystem as is shown in Figure 6. It must be stressed that the speed of innovation that companies are facing is rapidly accelerating, making the fast adoption of SC innovations a key capability for organizations. As customer expectation is continuously boosted, through new service offerings based on innovations in the market, it is pulling companies to adopt speedily those innovations in order to keep a competitive advantage (Barkawi, 2018).

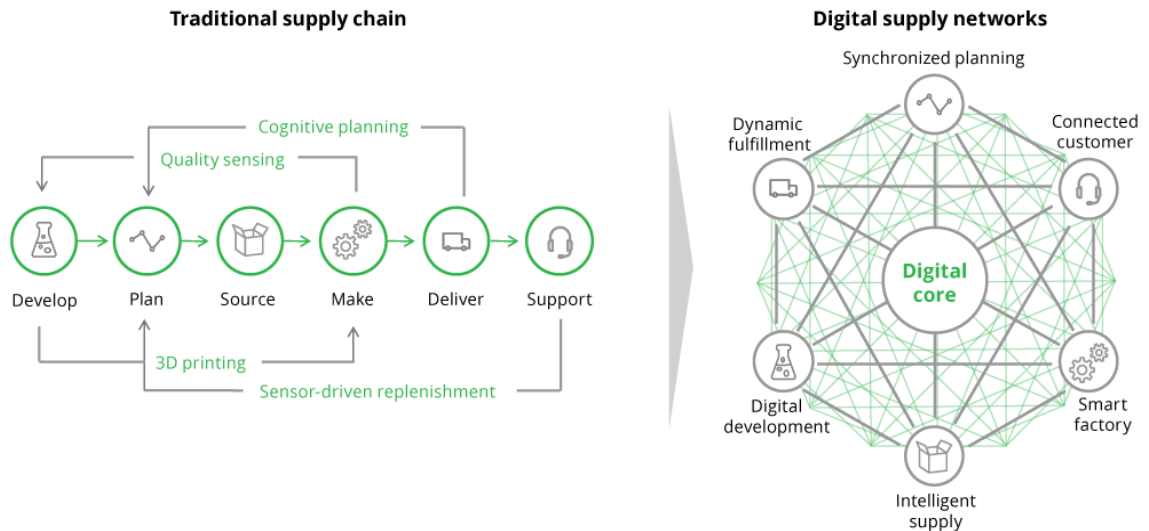
This enhanced innovation speed that digitalization is driving is affecting simultaneously all business functions of each partner of the SC, allowing the digitization of products and services, and the digitization and integration of every link in a company's value chain (Barkawi, 2018; PWC, 2016). The implementation of a wide range of digital technologies

(i.e. Big Data, the Internet of Things (IoT), augmented reality, etc.) is enabling new business models, which ultimately permitted the optimization of resources while fulfilling the customer needs. Thus, the digitalization of the SC generates opportunities to raise the level of customer service towards an agile and efficient SC (Barkawi, 2018).



**Figure 8: The goal of supply chain digitalization (Barkawi, 2018)**

Considering the supply chain digitalization framework of Deloitte (2016), the digitalization enabling technologies transform all the traditional SCOR processes of the SC— plan, source, make, deliver, return, and service – into an integrated SC ecosystem or digital supply network (DSN) (see Figure 9). In traditional SC models, the information flow is linear with dependency of the step before. Thereby, potential inefficiencies in a step can generate a cascade of similar inefficiencies in following stages. Data entry errors, fraud attempts, double entries, obsolete data or data definition misunderstanding are some of the inefficiencies that represent a challenge in SC information management, which subsequently affect the following SC processes. The scarce of visibility into the processes of other partners of the SC limits the ability to respond to market changes and unforeseeable situations. Because of that, the “bullwhip” effect commonly appear in SCs (Deloitte, 2016).

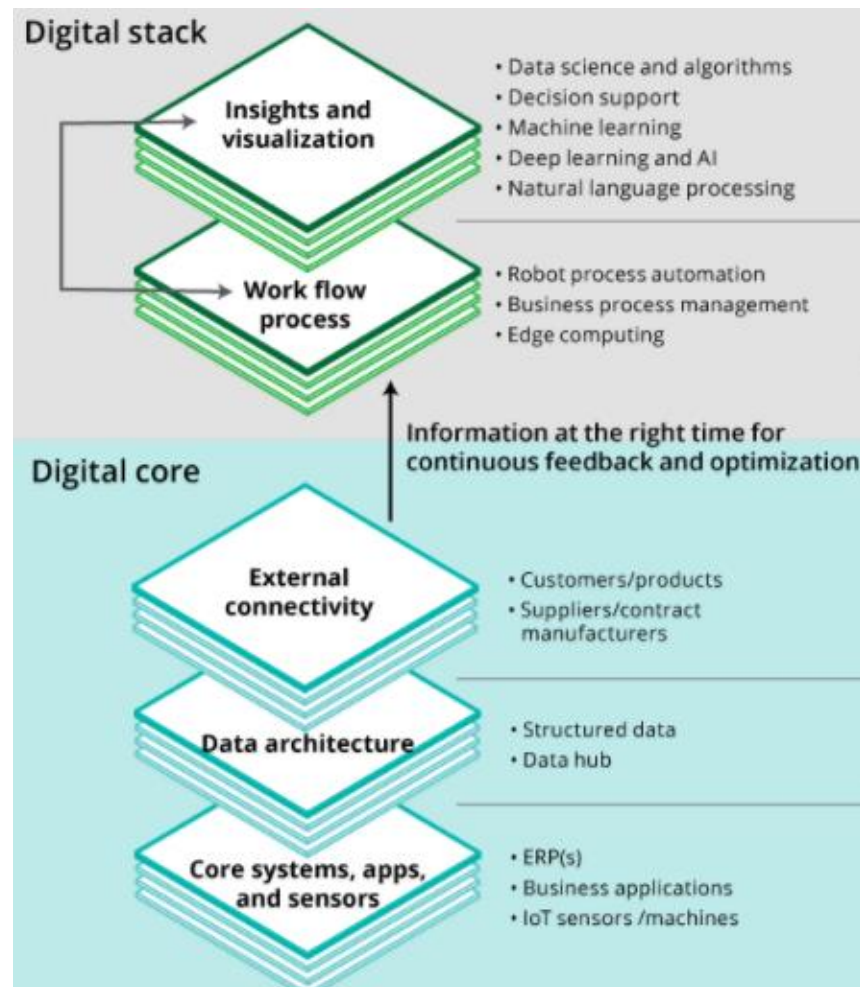


**Figure 9: Shift from traditional SC model to DSN (Deloitte, 2016).**

In the DSN vision, each node of the SC becomes more capable and interconnected thanks to technology. The digital central control core interconnects all the stages allowing a continuous flow of information that facilitates automation, adds value, and improves workflow and analytics across the entire supply network. Thus, a potential for interactions from each node to every other point of the network appears, allowing higher connectivity among areas that traditionally has been disconnected by links in the SC. By this way, DSNs can minimize the latency, risk, and waste found in linear supply chains, and achieve new levels of performance, improve efficiency and effectiveness, and create new revenue opportunities (Deloitte, 2016).

The network data from multiple sources of the DSN —products, customers, suppliers, and aftermarket support— is synchronized gathered in the DSN digital core to reduce cost of storage and improve data availability through enterprise-wide data warehouse access. This data is integrated to create a single point of connectivity to the supply network. Thus, the information can be accessed at the right time by an integrated DSN hub or stack, which provides a single location access to DSN core data (see Figure 10). This hub supports the free flow of information across the whole network and includes multiple layers to integrate this data to support and enable informed decision-making (Deloitte, 2016).

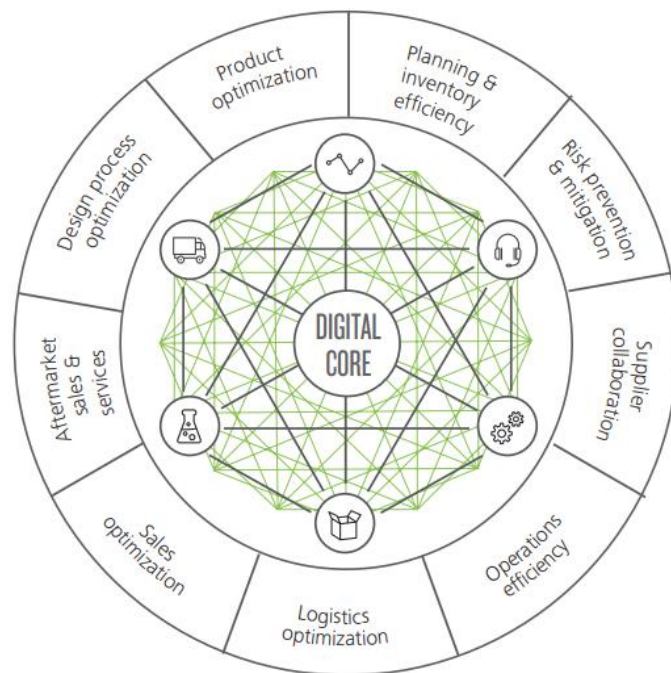




*Figure 10: The digital core and stack of DSNs (Deloitte, 2016)*

The DSN's capabilities have a key role in addressing the SC strategy. They enable always-on agility, connected community, intelligent optimization, end-to-end transparency, and holistic decision-making across the DSN. Thus, the integrated DSN may achieve more than one priority or competitive differentiating factors, such as speed or service, by dismissing or eliminating trade-offs whereas still keeping competitive. As all the partners of the SC communicate with each other, priorities identified during the strategic decision-making process can be addressed on multiple fronts. In effect, this gives DSNs new strategic decision-making abilities unlike any they have had before (Deloitte, 2016).

Once the organizations in the DSN have determined the strategy to pursue, they should design the kind of supply network needed to achieve it, which is the capabilities of the DSN required. In order to realize the chosen strategy, companies can configure the SC with multiple different transformations. These strategic transformations that companies can make are shown in Figure 11, each one is based on strategic tactics that employ multiple digital technologies, such as 3D printing or sensors (Deloitte, 2016).



**Figure 11: Strategic transformation in DSN (Deloitte, 2016)**

In this sense, companies who pursue a digital transformation of their SC have to decide which tools and technologies are the appropriate to reach the selected DSN strategy. According with the SC digitalization framework of Barkawi (2018), as is shown in Figure 12, the implementation of the multiple different technologies along different stages of the SC can lead into a more integrated and customer centric DSN. Thereby, these technologies enable that traditional SCOR processes to be integrated into a digital data flow, which allows a comprehensive understanding of the DSN based on KPIs and smart analytics in real time (Barkawi, 2018).

The main technologies to digitize the SC are described below (see Figure 12):

- Sensors and IoT

The data is captured and recorded automatically and in real-time via sensors, which are embedded in virtually all product components and manufacturing equipment. The sensors are connected with the central systems through secure wireless networks, providing online data that is recorded in a single information system with historical data. Highly sophisticated decision-making tools process this data, allowing close control, monitoring and real-time adaptation. The sensors and actuators of IoT enable automatization, responding rapidly to changing network conditions and unforeseen situations. Therefore, multiple stages in the DSN can become self-optimizing and interconnected with other locations (McKinsey&Company, 2015; Barkawi, 2018).

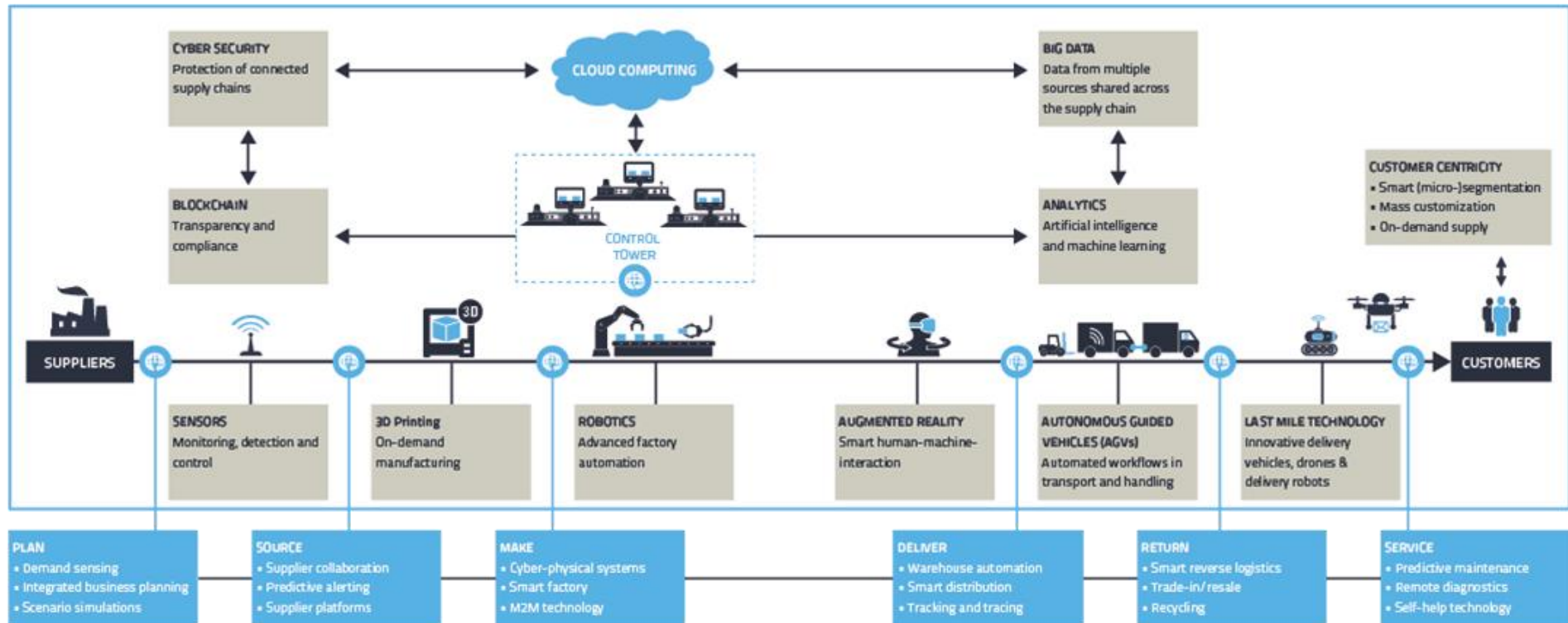


Figure 12: Supply chain digitalization framework (Barkawi, 2018)

- 3D printing

The 3D printing makes the conversion of digital construction data into a physical tangible work piece possible (McKinsey&Company, 2015). Thereby, spare parts can be manufactured on-demand at facilities maintained locally, so inventories can be reduced as well as freight costs. As a result, machine downtimes are minimized (McKinsey&Company, 2015; PWC, 2016).

This technology also enables the development of highly customized products based on customer requirements. The quickly manufacture of customized tools and molds to plug into production line machines increases the range of products that the lines can make. This augment the catalog of offerings to customers without increasing inventories (McKinsey&Company, 2015).

Other application of 3D printing in DSN is reducing the time to market of new products by speeding up the development process. A rapid prototyping through 3D printing is now possible, therefore it reduces the development cycle and achieves a cost reduction in R&D (McKinsey&Company, 2015).

- Robotics

The advanced robotics technology appears thanks to advances in artificial intelligence, machine vision and M2M communication, and cheaper actuators. The automatic data analysis leads in automation of knowledge work, which generates an autonomously system reaction (McKinsey&Company, 2015).

- Augmented reality

This technology enable new ways of human-machine interaction, helping in expensive and labor-intensive processes, which are often still carried out using paper and prone to human error (McKinsey&Company, 2015; PWC, 2016).

An example of application of this technology is the use of augmented reality eyeglasses to optimize the picking process in a warehouse. All the relevant information is shown on the display, superimposing on the employee's field of vision. This information helps them to locate items faster and precisely, guide them on optimal pallet building, and notice the handling of fragile items (McKinsey&Company, 2015).

- Autonomous guided vehicles

This technology is still under development, but it will reduce the need for human drivers. The main use of autonomous vehicles will be as driverless trucks in logistics, where they will depend on mapping software and short-range radar to assess the ve-

hicle's surroundings. In addition, they will employ wireless connections to other vehicles and to the road in order to obtain information that will make them to speed up traffic flow and reduce roadway congestion and accidents (PWC, 2016).

This technology will allow faster and more reliable delivery times, while reduce emissions thanks to more efficiency operations and routing. Moreover, the cease of human drivers allows lower labor costs and the removal of human error (PWC, 2016).

- Last mile technology

Last mile delivery technologies will automate the process of getting products into the hands of the customer. They offer a way for lower logistics costs while provide a greater customer value in processes that are labor-intensive and highly interactive with customers. The main proposals are self-driving delivery robots moving at pedestrian speeds to distribute packages along flexible routes or drones to drop packages from the sky onto customers' front door (PWC, 2016).

- Cloud computing

The cloud computing is a virtual infrastructure offering a central commander center which connect the end-to-end processes with DSN partners. Thereby, this cloud-based platform facilitates collaboration and offers a number of deployment environments and tailored databases (McKinsey&Company, 2015).

- Big Data

Big Data refers to databases whose size is beyond the ability of typical dataset software tools to capture, store, manage and analyze. The Big Data engines identify, combine, and manage multiple sources of data, including real-time and historical data. Firstly, they identify and connect the most important data, following with a cleanup operation to synchronize and merge overlapping data and then to work around missing information. Then, the result are used to perform advanced analytics, whereby they analyze Big Data to make better decisions and capture value (Manyika, et al., 2011).

- Advanced analytics

The advanced analytics include the use of sophisticated technics and tools such as machine learning, artificial intelligence, data mining, patter matching, forecasting, visualization, semantic analysis, sentiment analysis, network and cluster analysis, multivariate statistics, graph analysis, simulation, complex event processing, and neural networks. The advanced analytics models are run over a Big Data infrastructure to discover deeper insights, make predictions, optimizing or generate recommendations (Gartner, 2017).

The data assets, together with the analytics capabilities of companies, derive competitive advantage to DSN. The advanced analytics supports better and faster decision-making, helping organizations to improve operational effectiveness and efficiency (Bain&Company, 2018).

- Blockchain

The blockchain is a decentralized immutable record of data, where companies can digitalize physical assets and record all their transactions. Moreover, it provides a common access to all SC partners to the same information, reducing potential communication or data errors transference. As a result, less time is necessary to validate data, so these resources can be allocated to improve quality, reducing cost, or both (Deloitte, 2018).

By this way, blockchain can help to record price, date, location, quality, certification and other relevant information to manage more effectively the DSN. This innovation drives potential to deliver business value by increasing SC transparency and accurate end-to-end tracking in the SC, reducing risk and fraud, and improving efficiency and overall SCM (Deloitte, 2018).

### **3.3 Blockchain Technology in Supply Chains**

With the invention of bitcoin in 2008 and then its practical implementation in 2009, a new technology was introduced: the blockchain (Bashir, 2017). The foundations of this first cryptocurrency, explained in Satoshi Nakamoto's paper "Bitcoin: A Peer-to-Peer Electronic Pay System", serve also as basis for the technology invention behind the bitcoin and which makes it possible: the blockchain (Mougayar, 2016).

The blockchain technology can be defined from different and complementary approaches, enabling to better understand its capabilities (Mougayar, 2016). Technically, blockchain is a peer-to-peer (P2P) distributed ledger cryptographically secure, append-only, immutable, and updateable only via consensus or agreement among peers. Moreover, it can be understood as a layer of a distributed P2P network running on top of the Internet (Bashir, 2017).

From the business point of view, blockchain is a platform through which peers can exchange values and assets using transactions without the need for a central trusted arbitrator. This enables blockchain to be a decentralized consensus mechanism where no single authority is in charge of the database (Bashir, 2017). Finally, in legal terms blockchain is a transaction validation mechanism, which not requires intermediary trusted entities (Mougayar, 2016).

The introduction of blockchain in organizations has an impact on current technologies, changing them in a fundamental level (Bashir, 2017). Moreover, it has the potential to

transform the way business are currently run, affecting governance, traditional corporate models, society and global institutions, among others (Mougayar, 2016).

The enthusiasm about the blockchain is based on its feature to serve as a tool for achieving and maintaining integrity in distributed peer-to-peer systems allowing disintermediation (Drescher, 2017). Thereby, decentralized trust, cost savings, transparency and efficiency are some of the benefits envisaged for this technology (Bashir, 2017). The intrinsic characteristics of blockchain technology could be perfect to solve currently existing SCM challenges, such as lack of trust among SC partners, fraud attempts, process inefficiencies, etc., and, by this way, reaching a more effective SCM.

Despite its disruptive potential is now fully recognized, blockchain technology is still in preliminary exploration stage for many organizations, which are currently writing proof of concepts using it. Nevertheless, it is expected to progress more quickly as the technology is becoming more mature, and be ready for mainstream adoption in 5-10 years (Mougayar, 2016).

Before of introduce the potential uses cases of this technology in SC, first the basis of how the blockchain technology works have to be understand.

### 3.3.1 Blockchain technology

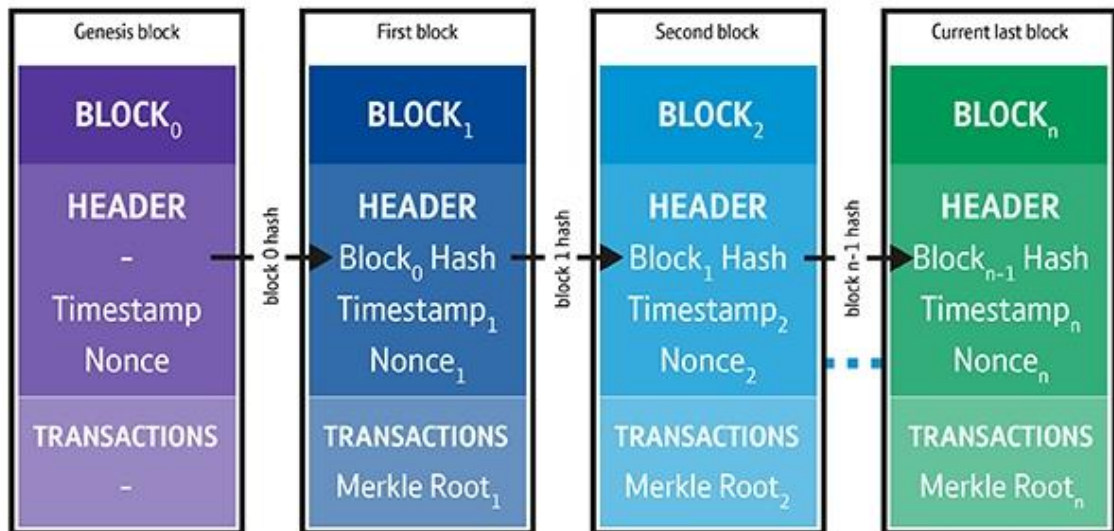
The fundamental unit of a blockchain is a **transaction**, which represents a transfer of value from one address to another. Each sender and recipient have a unique identifier called **address** that in practice can be a reusable or new generated for each transaction, depending on the characteristics of the blockchain (Bashir, 2017). A list of transactions are recorded in a **block** through a process called mining, creating a ledger over a given period. In every blockchain, the size, period, and triggering event for blocks is different (Laurence, 2017).

Thereby, a block is an aggregated set of data that can be identified using a unique cryptographic hash or digital fingerprint, as is shown in **¡Error! No se encuentra el origen de la referencia..** All blocks contain a hash of the previous block, so blocks can form a **chain** from the first block ever or genesis block to the formed block (Kovary, et al., 2018). The blocks also contain a timestamp, a nonce and a Merkel root (Tate & Daniel, 2017).

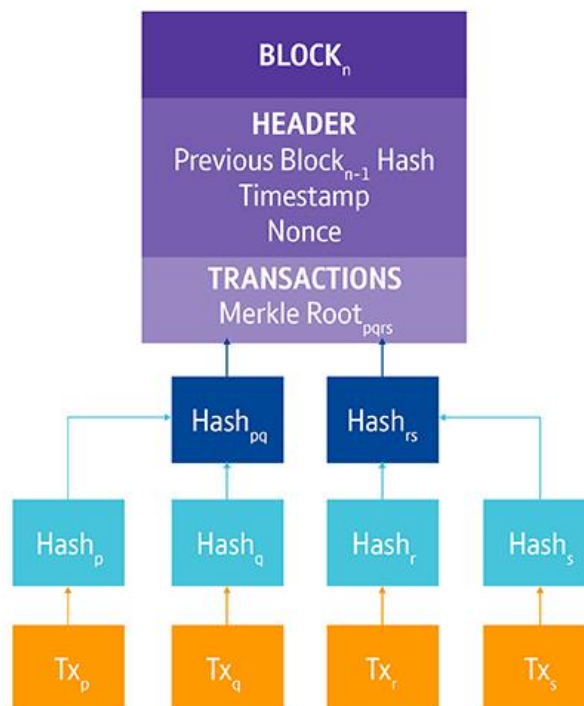
A nonce is an arbitrary integer, which only can be used once, necessary for producing the Proof-of-Work (PoW) algorithm to reach consensus during the block creation (Kovary, et al., 2018). The Merkel root is related with a set of valid transactions that are hashed and encoded into a Merkle tree structure (see Figure 14) (Tate & Daniel, 2017). This structure is based on a full binary tree of hash values where at the bottom level each transaction has a node containing its hash value (Kovary, et al., 2018). Afterward, the tree is built in a manner that the hashes of the transactions are organized into pairs of twos,



concatenated together, and then hashed again. The same is done to each set of outputs until something like a tree is formed, where the hash at the very top of the tree is called the Merkle Root (Pacia, 2017). The Merkle tree structure enables an efficient and fast validation of transactions without revealing the exact content, whereas the chain of block structure allows demonstrate integrity by tracking back from any point in the hash-based chain to the genesis block (Tate & Daniel, 2017; Kovary, et al., 2018).



*Figure 13 : Blockchain chain of blocks (Tate & Daniel, 2017)*

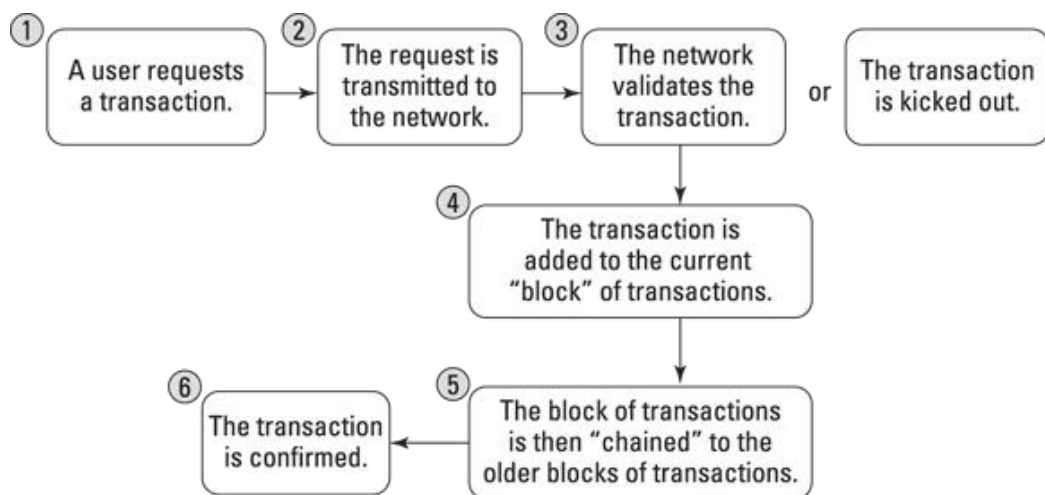


*Figure 14: Block configuration (Tate & Daniel, 2017)*



When a transaction is created, it has to be sent to the blockchain network to be processed in order to be validated and incorporated in a chain of blocks (Verhoelen, 2017). The blockchain is a set of nodes forming a network with the same communication protocol. A **node** can be a personal computer or a supercomputer, which processes the transactions (Preukschat, 2017). It can be located in any part of the world and can be operated by anyone. In addition, each node contains a complete record of all the transactions that were ever recorded in that blockchain (Laurence, 2017).

The nodes can propose and validate transactions by mining, and secure the blockchain by following a consensus protocol (Bashir, 2017). To process transactions and validate them by append them to the history in blocks, the node is required to solve a complex mathematical problem (see Figure 15). This approach is called Proof-of-Work (PoW), a computational effort to prove that enough resources have been spent in order to build a block (Kovary, et al., 2018). The main idea under this concept is that a random node is selected every time to create a new block. In this model, nodes compete with each other in order to be selected in proportion to their computing capacity (Bashir, 2017).



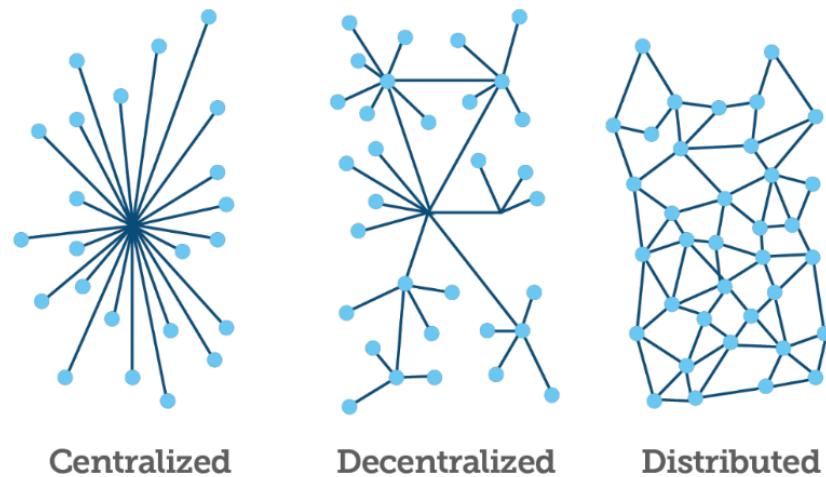
**Figure 15: How blockchain works (Laurence, 2017)**

The PoW algorithm is used as consensus algorithm in the blockchain. The consensus is the process of developing an agreement among a group of commonly mistrusting shareholders, presenting a single version of truth that is agreed upon by all parties without the requirement of a central authority. Thereby, blockchain is an honest system that self-correct without the need of a third party to enforce the rules (Laurence, 2017).

Moreover, this consensus must provide an up-to-date copy of all transactions in real time to all the nodes of the network (Laurence, 2017). This allows demonstrate the integrity of the blockchain by tracing back from any point in the hashed chain to the genesis block, supposing no single point of failure by design (Verhoelen, 2017; Tate & Daniel, 2017). Thereby, the blockchain can only be written by consensus and once the records are added onto the blockchain are immutable (Tate & Daniel, 2017).

The cryptographic features of the blockchain ensure the impossibility of changing transactions in the history without invalidating the following ones (Verhoelen, 2017). Thus, the blockchain is secure, providing the confidence that computer attacks, failures or falsifications cannot be committed (Tate & Daniel, 2017). Because of that, the aim of blockchain is to provide an unchangeable, secure and perfectly verified history (Verhoelen, 2017).

In the blockchain network, there is no central node processing and distributing the data (Kovary, et al., 2018). The net of nodes are forming a decentralized **P2P network** where all the nodes are equal to each other resulting in a **distributed** system (see Figure 16). In such a manner, even if a node fails, the data could reach those others to which it is connected by alternative routes (Crowe, 2016). Thus, the blockchain is designed to be highly available and can be operated with an infinite amount of nodes (Verhoelen, 2017).



*Figure 16: Types of net models (Crowe, 2016)*

In the last few years, the blockchain networks have evolved into different types, allowing divide them according to their attributes. This conduces to a classification of blockchains based on the following features (Bashir, 2017):

- Public, private and semiprivate blockchains

The public blockchains, also known as permission-less ledgers, are publicly open and anyone can participate as a node to read and write on it. On the other hand, private blockchains are only open to a consortium or group of individuals or organizations that has decided to share the ledger among themselves. Finally, the semiprivate blockchain is a combination of both; where a part is private and controlled by a group of individuals while the public part is open free for participation (Bashir, 2017).

- Permissioned and permission-less ledger

A permissioned ledger blockchain is one where all the participants of the network are known and already trusted. Thus, instead of a consensus mechanism to ensure trust, an agreement protocol is used to keep a shared version of trust about the state of the records (Bashir, 2017).

The permission-less blockchain, all users maintain a copy of the ledger on their local nodes and use a distributed consensus mechanism in order to reach a decision about the eventual state of the ledger (Bashir, 2017).

- Tokenized and tokenless blockchains

The standard blockchains are tokenized, in other words, they generate cryptocurrency because of a consensus process via mining or via initial distribution. Furthermore, the tokenless blockchains just share data among various already trusted parties (Bashir, 2017).

### **3.3.2 A framework for blockchain technology in supply chains**

In today's business landscape, the SCM is fraught with challenges (Uhlenberg, 2017). Modern SCs have become increasingly more sophisticated, where the interlinked nature of them suppose an inherent risk. The macro trends of globalization and more global interconnecting lead in a longer and more complex environment, in which companies are struggling to have a clear view on their SC, both internally and externally. The lack of visibility along the SC involves risks related to fraud or product shortage between others (MarCom, 2017).

On the other hand, the currently fast-changing markets require the companies to react to sudden demand changes on an increasing pace. This generate shorter product life cycles, which demand flexible SC for manufacture new or updated products. In addition, global markets involve fierce competition that put pressure on margins (MarCom, 2017). Combined with this, the growing quality and compliance requirements suppose an increasing pressure to create high-quality products and to create them consistently. As quality goes hand-to-hand with compliance, companies need to ensure that they meet local and international regulatory standards and elaborate compliance documents such as licenses or certifications (Uhlenberg, 2017).

At a core of all these SC challenges is the need for better data management and integration (Uhlenberg, 2017). The information flow of the whole SC relies on the trust between SC stakeholders, meaning the willingness to communicate true information. If the SC stakeholders do not trust on each other, they need to trust the security integrated in the common

information system. Moreover, the information flow also is based on the data being effectively and accurately collected, reconciliated and made it available by the information systems (MarCom, 2017).

The blockchain technology has the potential to solve all the SCM challenges above by its intrinsic properties (Uhlenberg, 2017). This technology offers the following features by design:

- Secure

The blockchain technology is an immutable and irrevocable record of data, with no simple point of failure. These features turn the blockchain into a tamper-proof record of data, providing a reliable fraud detection. The cryptographic hash secures the blockchain's data with a digital signature, establishing a proof of authenticity (MarCom, 2017).

- Transparent

As all the authorized participants of the blockchain network have an automatically updated full copy of the history ledger, the data is always available and visible for all the participants (MarCom, 2017). Thus, the data shared in the SC is all the information needed, not just the information that one party is willing to share (Myler, 2017).

- Resistant to outages

The distributed network allows the blockchain to be highly available by design. If a node fails, the data can reach the other nodes to which is connected by alternative routes (Crowe, 2016).

- Auditable

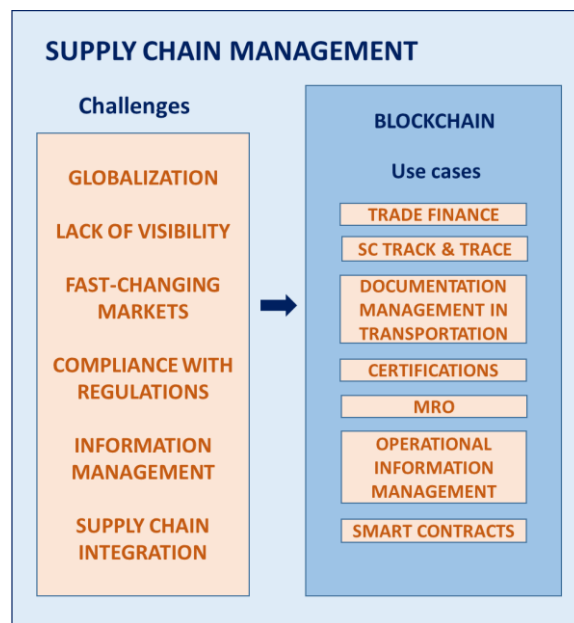
The transactions in the blockchain are inherently immutable and irrevocable recorded, being resistant to modification of any data. Thanks to this characteristic, every transaction is trackable within the ledger with reliability (Psaila, 2017).

- Efficient

The transactions are processed directly from P2P in the blockchain, so fewer intermediaries are needed. Moreover, the resources used to validate the transactions are mainly computer power that cost less than traditional manpower, dropping the verification costs (MarCom, 2017). The data is optimized and simplified into one common source, avoiding spend important resources and labor in checking and integrating the data. Thereby, double entry errors are avoided (Myler, 2017).

On the other hand, the data is automatically updated in the common ledger of every node. Thus, the access to a unique common source of updated data enables an efficient data capture (MarCom, 2017).

Realizing the potential of blockchain technology, a framework about the different potential applications of blockchain in SCs is proposed, as it is shown in Figure 17. The use of this technology in a SC can help to overcome previously discussed SCM challenges, such as globalization or SC integration, establishing more end-to-end visibility, flexibility, interfered trust, and control along the SC. Which ultimately derives a more efficient SCM due to the better achievement of SC main goals: a reliable, efficient, trusted and resilient SC (MarCom, 2017).



**Figure 17: Blockchain applications in SC framework**

The use of blockchain technology in a current SC helps to improve the management of information flows, helping to communicate and share the information efficiently between the different partners involved in the SC. The intrinsic features of this technology will enable the efficient access to the massive amount of data that is produced along the SC, while ensures a secure sharing and enhance SC visibility (MarCom, 2017).

Each SC has its own challenges because of its complexity and own structure. No two SCs are alike. For this reason, the applications of blockchain technology vary depending on each particular case. However, generally, the following potential use cases of blockchain in SC are identified: trade finance, SC track and trace, certifications, document management in transportation, maintenance, repair and operations (MRO), operational information management, and smart contracts.

Hereunder, the blockchain potential use cases in SC are described with more detail, explaining why they are needed and how they would solve SC challenges and problems.

## **TRADE FINANCE**

The trade finance is an activity that has not seen much innovation over time (Groenewegen, et al., 2017). The traditional trade finance is based on financial institutions, which provide credit facilities in order to guarantee exchange of goods (Deloitte, 2017). In fact, one of the major challenges of today's SC is the record of trade finance, which is currently based on inefficient systems, such as faxes, spreadsheets, emails, phone calls, and paper-based. These make the process error-prone, time consuming and fraud sensitive (Mearian, 2018).

Nowadays, the most common and standardized form to finance international trade, with a bank as an intermediary, is the letters of credit (L/C) (Francisconi, 2017). This is a bank document released to safeguard the interest of both seller and buyer. It means that the buyer has briefed his bank to notify the banking agent in the seller's country to effect payment to that supplier against the submission of specified documents, to specified terms and within the period of validity of the L/C, to cover a purchase (UNDP, 2008).

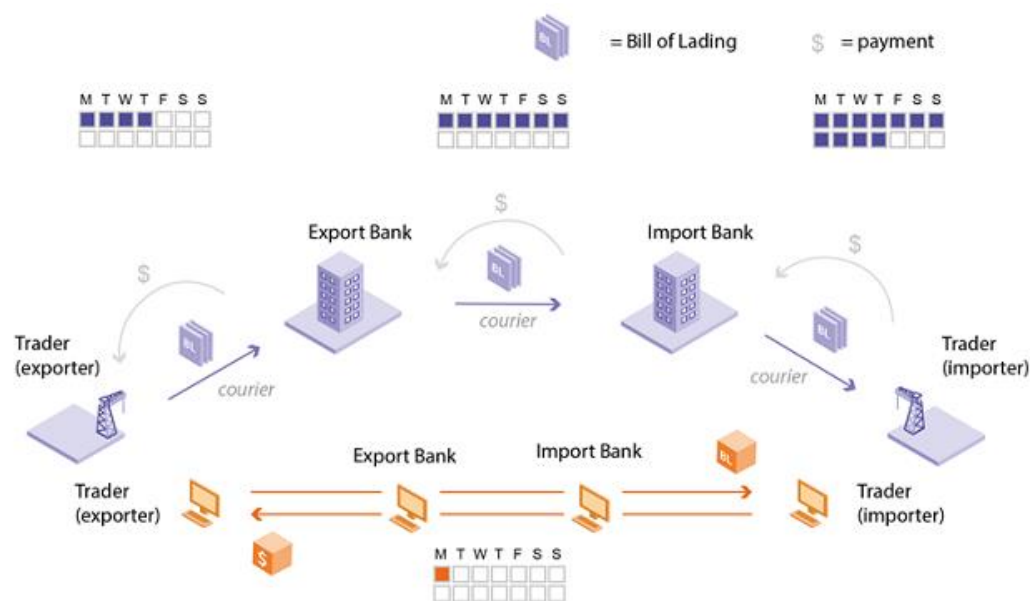
The L/C document has been the target of several fraudulent attacks in last decades. Most common popular L/C frauds are related with the inexistence of the cargo, less valuable or amount of goods traded, same goods are sold to two or more parties, or where bills of lading are issued twice for the same goods (Francisconi, 2017).

In order to prevent these fraud attempts, the banks require a long time to process and validate the financial transactions (Francisconi, 2017). In the beginning of the process, the contract is created manually, which implies manual reviews by the import bank of the financial agreement provided by the importer and the send of financials to the correspondent bank. Usually, the multiple checkpoints by intermediaries along the transport process are slow and time consuming, causing considerable delays in the shipment of goods (Deloitte, 2017). They involve the check of legal documents required for the carriage of cargo, such as the bill of lading (B/L). The B/L is the receipt delivered by a carrier, confirming that the goods therein specified (types of goods, number of packages, etc.) have been loaded or taken in charge for loading on a designated vessel for carriage to a specified port (UNDP, 2008). The B/L, which is a document required in the L/C because it acts as a title of property of the goods, must to be sent by carriers to the banks in order to receive finance (Groenewegen, et al., 2017).

In addition, as banks are not integrated in the information systems of the ports, the miscommunication is a common issue. As they do not receive real-time notifications on the status of the container, the containers are hold in the terminal until they receive the B/L by the commercial bank. This lack of coordination makes the process relatively slow, increasing the transportation cost and the detention cost of goods (Francisconi, 2017).

The blockchain technology has the potential to change this industry. The introduction of this technology in the trade finance can bring efficiencies, reduce cost base and provide new revenue opportunities, such as new models of trade finance credit (Deloitte, 2017).

One potential application of blockchain in trade finance is as a decentralized distributed system to store trade finance documents (Francisconi, 2017). As it is shown in Figure 18, the traditional trade finance documentation management process (blue) takes multiple days to be completed. The B/L is sent by courier and checked manually by banks, supposing that a normal L/C is slowly processed (Groenewegen, et al., 2017). This generates delayed shipment of goods, increasing costs and delayed payments that make exporters to use invoices to achieve short-term financing (Deloitte, 2017).



**Figure 18: Traditional vs. blockchain-based trade finance process (Groenewegen, et al., 2017)**

The digitalization with blockchain speeds up the whole process and enable more timely information (Groenewegen, et al., 2017). The documentation required by the L/C, such as the B/L, is uploaded to the common decentralized distributed system, wherein the banks and the parties involved have authorized access. Thus, the financial documents arrive instantaneously and are reviewed and approved in real time. As all the documents are accessible to all parties, the payment status can be tracked. In addition, the B/L and L/C are tracked, improving visibility, eliminating double spending and reducing potential fraud (Deloitte, 2017).

On the other hand, the blockchain allows disintermediation of banks, not requiring a trusted intermediary to assume the risk. Thus, the correspondent banks are not needed in trade finance (Deloitte, 2017).

The blockchain technology also enables the introduction of smart contracts in trade finance, which are new models of credit (see orange path in Figure 18). Before the purchase of goods, the agreement of sale between the importer and exporter is shared with the import bank using a smart contract. In real time, the import bank can review the agreement, draft the terms of credit and submit obligation to pay to the export bank. Once the export bank has reviewed and approved the payment obligation, a smart contract is generated to cover terms and conditions and lock-in obligations. Subsequently, the exporter receives the obligation to digitally signing the blockchain equivalent of L/C within a smart contract to initiate the shipment (Deloitte, 2017).

In the exporting country, the goods are inspected by third parties and customs. All of them register their respective approval signature on the smart contract. Afterwards, the goods are transported from one country to other. Upon delivery, the importer digitally acknowledges receipt of goods and trigger payment. Finally, the blockchain executes automatically the payment from importer to exporter via smart contract without human intervention (Deloitte, 2017).

Other potential use case of blockchain in trade finance is if the digital title of ownership is linked with the payment by smart contracts. The blockchain could record ownership and changes of ownership of assets due to commercial transactions, at the same time it automates the settlement of payments. This could improve transparency into the location and ownership of the goods (Deloitte, 2017).

The use of blockchain technology in trade finance contribute by providing a smoother process flow, reducing total process time and reconciliation cost, while preventing frauds (Francisconi, 2017).

## **SUPPLY CHAIN TRACKING AND TRACING**

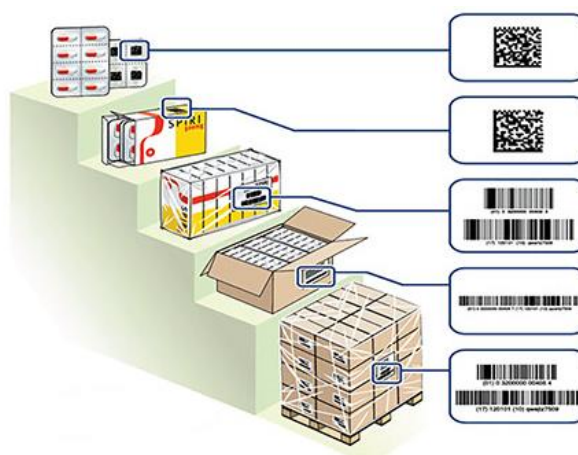
In today's business environment, track and trace (T&T) solutions are becoming popular in certain industries in order to enhance pilferage reduction, counterfeit prevention and targeted recalls, as well as improving SC efficiency, customer service, synchronization, visibility, and security (Pizzuti, et al., 2013; Rotunno, et al., 2014). T&T processes can suppose a key differentiator for customers, who nowadays are more and more demanding (Rotunno, et al., 2014).

According to Rotunno et al. (2014), track and trace is defined as the ability to monitoring products throughout the whole SC, by recording a given set or type of information that allows the verification of history, location or application. T&T is obtained assuring the observation in both forward and backward directions of the SC, being these functions respectively called as tracking and tracing (Pizzuti, et al., 2013). In T&T systems is important do both track and trace processes because of an effective tracing does not imply effective tracking, and vice versa (Jansson & Petersen , 2017).



Tracking is the process by which a particular good is followed by from upstream to downstream in the SC, knowing its physical location within the SC at any time (Pizzuti, et al., 2013; Rotunno, et al., 2014). Thereby, the ability to track in SC allows the efficient recalling of non-compliant items (Jansson & Petersen , 2017). Conversely, tracing is the reverse process of tracking. In other words, tracing consists on reconstructing the history of a particular good through the information recorded in each step of the SC, being necessary for finding the cause of non-compliance in goods (Pizzuti, et al., 2013; Jansson & Petersen, 2017).

Conceptually, T&T systems consist on the capturing and recording of traceability data of uniquely identify traceable items and the subsequently data sharing between SC partners. To successfully identify and distinguish one traceable resource unit (TRU) from another, some identifying technologies are needed. The serial number identification is one of the most robust identification systems that is used to identify a wide range of TRUs. The serial number can be attached to the physical object, such as a barcode, QR-code, or an RFID tag. In order to ensure the uniquely identifying of objects, the GS1 has created several standards for serialization to correctly identifying objects of different precision and granularity (see **¡Error! No se encuentra el origen de la referencia.**). Some of these standards are GTIN (Global Trade Item Number), SSCC (Serial Shipper Container Code), and GSIN (Global Shipment Identification Number). Other identifying technologies that also can be employed are DNA identifying and detailed records (Jansson & Petersen , 2017).



**Figure 19: Serialization in track and trace processes (inemur.com, 2018)**

Once the traceable items undergone a process, the relevant data must be captured in order to link the process to the specified object. Depending on the identification method used, the data capturing process varies. For example, TRUs labelled visually as barcodes or QR-codes can be scanned by hand-held scanners or automated scanners at each traceable event in the SC. The Wireless Sensor Networks (WSN) can be also used to capture information in combination with IoT in order to get an intelligent T&T system. The IoT technologies, as RFID sensors, can improve process efficiency by reducing manual labour.

This technology not only allows real-time scanning data, but also introduce the possibility to append new data to the TRU, such as temperature, humidity conditions, etc. (Jansson & Petersen , 2017).

The traceability data captured is stored in the internal systems of the company. If the data is intended to be shared, data sharing technologies are needed to store and exchange data between SC parties. In cases of multiple traceability applications throughout the SC, global standards for interoperability are necessary to successfully achieve SC traceability. The GDSN and EPCIS are some of the standards for traceability data sharing developed by GS1 (Jansson & Petersen , 2017).

An important consideration in T&T is when a product is processed, it should be T&T from raw materials to finished product and anywhere between. Thereby, the input TRU(s) might not be the same as the output TRU(s). To preserve the traceability of an object through such a process within a company, the details of the process must be described and recorded (Jansson & Petersen , 2017).

T&T systems can lead in a better SCM by increasing end-to-end visibility, interoperability and communication among SC partners. T&T have a wide application in SC, from anti-counterfeiting technology to optimization and synchronization of the SC and its main actors (Rotunno, et al., 2014). In addition, the traceability capabilities can be used to monitor and improve quality of raw materials to reduce costs and support inventory management. T&T systems can be also employed to ensure product quality, especially when specific quality attributes of a product are subtle or hard to verify. For example, if the product originates from a specific region or is produced by a special brand. T&T help to mitigate those issues, with detailed information about the product's path through the SC (Jansson & Petersen , 2017).

On the other hand, the T&T systems enable a better identification and traceability of non-compliant products at any stage of the SC when quality or safety standards are not met. This feature is of particular importance for food and pharma industry due to the increasing complexity of governmental regulations. By T&T, a foodborne disease outbreak can be prevented through effective recalls of hazardous or defective products (Jansson & Petersen, 2017; Hackius & Petersen, 2017). Moreover, the ability to trace non-compliant products in the SC also enables efficient identification of the underlying cause of the non-compliance (Jansson & Petersen , 2017).

Nevertheless, current T&T systems are characterized by inefficiencies in data scanning, recording and sharing, lack of a common standard along the SC, many fragmented partners and different technologies, among others (Pizzuti, et al., 2013; Potts, 2015). Commonly, the products are only traced at certain points of the SC and the data is not communicated effectively among SC partners. This situation represents a key issue that directly affects SC efficiency, product safety and security, deep tier risks management, on-

time delivery performance, troubleshooting customer issues, controlling costs, and regulatory compliance (Potts, 2015).

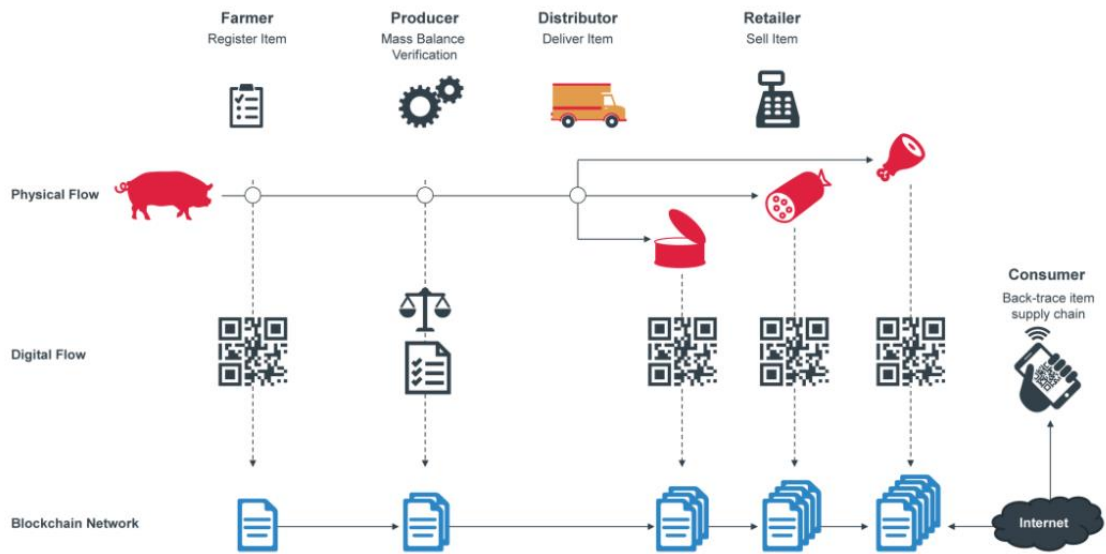
The blockchain technology has a great potential supporting the T&T processes. The blockchain can provide a decentralised and secure database where information can be collected at each point of the SC and accessible for all authorised partners. In such a way, the blockchain enables a shift from the traditional data management carried out in siloes to a common data system where no one organization has control of the information (Potts, 2015). The serial numbers, such as barcodes or RFID tags, which represent physical goods in the SC can be tokenised in the blockchain by linking that serial number to a blockchain's block. Each time a new process is performed to the TRU, the data associated is immutably record in the blockchain. This allows creating an immutable and chronological order of entries in a shared ledger related to a specific product, providing visibility of the product throughout the SC from the source to the point of sale or consumption (Francisconi, 2017; resolvesp.com, 2018). Thereby, the data stored in the blockchain can be audited and inspected in real time, increasing the SC transparency (Francisconi, 2017). This characteristic also enable the identification of issues faster and the possibility of easily recall non-compliance products and identify the causes for such incompliance.

In addition, the blockchain provides a more trusted data sharing among parties due to its features by design such as the immutability, which enables error and fraud detection in certificates or provenance and prevent the attempt of counterfeit of goods (Hackius & Petersen, 2017).

One of the most important potential applications of blockchain is in food traceability. As is shown in the Figure 20, blockchain technology enables an efficiently record and share of traceable data in the food SC. A food item is digitally linked with its information by TRU identification technologies such as QR-tags. This information includes farm origination details, batch numbers, factory and processing data, expiration dates, storage temperatures and shipping details. As the product is moving from the farmer to the retailer, the information is captured during each transaction and it is validated and added to the blockchain by consensus. Thereby, the record of each transaction forms a block in the blockchain, which become a permanent record that is accessible in real time for all the SC partners (resolvesp.com, 2018).

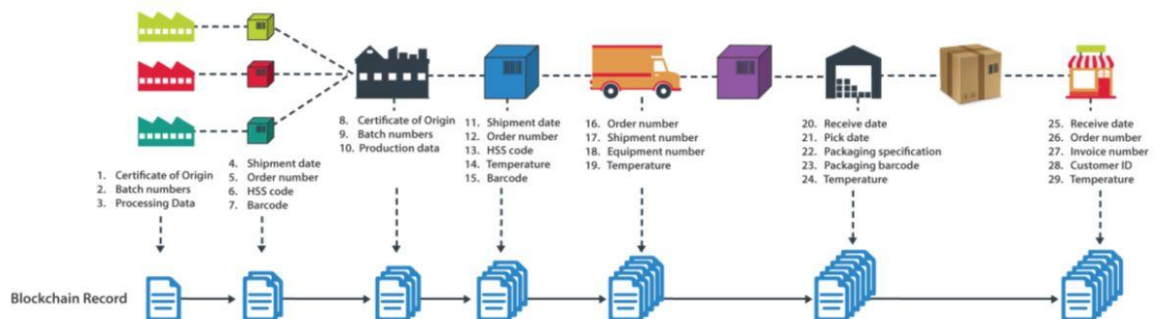
When the retailer receives the product, it can be verified as authentic. In addition, the digital record of the product in the blockchain can be tracked and reveal all the issues picked up between farm and store, being extremely useful in food safety. In today's food SC, if a foodborne disease outbreaks, it can take weeks to track down the source of contamination. Thereby, the blockchain enables an improvement in customer trust and the capability to identify issues faster. In addition, it can be used to improve the value to customers by offering them the opportunity to scan the TRU and trace back the item through the SC, increasing the visibility of the food SC. On the other hand, the T&T

systems supported by blockchain technology can also help retailers to manage better the shelf life of products in individual stores (resolvesp.com, 2018; Hackius & Petersen, 2017).



**Figure 20: Traceability within Food Supply Chains (resolvesp.com, 2018)**

Other potential use of blockchain in T&T is related with the record of information and transfer of assets through the SC, especially in freight industry. The location as well as other information related to TRUs, such as provenance, ownership or transport documentation could be recorded in the blockchain as the TRUs move between SC nodes (see Figure 21). The blockchain technology allows keeping an accurate, immutable and in real-time record of the pallets, containers or delivery and handling units, enabling end-to-end visibility in the SC. Moreover, the blockchain can be combined with the use of IoT in T&T systems, entailing the record of more item features, such as the temperature (Francisconi, 2017; resolvesp.com, 2018).



**Figure 21: Blockchain technology in T&T systems (resolvesp.com, 2018)**

## CERTIFICATES

In a more globalized and complex SC environment, the customers are progressively demanding more information about the products they purchase. Nowadays, a product before to be bought by an end-customer often travel along a broad network of SC partners. The limited visibility of the product journey by the end-customer generates concerns related to environmental, social and political issues (Francisconi, 2017). One of the primarily concerns is the product integrity. This is related with the fairness and authenticity of the product in its SC, both at the physical and the digital layer (Ge, et al., 2017). The lack of trust together with the more transparency demanded have encouraged the emergence of a great variety of certifications schemes associated with the products (Francisconi, 2017).

Quality, provenance, fair trade or organic certifications are commonly added to physical assets, especially in food and beverages, with the aim to understand better the product journey along the SC (Ge, et al., 2017; Francisconi, 2017). These certification standards involve the audition of large amount of information related with the product through the SC by trusted third parties (Ge, et al., 2017). However, these accreditations are not verifiable for the end-customers due to them presentation as merely printed logos on the product packaging (Francisconi, 2017).

Currently, the compliance data and information, which must to be gathered by the trusted third parties, is in different information siloes owned by disparate actors in the product's SC. Afterwards, the results of the audition and the information associated is recorded in a centralized database or paper-based. This entire process is highly problematic: high costs, the paper-based and the information in siloes are highly inefficient, and both paper and databases are prone of fraud, corruption and error. The inability of current information systems to solve those problems present a threat to SC, aggravating the low transparency and trust issues (Ge, et al., 2017).

The blockchain technology has a huge potential in the certification scheme. The information from the different members of the product's SC and the certification process is recorded in a distributed ledger. The digitalization of this information and its storage in the blockchain suppose an enhancement of the process efficiency due to paper elimination. The immutable and tamper-proof features by design of the blockchain ensure the permanence of record while prevent the data tampering. The integrity of data recorded, which includes both reliability and data handling, and the impossibility of double spending or conflicting records are also assured by the cryptographic characteristics of the blockchain. Thereby, the blockchain increases trust on the information recorded in the ledger, averting fraud and errors, such as product manipulation or counterfeit products (Ge, et al., 2017).

The blockchain as database for certifications means a shift to more transparency in SCs. For certification bodies, it supposes a decentralized proof of existence of documents,

where permissioned parties can access to the same information. This application facilitates the certification audit processes and remove the necessity of trusted third parties, which reduce costs. In addition, the verification of validity of a certification is possible for all participants of the blockchain (Ge, et al., 2017). If the end-customers would be allowed to access to the whole or part of the certification information, they would be able to trace and track the product certification. Thus, the application of blockchain in certification can potentially increase its value by increasing trust and visibility for end customers and the whole SC (Provenance, 2017).

Other application of blockchain technology to add to the previous one is the introduction to smart contracts. The storage of smart contracts in blockchain could automate the certification process, reaching new levels of process efficiency and cost reduction (Ge, et al., 2017).

## **DOCUMENTATION MANAGEMENT IN TRANSPORTATION**

The transportation of goods involves not only the physical movement of assets, but also information related with the shipment along the SC (Francisconi, 2017). The transportation documentation provides an accountable record of the transaction, instruction on how and where to ship the goods and shipment handling statement. Depending the mode of transport, the transportation documentation required is different. For instance, the CMR for road transport or B/L for cargo shipping (Llamazares, 2018). Moreover, other documents are also needed to complete any transaction, such as the certificate of origin, insurance certificate or L/C (UNDP, 2008).

Nevertheless, all transport systems has in common an extensive paperwork associated to the shipment of goods. Generally, it involves multiple documentation issued, stamps and approvals of the different SC partners. These paperwork processes present little innovation since decades, being widely paper-based. The lack of digitalization in the process generates inefficiencies in the documentation sharing, which currently is time and money consuming (Hackius & Petersen, 2017). Each company in the SC creates its own updated information related with the transportation and record it in its own ERP system. As information is not accessible by all the partners of the shipment process, it acts as information siloes. Because of the asymmetries in information sharing, there is often information mismatch between the information on the documentation hardcopy and the reality. This problem is usually solve by bilateral communication between parties by phone call, email, fax, etc., which is not efficient (Francisconi, 2017). In addition, paper-based documents are prone to loss, tampering and fraud (Hackius & Petersen, 2017).

Especially, the global container shipping in ocean freight is still enormous bureaucratic, with a long tail of paperwork associated. For instance, according to Kralingen (2018) a refrigerated container of goods from East Africa to Europe can pass through 30 individ-

uals and organizations, and requires over 200 unique interactions. All this process generates a four-inch stack of paper records, whose cost of the paperwork related with the trade is estimated between 15 and 50 percent of the physical cost of transport (Hackius & Petersen, 2017). In fact, in some cases, this cost is so great that does not compensate the shipping (Kralingen, 2018).

The blockchain technology has the potential to remedy those inefficiencies in transportation document management. A potential use case of this technology is a common platform of digitalized document records of shipment that connect shippers, carriers, ports and customs (Hackius & Petersen, 2017). The information related with the cargo is recorded in the blockchain by the information owner, and is accessed by the authorized organizations when is needed. Thus, the data sharing system shifts from data passing (push) to data requesting (pull) (Francisconi, 2017).

As there is not intermediaries between the data owner and the user, there is less risk of data inaccuracy or errors in documentation. Moreover, the intrinsic characteristics of the blockchain ensure a trusted tamper-proof ledger, preventing to fraud attempts by ensuring the uniqueness. This solution enables full visibility of container status, increasing the speed of the overall document transfer process. On the other hand, the digitalized and streamlined process of transportation documentation sharing reduces remarkably documentation management costs (Francisconi, 2017).

### **MAINTENANCE, REPAIR AND OPERATIONS (MRO)**

In current industries, hundreds of thousands of parts are requested through the year for maintenance, repair and operations (IHS, 2007). These MRO items are indirect supplies consumed in the production process, but which are non-production parts. In other words, these supplies do not become part of the company's output, but which are needed in order to generate it. They can be industrial equipment, plant upkeep supplies, consumables, etc. (Anon., 2018).

These items are recorded in MRO's databases, in order to monitor the MRO items status and place orders to MRO suppliers when is needed (Murray, 2017). The processes and methods in MRO data gathering often generate outdated data, unidentifiable, duplicate or non-comparable MRO items in the databases. Inaccurate data in MRO databases can generate a cascade of similar inefficiencies in other SCM systems, such as in ERP (IHS, 2007). Overspending, stock-outs, non-critical part identification or inaccurate lead times on MRO inventory are the most common pitfalls related to MRO items (sdexec, 2014).

The management of MRO items is a key issue in SCM, which can affect the asset utilization, safety and operational performance of a firm (sdexec, 2014). Thereby, companies need an effective way to manage the MRO materials information, requiring a single, consolidated catalog with complete and consistent descriptions, free of duplication and ambiguity (IHS, 2007).

When companies are optimizing their SC, they should pay attention to all facets of the operations to accomplish it. The MRO, which is usually an overlooked element in SCM, has the potential to strongly influence an organization's profit margins, shareholder value and operational excellence goals, involving hundreds of thousands of euros each year. An effective MRO management can result in an improved operational performance, increasing product quality and a more efficient asset management, which leads into cost savings (sdexec, 2014). An efficient management of MRO ultimately improves the efficiency of SCM.

A potential use case of blockchain technology is improve the MRO processes. The blockchain can be used as a digital distributed ledger shared by companies, MRO organizations and OEMs to record events, operations conditions and scheduled machinery maintenance reviews. Moreover, it can be linked with MRO items acquisition (Bellamy III, 2017).

The introduction of blockchain in MRO offers an increased transparency to maintenance processes along SC. The relevant information related to MRO is commonly stored in an automatically up-to-date single common source of trust that by design supposes a secure network. Thus, it offers transaction time reduction, less intermediary costs, and a tamper-proof system to prevent fraud in MRO (Derber, 2017). Moreover, it could improve the efficiency of maintenance planning and machinery's capacity scheduling (CAPA, 2017).

The blockchain technology together with other technologies, such as IoT or cloud computing, can also introduce innovation to MRO processes. The use of sensors and machine learning algorithms can improve predictive maintenance, among other potential activities (Bellamy III, 2017).

The potentially main implementation of this use case is in the transportation industry, especially in aviation. In this industry, the MRO activities are of particular relevance. They help to avoid lost flights due to failure, maintain good performance, ensure passenger safety and helps to extend the life of the aircraft. Moreover, the MRO activities in avionics are highly regulated in order to ensure secure airworthiness (TheAtlasGroup, 2016).

## **BUSINESS OPERATIONS MANAGEMENT**

The business operations management focuses on how to utilize business resources in order to run effective and efficient business operations. Some of the strategic issues that involve the business operations management include management of inventories, delivery of products to customers, and quality control among others (Investopedia.com, 2018).

In order to acquire, develop and deliver goods to customers as efficiently as possible to maximize the profit of an organization, companies must be aligned with their SC partners (Investopedia.com, 2018). A company will be only able to run effective and efficient operations, if it shares regular and reliable information with its SC partners that support its



business. Currently, companies store their business operational information in their own systems, and share only certain information under request. This information exchange is full of inefficiencies due to the dominance of manual processes, such as point-to-point communications, authoring documents, disputes and information reconciliations. All of them result in a time and cost consuming process with an unnecessary complexity (Cutlan, 2018).

These inefficient processes and lack of transparency through the SC directly affect companies' operations, generating disruptions or slowing them down and still locking the value remaining in the SC. The blockchain technology has the potential to streamline and secure the information exchange across the SC (Cutlan, 2018). Thereby, this new approach changes how the data is managed, from redundant siloes system to one where all parties have controlled access to a shared copy. The intrinsic features of blockchain provide a transparent and trusted shared ledger where data can be confidently and securely shared. Consequently, information exchange through the blockchain boosts security, increasing cost efficiency, and optimizing reconciliation processes. With blockchain, companies can reengineer their processes and eliminate redundant steps that provide no value added (Gilbertson, et al., 2017).

The information recorded in the blockchain enables a more complete vision on SC strengths and weaknesses, as well as the ability to see value outside their own organization (Gilbertson, et al., 2017). Hence, better strategic business operational decisions can be taken to obtain the best possible competitive position.

As mentioned above, blockchain technology can be implemented to improve trade finance or MRO, which can be considered part of business operational management. However, these are not the only potential use cases of this technology. As all the operational information can be stored in the blockchain, from the product purchase order or service booking to the delivery, all the operational processes leave a great deal of scope for improvement. For instance, sourcing and category management, finance and accounting processes or logistics processes (Gilbertson, et al., 2017).

There is also need to consider the combination of that operational information with the one gathered by IoT sensors. This vast amount of data together with Big Data and advanced analytics can improve specific business operations, such as demand forecast, order management, estimated delivery time, order status, etc. Thus, the blockchain not only helps to streamline and make more efficient the internal processes, it also adds new value and product/service offering to customers.

## **SMART CONTRACTS**

A smart contract is a contractual arrangement between parties formulated in a computer code format and stored in the blockchain (Mattila, 2016). The smart contracts are tools running across the blockchain platform, whose terms of the contract are automatically

executed when a preprogrammed condition of the contractual agreement is triggered (Crosby, et al., 2016). In fact, smart contracts are not legal contracts. Currently, legal contracts are written by lawyers, judged by courts and enforced by the police, whereas smart contracts are encoded into blockchain to make them self-executed, irreversible, and beyond the reach of courts and police (Ammous, 2016).

The smart contracts are stored on top of a blockchain, in which authorized participants share information through that shared ledger (Tapscott, 2017). Thanks to the blockchain technology is easier to register the contracts, verify the contractual terms and execute them when the conditions are met (Crosby, et al., 2016). In order to formulate a smart contract, a conventional paper-based arrangement must to be expressed in a logical form. The logical dependencies between terms are completely covered averting ambiguities of whether a specified condition has been adequately met or not (Mattila, 2016).

Low value-added transactions can be automated by smart contracts, eliminating the need of physical documents and reducing the necessity of human intervention. These transactions can be processed without any user input, which entails lower associated risks and more cost efficiency. On the other hand, blockchain technology supports the smart contract processing, providing a transparency, tamper-proof to attempt fraud and a way to ensure that the transactions are verifiable. This promotes the compliance and accountability among parties (Crosby, et al., 2016; Aitken, 2017).

The potential of smart contracts in SC is virtually endless: order fulfillment automatization in e-commerce, frequently repeated business-to-business (B2B) transactions, management of ownership rights, or payment execution among others (Crosby, et al., 2016; Aitken, 2017).

A potential use case of smart contracts in SCs to highlight is its combination with IoT. Data gathered by smart devices can be directly registered on the blockchain. The combination of this data with smart contracts have a large potential related to process automatization, enabling it in terms of physical, financial and information flows (Francisconi, 2017).

Other example of smart contracts in SC is in order to counter the risk of a loss in the shipping industry. Thereby, the execution of the payment of the sender only will be effective once the shipping company confirms the delivery of the asset (Hackius & Petersen, 2017).

## 4. STUDY CASES PRESENTATION

In this section, the study cases used in the research are introduced. This research strategy provides the opportunity to answer 'how' or 'why' questions with little control on behalf of researcher over occurrence of events. Despite the previously discussed benefits of employing this technique, the lack of rigor and challenges associated with data analysis are the most common limitations of the study cases (Saunders, et al., 2009).

Hereafter, the study cases are presented (see table 2). Each study case is identified and briefly summarize. In addition, information about the status of the implementation of the technology in the study case is given, as well as the potential use case of the framework that fits the most and the information sources employed in each study research.

### Study cases

nº	Case name	Description	Use case	Status	Resources
1	Natixis, IBM and Trafigura	Commodity trading platform based on blockchain for US crude oil transactions	Trade finance	Proof of Concept completed	Press release Newspapers Interviews Brochure White paper
2	BASF, Ahrma and Quantoz	Smart pallets tracking system	T&T	First pilot completed	Press release Newspapers
3	Agridigital and CBH group	Commodity trade platform based on blockchain, which includes the creation of digital title and supply chain traceability	Trade finance T&T Smart contracts	Pilot completed Platform in usage	Press release Interviews Brochure Pilot results report
4	Wageningen University and TNO	Certification and provenance of table grapes from South Africa	Certification	Pilot study	Pilot results report
5	Provenance, IPNLF and Humanity Reunited	Tracking fish caught by fishermen with verified social sustainability	Certification T&T	Pilot completed	Press release Newspapers White paper
6	Provenance and COOP	Real-time data to prove the journey and credentials of fresh produce	T&T	Pilot completed	Press release Newspapers Webpage
7	Provenance and the Soil Association	Interactive version of the Soil Association mark	Certification	Pilot completed	Press release Newspapers Webpage

8	Provenance and FairFood	Using blockchain technology to track ethical claims, and digitally prove fair trading practices	T&T	Pilot completed	Press release Newspapers Webpage
9	Wells Fargo, Commonwealth Bank of Australia, Brighann Cotton and Brighann Cotton Marketing Australia helped by Skuchain	Trade transaction between two independent banks combining the emerging disruptive technologies of blockchain, smart contracts and IoT	Trade finance Smart Contracts T&T	Proof of Concept completed	Press release Newspapers Interviews Brochure
10	BBVA and Wave	Using blockchain to automate the electronic submission of documents in an import-export transaction between Europe and Latin America	Trade finance	Pilot completed	Newspapers Interviews
11	Walmart and IBM	Collecting data about the origin, safety and authenticity of food, using blockchain technology to provide real-time traceability throughout the supply chain	T&T	Pilot completed	Press release Newspapers Interviews Brochure
12	IBM and MAERSK	Trading network platform, real time exchange of original supply chain events and documents	Documentation management in transportation	Pilot completed Joint Venture	Press release Newspapers Interviews Brochure
13	Marine Transport International	Container Streams system	T&T	PoC completed	Press release Newspapers Whitepaper
14	PIL, PSA and IBM	Tracking and management between the companies to keep track of all the ships and containers	Documentation management in transportation Business operations management	PoC Completed	Press release Newspapers

15	HMM, Samsung SDS and IBM	Blockchain was employed for not only paperwork but also tracking cargo, all the way from shipment booking to cargo delivery. Real-time monitoring and managing of the reefer containers on the vessel was enabled as well	T&T Documentation management in transportation Business operations management	Pilot Completed	Press release Newspapers
16	Dnata, Emirates Innovation Lab, IBM and flydubai Cargo	Blockchain system for recording the handoff of cargo throughout the SC	Documentation management in transportation	PoC Completed	Press release Newspapers
17	Bolero and R3	Electronic bill of lading (eBL) application	Trade finance	PoC Completed	Press release Newspapers
18	IBM and AOS	Truck-Tracking Solution	T&T	Prototype	Press release Newspapers
19	SMFG, SMBC, JRI, Mitsui & Co. , MOL, MIS and IBM Japan	Blockchain application to digitally record and share among participants a wide variety of documents, including trade agreements and logistics/insurance documents	Trade finance Documentation management in transportation	Demonstration test completed	Press release Newspapers
20	Air France KLM and RAMCO aviation	Managing replacement parts on in-service airplanes	MRO	Demonstration test	Press release Newspapers Webinar
21	IBM: IoT and Blockchain for avionics	Blockchain used as a ledger to record flight events, operation conditions, and maintenance actions, and make the logs available	MRO	Proof of Concept	Press release Newspapers Video
22	SmartLog Kouvola innovation	Operational information management system	Business Operations Management	Pilot programme	Press release Newspapers Website

23	T-mining and NxtPort	Secure Container Release	Smart contracts Business Operations Management	Pilot completed	Press release Newspapers
24	Port logistics	Blockchain technology in application to port logistics	Trade finance Smart Contracts T&T Documentation management in transportation	Explorative research	Master thesis
25	Renault, VISEO and Microsoft	Digital car maintenance log based on blockchain	MRO	Prototype	Press release Newspapers
26	Martine Jarlgaard and Provenance	Enabling brands to provide verified information about the materials, processes and people behind products	T&T	PoC	Press release Newspapers Webpage
27	The MediLedger Project	Medicines tracking system	T&T	Pilot programme	Press release Newspapers Webpage Results report
28	Bayern AG.	Benefits and guidelines for utilizing blockchain technology in phar- maceutical supply chains	Smart contracts T&T	Explorative research	Master thesis

*Table 2: Study cases employed in the research*

## 5. APPLICATIONS OF BLOCKCHAIN IN SUPPLY CHAINS

In this section, the applications of blockchain technology discussed beforehand in the framework presented are verified by its usage in different study cases. The introduction of this technology in those supply chains serves as a solution to overcome the current challenges presented in supply chain management.

The impacts of the application of blockchain in the studied supply chains are discussed in the next chapter.

### 5.1 Trade finance

The current transaction processing in trade finance is highly inefficient, being very time and cost consuming. The use of paper ledgers and manual processes make it more error and duplication prone and fraud sensitive than ever (Commbank.com.au, 2016). The lack of security as well as the ripe for disruption are the major pain points for trading buyers, who are seeking for an extra visibility in the transactions. The digitalization of trade finance is still in adoption phase because of suppliers consider this digitization as additional cost without benefits (Besnainou, 2017). The blockchain technology has the potential to change this. This technology promises an efficient and secure way to speed up the settling trade transactions, which enables to increase transparency, bringing down costs, lowering operational complexity, reducing risk and lowering working capital needs. Moreover, its combination with IoT and the possibility of establish smart contracts can reshape the trade finance by creating new financing methods (Groenewegen, et al., 2017).

In October 2016, the study case 9 undertook the first trade finance transaction on the blockchain, combining this technology with smart contracts and IoT. The parts entailed in this proof of concept were the seller, Brighann Cotton, and the buyer, Brighann Cotton Marketing Australia, and their respective banks, Wells Fargo & Co. and Commonwealth Bank of Australia (Commbank.com.au, 2016). The cross-border transaction involved the bought of 88 bales of cotton for \$35,000, and its shipment from Texas, USA to Qingdao, China (Kaye, 2016).

The transaction was made employing the Skuchain's Brackets system – a smart contract that governs all phases of a trade agreement from onboarding to order, shipment, invoice and payment with bank grade accounting of inventory (Skuchain, 2015). This new financing method in trade promises solve the real world challenges customers face, adding new dimensions to traditional trade, specially focused in inventory financing (Besnainou, 2017). The trade involved a smart contract on a private distributed ledger between the



buyer, seller and their banks, supposing an open account transaction, mirroring a L/C. All the documents related are stored in the blockchain, making them accessible to all parties involved. The execution of the smart contract was linked to a physical condition, meaning that a confirmation of the geographic location of goods in transit by GPS was required as a trigger to allow for release of payment. This T&T feature brings visibility of where the goods are in real time, increasing security (Commbank.com.au, 2016). In addition, this smart contract change the traditional inventory financing approach based on the receivable to a one financed from the buyer's cost of capital. Skuchain can finance the transactions thanks to blockchain technology due to now the chain of title attested is clearly visible on the blockchain, from supplier to Skuchain to the buyer, and the smart contract supposes a payment guarantee from the buyer. The combination of these elements is sufficient for third-party financiers to consider this transaction as virtually de-risked, making them willing to provide financing off the buyer's cost of capital. With this approach, the supplier is paid immediately and the buyer is able to hold the inventory off their books as long as possible (Besnainou, 2017).

At the end of the 2016, the first transaction between farmer-buyer in the agriculture industry that utilized blockchain technology as a means of transaction settlement was undertaken. The Australian farmer David Whillock delivered 23.46 mt of wheat to Fletcher International Exports in Dubbo, New South Wales using a smart contract ran by commodity management platform AgriDigital (Hall, 2017). Almost a year later, AgriDigital published the results of the second pilot carried out together with CBH group to test the application of blockchain in the Australian grain industry trading. In this study case number 3, the AgriDigital commodity management platform was combined with blockchain technology and the same smart contract in order to conduct various pilot scenarios. One of them was related with matching the title transfer of the grain asset to payment (AgriDigital, 2017).

In this scenario, the solution was based on two different blockchain tokens: one for the digital title and one for the payment. Initially, a digital title token was generated on the blockchain related to a delivery of oats and owned by the grower. Once the grower made the physical delivery and was received by the buyer, the AgriDigital platform that includes all the information around the quantity and quality of the commodity captured along the process, the title token was held until the payment was done. Then was when the second token appeared to refer the payment on the blockchain. Moreover, a smart contract was employed to auto-execute the payment on the blockchain layer with the token, which was parallel processed using traditional banking methods. Once the payment was done, the Agricoins were then destroyed and the ownership in the digital title is changed (AgriDigital, 2017).

This method of matching the title transfer to the payment provides instant benefits to growers and sellers through reduction of counterparty risk and increased security over the asset until title is transferred (AgriDigital, 2017). This blockchain-based commodity trade

platform is currently in usage phase with more than 2.02M tons transacted, \$436M payments made and 1507 active users, including the leaders of the Australian grain industry. Despite the AgriDigital platform is designed for enclose all supply chain participants, freight and inspection services are still not able to act and will be incorporated in the future (AgriDigital, 2018).

After that, other pilots and proofs of concept has been released. In March 2017, the study case 1 was held by Transfigura, Naxitis and IBM, who have pioneered the first blockchain solution in commodity trade finance to manage US crude oil transactions with the objective to create an industry-specific platform (IBM, 2017). During that month, the platform had been tested by running simulations using the Naxitis's existing crude oil deals along Texas pipelines, being the first test for blockchain in the US physical oil market (Meyer & Hume, 2017). The new trading platform, which is based on a permissioned blockchain network built on the Hyperledger Fabric, allows major steps in a crude oil transaction to be digitized, as well as the information sharing, on the blockchain. As the buyer, seller and their respective banks all on the same ledger, all parties can simultaneously view and share data on the status of a transaction, from the time a new trade is confirmed and validated, to when the crude oil is inspected, to its final delivery and cancellation of the L/C. This means that the trade documents, shipment updates, delivery and payment status can be shared across a single shared ledger, helping to reduce transaction time, duplication of documents and authentication processes among all trading partners (IBM, 2017). It is expected that this platform will be extended to allow all parties in the oil transaction to enter data directly onto the ledger. For instance, the shipping company, pipeline operator, inspector or warehouse can provide real-time status updates via the blockchain on the crude oil transaction, helping to lower the risk of fraudulent transactions (IBM, 2017).

After a few months later, the study case 10 consisted in the first pilot ran using blockchain to automate the submission of documents in an import-export transaction between Europe and Latin America by the Spanish bank BBVA with the collaboration of Wave. The transaction involved the purchase of more than 25 tons of frozen tuna from Pinsa Congelados, of Mazatlan, México by Frime, a company of Barcelona, Spain. The payment was made using a traditional L/C, in which BBVA Spain issued the letter and BBVA Bancomer processed the payment. This pilot of blockchain represents a step forward in improving the efficiency of international trade transactions. Nowadays, the management of the large amount of documentation associated with a L/C requires multiple processes, such as manual checks and sending physical documents that are both time-consuming and error-prone. With the blockchain, all parties involved (the banks, the importer and the exporter) can securely register and validate the documentation and be aware of it status. The Wave's system added also the feature to make changes or corrections of discrepancies in the presentation of documents from the moment the goods were loaded until their arrival at

the destination. The pilot also included the electronic signature of documents, the simultaneous distribution of copies to all parties and the reception of the ownership of the documentation at each step along the way (Fernández Espinosa, 2017).

In December 2017, a set of major corporations comprising SMFG, SMBC, JRI, Mitsui & Co., MOL, MIS and IBM Japan verified the applicability of blockchain technology in cross-border trade operations. In this study case 19, the demonstration test was based on a blockchain trade platform, in which participant companies introduce digitalized information of real trade transactions that are recorded and shared among participants in real time. This information included a wide variety of documents, such as trade agreements or logistics/insurance documents. The objective of this test demonstration is to verify the effectiveness of blockchain technology to streamline and upgrade current cross-border trade operations. This technology has the potential to enhance security and reduce the time required to settle cross-border trade transactions, discrepancies among related documents and administrative costs, supposing an enhancement of productivity in trade transactions and new business opportunities in trade finance (MOL, 2017).

One relevant application of blockchain technology in trading documentation management is the study case 17. In October 2017, Bolero and the R3 fintech consortium signed a memorandum of understanding with the aim of redesign Bolero's electronic bill of lading (eBL) service using blockchain technology by developing a set of pilots the last quarter of 2017. Using this solution, the relevant parties can endorse and verify an eBL title without having to use paper, supposing an efficient and productivity-boosting solution for all parties involved in the trade transaction (Fintechist, 2017).

Alongside the previously commented real proofs of concept and pilots, in several university research studies conducted during the last years also envisioned the applications of blockchain technology to trade finance. This is the case of the Master of Science Thesis of Francisconi (2017). In this study case number 24, he purposed a blockchain-based system to store trade finance documentation, such as the L/C, as well as include banks into the port's information systems with the main objective to faster communications and speed up the process of container commercial viability. Thereby, when the containers are unloaded from the vessel at the terminal, an on-time communication can be sent to the consigner bank, which is part of the port's communication system. Subsequently, the bank check the consignee's solvability and send the confirmation of container's commercial viability, speeding up the process that currently performed and could lead up to two days of process delays.

## 5.2 Supply chain tracking and tracing

Track and trace (T&T) is an integral part of SCM, affecting the SC efficiency, product safety and security, risk management, on-time delivery performance, troubleshooting customer issues, controlling costs, and regulatory compliance (Potts, 2015). Despite the importance of the ability of T&T the SC for business performance, the companies still face challenges involved in undertaking this activity. Current T&T is characterized by inefficient data scanning, recording and sharing among the SC partners. In addition, the lack of common standards along SC together with many fragmented partners with different technologies and information systems add more complexity to T&T processes (Pizzuti, et al. 2013; Potts, 2015). Commonly, the products are only traced at certain points of the SC and the data is not communicated effectively among SC partners (Potts, 2015).

T&T processes are of special importance in agrifood industry, where food safety is a priority issue for consumers and SC partners. In October 2016, IBM, Walmart and Tsinghua University (study case 11) announced a partnership to enhance the safety of food on the tables of Chinese consumers by digitally T&T food products throughout the SC using a blockchain platform (IBM, 2016). In this pilot, different pork products were digitally tracked from a single farm to different Chinese stores (Hackius & Petersen, 2017). The information captured in each transaction along the journey of the pork products to the shop were recorded in the blockchain and was instantly available for all SC members. By doing so, the food items were connected to digital information associated to them, such as farm origination details, batch numbers, factory and processing data, expiration dates, storage temperatures and shipping details. This permanent record of transactions can be used as an alternative to traditional paper tracking and manual inspection systems. Each piece of information recorded in the blockchain provides critical data points that help quickly revealing food safety issues, enabling finding sources of contamination in matter of seconds (IBM, 2016).

During that year, IBM and Walmart conducted a similar pilot, but in this case related to tracking back a package of sliced mangoes back to their source (McKenzie, 2018). In this PoC, the international movements of the mango produced in Mexico and offered for sale in the United States were recorded in the blockchain (Hackius & Petersen, 2017). Given the successful results of the pilots, in October 2017 IBM announced a collaboration with-Dole, Driscoll's, Golden State Foods, Kroger, McCormick and Company, McLane Company, Nestlé, Tyson Foods, Unilever and Walmart to identify new areas where the global supply chain can benefit from blockchain and address food safety worldwide (IBM, 2017).

On the other hand, the company Provenance has been conducting many pilots in collaboration with several companies from different industries with the objective to proof the feasibility of a T&T system based on blockchain technology. In March 2017 the study case 6 was developed, in which Provenance and the Co-op carried out a pilot in order to

track fresh products from origin to supermarket, proving product claims with data gathered from the entire SC. In this pilot, data about the supplier, locations and environmental and social impacts of each business were gathered at every point in the product journey (Provenance, 2017). This information was stored in the blockchain, building a real-time digital history for the fresh produce that can be accessible by all the stakeholders. Thus, the end-customers can access to the verified data gathered from all along the SC by a unique URL for each specific batch (The Provenance Team, 2017).

The Provenance team has also envisioned the potential of blockchain technology for tracking ethical claims and digitally prove fair trading practices within the study case 8. Provenance and the Dutch NGO Fairfood ran a pilot-study about proving the fair pay to agricultural workers on 1000 coconuts. Using a grassroots certification approach, the payment and the product were registered in the blockchain by 55 farmers from Yogyakarta, a town on the Indonesian island of Java, via SMS. Afterwards, it was integrated with Fairfood's platform, where a page displaying each farmer's profile, proof of the payment they received, and a timeline of the coconut's journey from Asia to Europe is accessible by scanning a code on the product (The Provenance Team, 2017).

Furthermore, ethics claims in fashion industry could be also tracked with the help of the blockchain technology. In this sense, the study case 26 encompass the collaboration of Provenance with Martine Jarlgaard to conduct a pilot with the goal of enable both transparency and trust around her collections. In this pilot-study, each step in the garment production is registered in the blockchain via the Provenance app, building a digital history of information associated with the garment that includes location data, content and timestamps. Subsequently, this information can be accessed through the item's QR code or NFC-enabled label by the customers, enabling track the journey of the piece form raw material through the supply chain (Arthur, 2017).

In the pharmaceutical industry, the T&T processes are key to combat counterfeit and theft of drugs and ensuring product integrity and quality. In September 2017, a group of companies, including major pharmaceutical conglomerates Pfizer and Genentech, announced the MediLedger Project (study case 27), which consist on the exploration of the blockchain technology to meet T&T regulations, and to provide an improvement in the overall operation of the SC (Mediledger, 2018). This project would use the blockchain to enable SC partners, including manufacturers, wholesale distributors, hospitals, and pharmacies, to T&T prescription medicines. In addition, this blockchain-based system can help companies to meet the requirements of interoperable systems for managing records of ownership and transfer set by the US Drug Supply Chain Security Act (DSCSA). As the 2017 progress report explains, the working group has successfully set up a prototype system to register and verify drugs in the blockchain, which has been tested during that year. Moreover, they has announced that the next step is to develop business models and operational requirements on the blockchain (Pharmaceutical Technology Editors, 2017).

In regards with logistics, the blockchain has supposed an opportunity to improve current T&T processes and enhance the visibility of containers or pallets during its transportation. In the study case 18, IBM and AOS announced a partnership in June 2017 with the aim to develop a new blockchain and IoT solution for the logistics business in Colombia. It consists on the digitalization of cargo related transactions by capturing directly information from sensors placed on the trucks and recorded it into the blockchain. Thereby, the ledger generated enables track the provenance and status of trucks and the goods transported, as well as all the exchanges, stops and transactions made by each truck and its respective load, from the distribution point to the final customer. In addition, this solution enables to monitor what is happening with the trucks and provide a better estimation of the delivery time to customers. This is possible by capturing external information, such as weather, humidity, temperature and driver's data and correlate them with information to define the availability capacity of the truck (IBM, 2017).

In the study case 3, Marine Transport International (MTI) announced the completion of a pilot with the release of a white paper at the end of August 2017, detailing the project called Container Streams system. In this pilot program, a blockchain system was built to combine and share data on suppliers, shippers, load points, customs and terminals, making it accessible to all parties involved (Fearn, 2017). One unique feature of this system is the interoperability with current systems, avoiding the replacement of existing ones. Through this pilot program, the resilience of blockchain systems against cybersecurity threats that target the shipping industry was tested and validated by the University of Copenhagen and Bloc (PRNewswire, 2017; Fearn, 2017).

Moreover, since December 2017, BASF together with the start-up Ahrma are conducting pilots to test the applications of Ahrma's smart pallet at BASF's SC (study case 2). The smart pallets contain IoT sensors that make them able to gather information related with the position and movement of shipped goods, temperature fluctuations, load state and any possible impact or dropping. This information is recorded in a blockchain system accessible to authorized partners, providing complete insights on what is happening with the pallet in every moment (BASF, 2017).

### **5.3 Certificates**

In the last years, a wide variety of certification schemes associated with products has emerged to increase the visibility of the product journey along the SC (Francisconi, 2017). The end-customer demands on product integrity, related to fairness and authenticity of the product in its SC, has promoted the generation of several quality, provenance, fair trade and organic certifications. Currently, these certification standards involve the audition of large amount of information related with the product through the SC by trusted third parties to certify that the products meet with the scheme's requirements from the origin to the final consumer (NEPCon, 2017; Ge, et al., 2017). In this context, the information required for audition and the one generated to record the certificate verification

rely on paper-based chain of custody systems, not integrated in a common database (NEPCon, 2017). This entire process is highly inefficient due to lack of digitalization and system integration, costly and prone to fraud, corruption and errors (Ge, et al., 2017).

To solve part of these inefficiencies, in the study case 5, Provenance together with IPNLF and Humanity Reunited associations have worked in a 6-months pilot ran from January to June 2016, about tracking fish caught by fishermen with verified social sustainability. The pilot consisted on 3 phases as is shown in the **¡Error! No se encuentra el origen de la referencia..** The main goal of this pilot was to enforce the proof of compliance to standards throughout the SC, prevent double spending of certificates and exploring the opportunities of blockchain and IoT for enhancing product transparency. Given the current challenges in effective interoperability and data sharing along the SC, the blockchain appears as perfect opportunity to share the same truth between all the SC stakeholders, without giving any of them a backdoor to the system. This pilot consisted on a new method for enabling a secure flow of information and allowing a fully accessible chain of custody, including key social attributes such as fishing method, vessel type and compliance data (Provenance, 2016).

The pilot was tested in Indonesia, which is the largest tuna-producing country, and it was focused in two tuna SCs: yellowfin and skipjack tuna fish, from fisherman to export stage. In an initial research phase, the opportunities for digitalization of SC data and its transfer were analyzed by interviewing all the stakeholders involved. The first stage of the pilot was focused on the data collection and registration from the first mile. Daily catch is registered as new asset, with unique ID, on the blockchain when the fishermen sent a SMS message. In this way, the assets become linked to the fishermen as the owner in the blockchain. When the assets are transferred on sale from fisherman to supplier, the transaction is digitally registered on the blockchain and the change of title of ownership is also updated. On the other hand, the verification of social and environmental conditions for the fishermen in the capture point is done by a trusted local NGOs, whose audit systems were compliance to an external standard. The certification records are stored in the blockchain associated to each fishermen activities (Provenance, 2016).

In the second phase of the pilot, the focus was on linking the blockchain with current ERP and other SC systems. The blockchain technology is interoperable by default due to the data is stored in the ledger as an address that can be accessed by any entity through the QR code or the RFID tag attached to the item. When a transaction or transformation is developed in the physical layer, it is also recorded in the blockchain associated to the unique ID of the asset. To manage the transformation of items along the SC, a smart contract was employed. The triggered condition to execute it consisted on the mass balancing to account the amounts of ingredients used in the transformation. As a result of the smart contract, the identifier encoded in the label of the transformed product appeared, which will

be passed with it through the chain. Lastly, the transformed products that leave the manufacturer as outputs are also register in the blockchain by scanning their labels (Provenance, 2016).



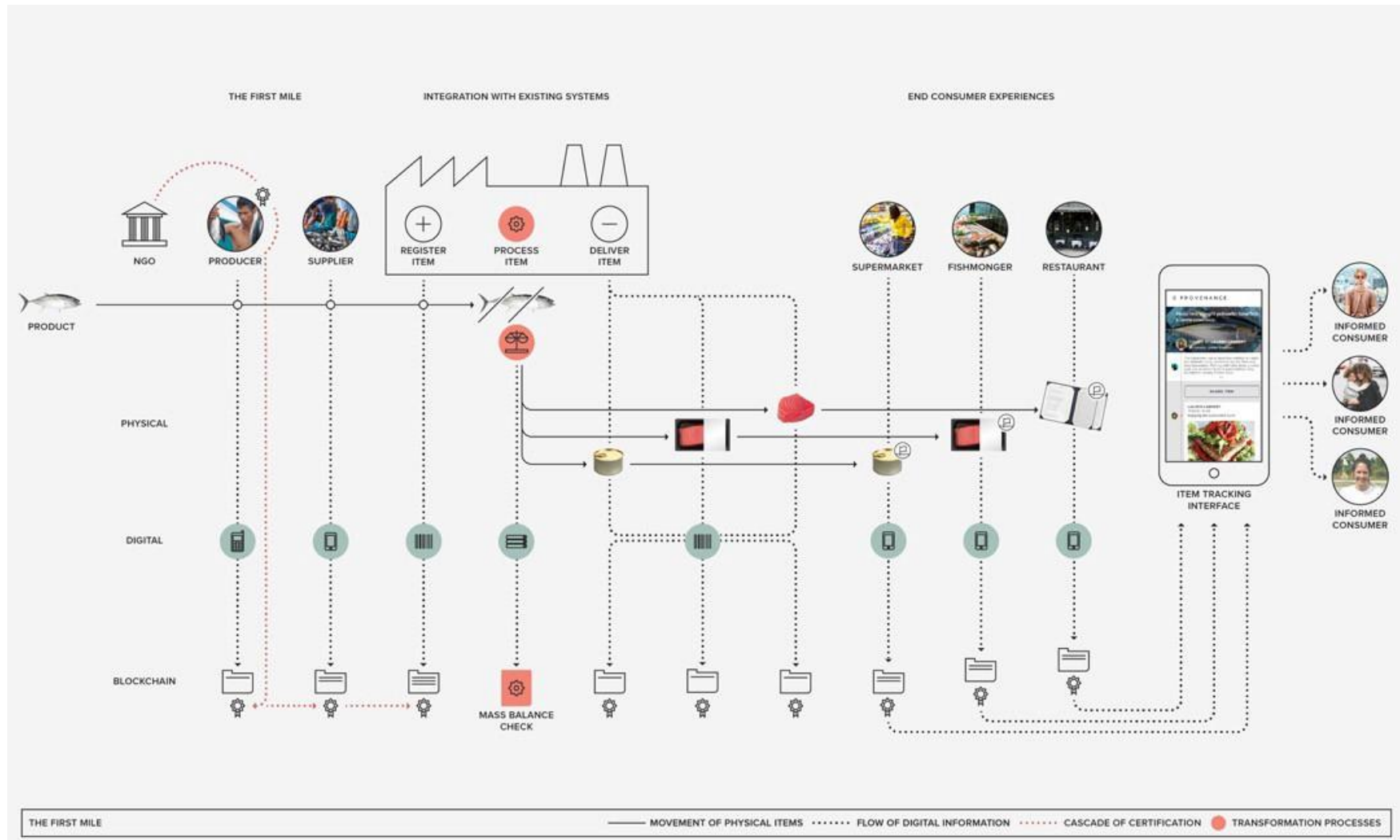


Figure 22: Provenance pilot about tracking tuna supply chain (Provenance, 2016)

Finally, the last phase of the pilot was related to make accessible to end-customers the records stored in the blockchain. Through smart stickers and packaging based on NFC tags, shoppers can hover their smartphones over a product to track its provenance on their screens (Provenance, 2016).

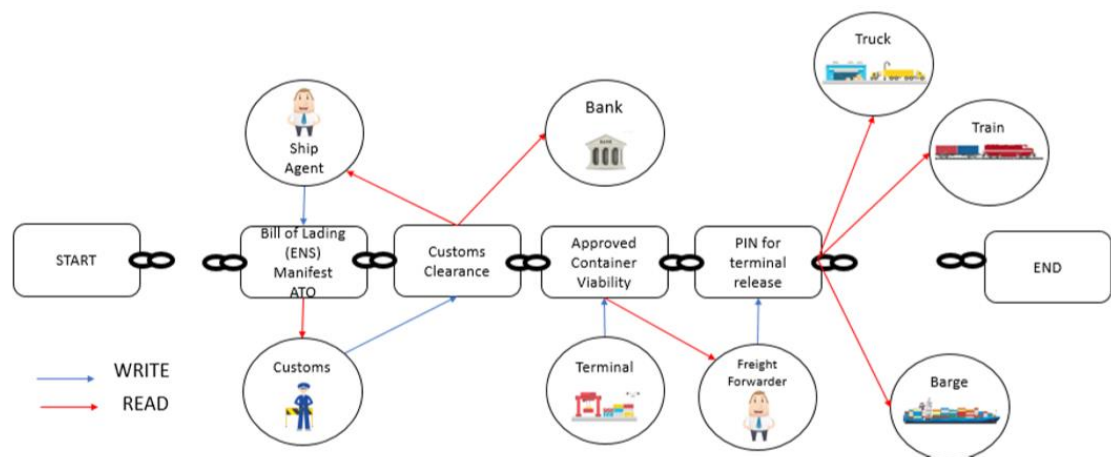
In September 2017, Provenance conducted another pilot in collaboration with the Soil Association (study case 7) based on an interactive certification version supported by blockchain technology (Provenance, 2017). This world's first digital certification mark consisted on a blockchain where the most important product claims and certificates can be recorded and viewed in real time, creating an auditable record. The link of the Soil Association Certification's databases with the blockchain provides a single source of truth where key verified data and batches of product are stored throughout the product's journey from farm to store. This information is accessible by hovering a mobile phone over the NFC-powered mark on the product package, allowing shoppers to see information including the certification's validity, the organic criteria met by the product, a map of its journey, and even photographs from the farm (Searle, 2017). During the pilot, the interactive certification was well received by shoppers in-store, who intuitively used Provenance to access information about organic products, increasing customer engagement (Provenance, 2017).

Other study case related with certification is the number 4, which is conducted by Wageningen Economic Research and TNO. In the pilot study report released in November 2017, the findings of the PoC started in March 2017 were described. The aim of this pilot was to keep track of different certificates involved in the table grapes SC from South Africa using a blockchain. The boxes of grapes are stored in the blockchain using a unique identification number. On the other hand, the organic table grapes are produced on a farm in South Africa that needs a certification for the individual boxes of grapes it produces, so an accreditation authority is necessary to sign an organic certificate to the farm. After certifying these grapes, they are shipped to a reseller in Europe, where they are sold to supermarkets or retailers. Each time the grapes change ownership is recorded in the blockchain. All parties involved can access to the blockchain, verify the validity of the organic certificate, and track the provenance. If non-compliance with the certification schemes is discovered during an audit, the certification authorities can revoke the certification issued to the farm and it will be recorded in the blockchain. As a result, this pilot has demonstrated that it is feasible to put basic information concerning certificates on a blockchain (Ge, et al., 2017).

## 5.4 Documentation management in transportation

The transportation industry involve a vast amount of data and paperwork associated with the shipment of goods. In 2014, Maersk conducted an experiment where a refrigerated container of roses and avocados was tracked from Kenya to the Netherlands. As a result, the company found that almost 30 people and organizations were involved in processing the container on its journey to Europe and over 200 communications were required. The shipment took 34 days to travel from the farm to the retailers, including 10 days of delays waiting for documents to be processed. A missing form was the cause of the container hold up in the port, while the goods inside spoiled. The document was finally found later amid a pile of paper (Popper & Lohr, 2017). The inefficiencies in the transport documentation management due to lack of digitalization and information systems of each SC member working as siloes generates asymmetries in the data sharing, and time consuming and costly documentation processing. On the other hand, the paper-based processes are prone to error, fraud and counterfeit, adding more challenges to documentation management in transportation (Hackius & Petersen, 2017).

Given that inefficiencies in documentation management, the blockchain technology appears as a perfect solution for the digitalization of current information flows in SC of transportation industry. In the theoretical study case 24 developed by Francisconi (2016) an information management system supported by blockchain was envisaged. The cargo-related information can be recorded in the blockchain by its owner and be accessible for all parties in any moment. In the figure bellow, the example of information management system purposed is shown.



**Figure 23: Blockchain application in documentation management in transportation (Francisconi, 2017)**

In March 2017, Maersk Line announced that was working with IBM on a blockchain solution with the aim of digitizing the paper trail traditionally used to track products across shippers, ports, freight forwarders, and customers in the shipping industry (study case 11). The solution consist on a securely and seamlessly exchange information about

shipment events in real time and digitalization of documents through a blockchain, which is accessible by all the partners. In this blockchain platform, the SC partners can securely submit, stamp and approve documents across national and organizational boundaries, which enable end-to-end visibility in real time by all the SC participants. On the other hand, the digitalization of documents helps to reduce the time and cost for clearance and cargo movement. Thereby, the container's progress through the SC, as well as the status of trade documentation, such as B/L or customs documents, are visible throughout the SC. This level of transparency helps to reduce fraud and errors, reduce the time products spend in the transit, improve inventory management and ultimately reduce waste and cost (IBM, 2017).

In order to prove the potential of this solution, Maersk line and IBM have worked with a large number of trading partners, government authorities and logistics companies. One of the pilots conducted involved a container at Schneider Electric in Lyon, France, that was trucked to Rotterdam, loaded onto a Maersk Line ship and transported to the Port of Newark and then to a Schneider Electric facility in the U.S.. In this case, Customs Administration of the Netherlands, U.S. Department of Homeland Security Science and Technology Directorate, and U.S. Customs and Border Protection were also participating in this pilot. Moreover, the international shipment of flowers to Royal Flora Holland from Kenya, Mandarin oranges from California, and pineapples from Colombia were also used to validate the solution for shipments coming into the Port of Rotterdam (IBM, 2017). As a result of the pilots conducted, in January 2018 Maersk Line and IBM has announced a joint venture with the aim to provide more efficient and secure methods for conducting global trade using blockchain technology (IBM, 2018).

In August 2017, IBM in collaboration with other organizations announced the launch of several proofs of concept in order to study and verify the potential applications of blockchain technology in documentation management within the transportation industry. One of them was the study case 14, where IBM, PIL and PSA signed a memorandum of understanding to explore and trial blockchain-based solutions from August to December 2017. In this PoC test, the blockchain was used to provide time-stamped record of manifests, loading and unloading events, docking events, departure and arrival events in a tamper-proof transaction log, which served to streamline SC tracking and management between the companies to keep track of all the ships and containers (IBM, 2017; Dotson, 2017). After conducting the tests in the platform to track and trace cargo movement from Chongqing to Singapore via the Southern Transport Corridor, a press release communicating the trial findings was released in February 2018. Given the successful results, the partners believed that now they are ready to take the concept to the next stage (Ngai, 2018).

In the study case 15, IBM collaborated with HMM and Samsung SDS with the goal of assessing the feasibility of blockchain in combination with IoT technology for reefer containers on board of a vessel. The pilot voyage took place from the South Korean port of

Busan to the Chinese Port of Qingdao, from August 24 to September 4, 2017. In this pilot, the documents were safely shared among parties through the blockchain. As all the papers related to the vessel arrival/departure info, B/L and cargo tracking sectors were digitalized and stored on the blockchain, it can be considered a “Paperless Operation” (HMM, 2017). In addition, the blockchain was also employed for tracking cargo from shipment booking to cargo delivery, real-time monitoring and management of the reefer containers on the vessel (Porttechnology.org, 2017). This pilot voyage was followed by more pilot voyages in India, Middle East, and Europe. At the end of 2017, HMM announced that after 7 months of pilot and internal analysis, the companies had completed the assessment on blockchain technology adopted in shipping and logistics, accomplishing the trial to prevent any alteration and forgery of import/export documents and simplify the document issuance process (HMM, 2018).

In December 2017, IBM also conducted another pilot together with the carrier MOL (study case 19). In this demonstration test, the companies participating record a wide variety of documents in the blockchain, including trade agreements and logistics/insurance documents. Thereby, the documents recorded can be timely accessible and shared among blockchain participants. This study case 19 has been previously commented as a use case of trade finance due to the ultimate goal of the pilot was to streamline and improve the trade finance process (MOL, 2017).

On the other hand, not all the blockchain applications are focused in cargo shipping by sea. In the study case 16, Dnata in conjunction with Emirates Innovation Lab, IBM and flydubai Cargo carried out the first airfreight service delivery using blockchain in November 2017. The successfully completed PoC test was based on a blockchain system for recording the handoff of cargo from the original purchase order all the way through delivery to the consignee warehouse. As a result, the blockchain test enable the digitalization of conventional paper-based processes and streamline the processes necessary to delivery cargo to its final destination (Woods, 2017).

## **5.5 Maintenance, repair and operations (MRO)**

Until now, the management of MRO items has not been considered as a critical operating component. The MRO is a field where little attention has been place, but current manufacturers are beginning to understand its importance and the potential of the introduction of its strategic management to save money and improve inventory management. The current MRO management involves the purchase of low value MRO items in large quantities, supposing 60% or more of total purchase requisitions, although they only cost around the 15% of the total purchases. This means that the MRO management involve a considerable administrative work, which is highly inefficient due to lack of digitalization and local purchasing systems that not seize economies of scale (DSI, 2018).

This situation is aggravated by the lack of integration of maintenance logs along the supply chain, causing visibility problems in MRO product life cycle monitoring. The main MRO SC challenge is when to make the right part and getting that part at the right time, in the right place, with the right cost and with the right reliability, security and quality. Despite the complexity of this process, the different parts must be traceable in order to correctly undertaking the maintenance and compliance with safety regulations. Nowadays, MRO systems are poorly working due to lack of uniform data exchange standards, continuous exchanges in the part data and frequent modifications not recorded properly (Ramco, 2017).

In line with this approach, several consulting firms envision the blockchain incorporation into MRO processes. For instance, in December 2016, a report of Accenture highlighted the potential of this technology for transforming the maintenance logs in avionics by ensuring that parts procured are legitimate. The blockchain can act as an immutable record of provenance of every part of the plane since the beginning of the aircraft's existence, where every time that it has been handled and by whom is recorded. The blockchain ledger would increase the visibility and can take the practice of maintenance, safety and aircraft security to new levels. In addition, loyalty, security and ticketing solutions are also mentioned as potential applications of blockchain in avionics industry (Accenture, 2016).

In the beginning of 2017, one of the world's biggest technology companies, IBM, had proposed a solution for MRO merging blockchain, IoT and cloud computing (study case 21). The video demo released by IBM focused on how the blockchain can be used as a digital ledger shared by airlines, MRO teams and OEMs to record flight events, operations conditions, scheduled aircraft maintenance checks and track the entire lifecycle of products and how they perform over time once are installed on an airplane. Therefore, each partner has access to the same updated information about the logs available, increasing the visibility within flight maintenance. The IBM's solution includes a machine learning algorithm on the blockchain to forecast when mechanical parts need maintenance attention based on flight schedules, weather, aircraft landing history and runway information (Bellamy III, 2017).

But it not was until the study case 20, in October 2017, when Air France KLM announced the creation of a MRO-lab in Singapur together with Ramco Aviation to study the potential use cases of blockchain technology in aircraft maintenance, processes and workflows to overcome current challenges in recording and managing parts on in-service planes. In this collaboration, they have demonstrate that the blockchain's digital distributed ledgers are a perfect solution as a digital record of replacement parts shared amongst engineers. In the PoC, once a fault on a part was identified on a mock flight, the details of a replacement were shared amongst Air France KLM logistics and loan officers, engineers and technicians in a blockchain, registering from the loan order to the received check and the register of the work execution (Kimani, 2017; Ramco, 2017).

In the automotive industry, the potential of blockchain to improve current MRO processes is also discussed, such as in the study case 25. In this case, the Renault group announced in July 2017 a collaboration with VISEO and Microsoft in a prototype for a digital car maintenance book supported by blockchain technology, in order to ensure that data in the car passport is stored in a secure and transparent manner (Renault, 2017). This prototype connects each new vehicle's maintenance events to the blockchain-based system, remaining each vehicle's maintenance history invariable and trustfully shareable even there is a change of vehicle ownership (Heutger, 2018).

## **5.6 Business operations management**

As well as in transportation, trade finance or MRO, the management of other business operations is still an inefficient process. The lack of digital processes together with the information systems working as siloes, generate a set of challenges that directly affects to the performance of current business operations. Nowadays, the companies record and store their business operational information in their own information systems, and share only certain information with their SC partners under request. This information exchange is full of inefficiencies due to the dominance of manual processes, resulting in a time and cost consuming process with an unnecessary complexity (Cutlan, 2018).

All the previously commented study cases related to the different proposed blockchain applications in the theoretical framework would serve as business operations management study cases. Despite that, this subsection is focused only on new study cases that provision new information about how blockchain can improve the performance of other business processes.

Since September 2016, the project SmartLog has been launch in order to introduce a blockchain technology application into the logistics business operational data transfer traffic (study case 22). The project funded by the European Union and with a duration of 3 years is aiming to reduce cargo transit times on main transport Baltics corridors. In this scenario, all kinds of logistics companies share and access to the relevant information related to the movement of intermodal containers in a common blockchain, which is connected to each company's information system. In addition, IoT trackers are attached to some containers to validate their movements in the corridors against the information recorded in the blockchain. The availability and accessibility of up-to-date information in the blockchain is hoped that will be able to enhance companies' operations, resource management and route optimization planning (Smartlog, 2016).

In the context of sea shipping, the blockchain technology has a great potential for overcome the universal challenges of ports, maritime logistics and SCM, as it is shown in the study case 23. In August 2017, T-Mining and NxtPort announced a pilot project to make container handling in the port of Antwerp more efficient and secure. As is the case in all ports, truck drivers who are going to pick up containers need to identify themselves by a

PIN code. The port terminal operator generates this PIN code for the particular container and subsequently it passes along to the forwarder who arranges the transport, and finally passes the code to the carrier. By this method, the PIN code passes between various different parties involved, so there is a risk of falling into the wrong hands and the container being collected by a non-authorized person. This blockchain-based logistics solution appears to solve this challenge. The digital rights related with the container has been created in the blockchain, so only the owner of the right is allowed to collect the container. The rights can be transferred between parties by the blockchain, being all the parties aware of the owner of the container in every moment. Thereby, only the owner of the corresponding right is allowed to collect the container on the terminal. In order to secure the containers release, a PIN code is generated and received by an app on the smartphone of the trucker (owner) notifying that the container is ready for release. The app also adds a geofencing level of security. This means that the PIN is not generated unless the truck driver is on the right premises, namely in the right port terminal where the container is waiting to be released. This is the first part of the pilot, in future stages is envisaged the elimination of the PIN code by a smart contract (iScoop, 2017; Port of Antwerp, 2017).

Other study case related with logistics operations is the previously commented study case 14 in 5.4, wherein IBM together with PIL and PSA has carried out a pilot from August to December 2017. In this pilot test, the blockchain was used as a database that provides time-stamped record of documents, which served to streamline SC tracking and management between the companies to keep track of all the ships and containers (IBM, 2017) (Dotson, 2017). After conducting the tests, a press release communicating the trial findings was released in February 2018. As a result, they highlight the improvements in execution of multimodal logistics capacity booking process, achieving a more transparent, trustworthy and regulatory compliant execution (Ngai, 2018).

## **5.7 Smart contracts**

The smart contracts are one of the most disruptive potential applications of blockchain technology, promising to revolutionize SCM. The smart contracts enable the automatization of low value-added business transactions, eliminating time consuming and highly cost processes that eventually are still based on physical paperwork. These transactions can be processed without any user input, which entails lower associated risks and more cost efficiency, while speeds up the transaction processing. Given the versatility of the smart contracts, there is a vast range of potential applications in the supply chain management (Mitchell, 2017).

As previously commented in the 5.1, the smart contracts have a great potential in Trade finance. This area remains with complex and largely paper-based processes with long cash-to-cash cycles that are costly, error-prone and fraud sensitive (Arnold, 2017). The introduction of smart contracts on the blockchain in trade finance, thanks to its intrinsic features, allows reducing human errors, fraud attempts, increasing privacy, reducing cost

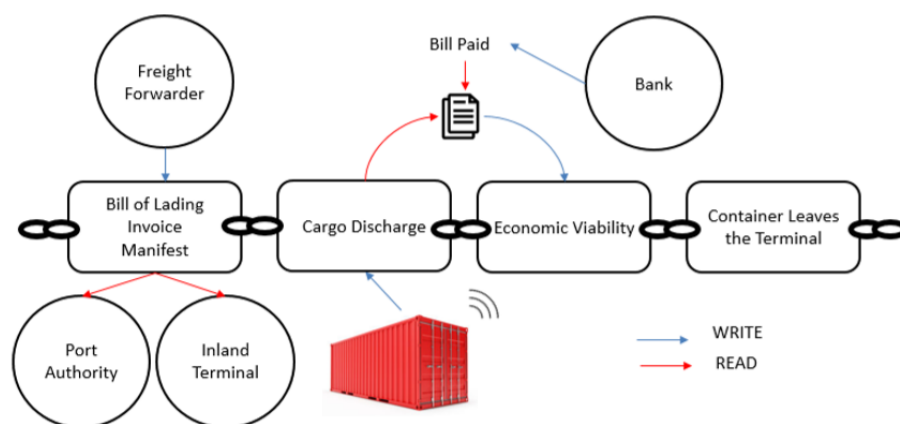


and lead times, as well as the trustworthiness. Some examples of smart contracts in this area have been given in 5.1, but they are summarized below.

The proof of concept carried out in the study case 9 by Brighann Cotton, Brighann Cotton Marketing Australia, Wells Fargo & Co. and Commonwealth Bank of Australia in October 2016, supposed the first trade finance transaction on the blockchain, combining this technology with smart contracts and IoT. This smart contract was linked to a physical condition, meaning that a confirmation of the geographic location of goods in transit by GPS was required as a trigger to allow for the release of the payment. Thereby, this solution not only streamline the process and enhance the efficiency of document management, but also the T&T feature supposed an increasing visibility of the location of the goods and the security related to the delivery (Commbank.com.au, 2016).

The other study case of smart contracts in this area, which has been previously commented, is the pilot developed by AgriDigital and CBH group in November 2017 (study case 3). In this case, they tested the AgriDigital commodity management platform combined with blockchain technology and a smart contract in order to match the title transfer of the grain asset to payment (AgriDigital, 2017).

In the field of logistics, the smart contracts have the opportunity to help to solve the inter-parties lack-of-trust that characterize the port's activities (Francisconi, 2017). According to the study case 24 of Francisconi (2017), the smart contracts could be employed in combination with IoT sensors to automatize low value added operations in the port. The IoT trackers installed on the containers can provide valuable information about the goods' conditions and location, and can be directly registered on the blockchain. This data gathered by the smart devices in combination with smart contracts can automate the execution of the payment of the container triggered by a physical condition than can be a certain location or a confirmation of the container's internal condition remains the same until to the legitimate container's opening (see Figure 24).



**Figure 24: Smart contract and IoT use case (Francisconi, 2017)**

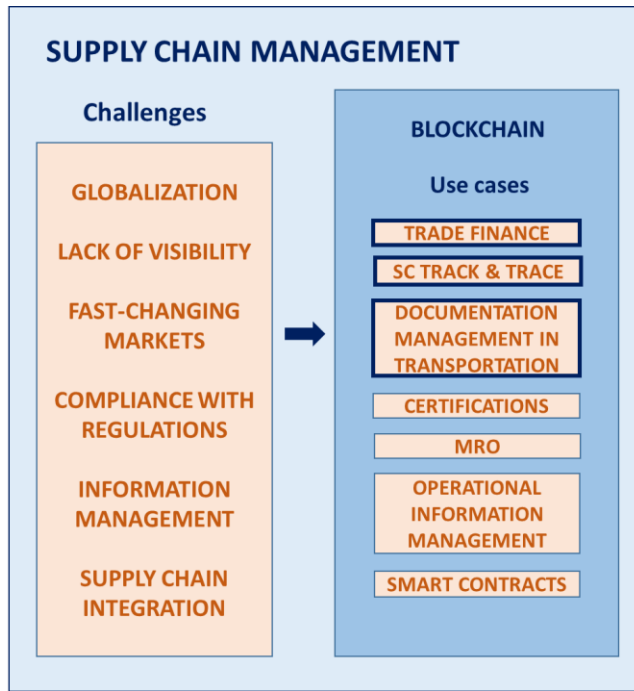
Other potential application of smart contracts in logistics is in the previously commented study case 23 in 5.6. T-Mining and NxtPort in the port of Antwerp already completed a test about making an efficient and secure container handling in the seaports based on blockchain in the first stage of the pilot. Given the successful results of that stage, a second one is envisioned with the aim to remove the necessity of the PIN code throughout the system and make the whole process more secure and efficient by its automatization using a smart contract (iScoop, 2017).

On the other hand, the smart contracts can be also applied in the pharma industry. According to the theoretical study of Kurki (2016) undertaken in the study case 28, the introduction of smart contracts on the blockchain is very suitable for pharmaceutical supply chains. The combination of RFID tags recorded in the blockchain with smart contracts can be used to automatize the execution of payments and ownership change only once the term to deliver the package to a certain destination has been verified with the help of RFID tags. On the other hand, IoT and the blockchain can be valuable for monitoring stock levels and making smart contracts to automatize the replenishment of products, placing orders to suppliers when is required. Finally, Kurki (2016) also explained the possible use of flexible terms of smart contracts. For instance, this could be used to allow patent usage only when the demand peaks would be higher than Bayer's manufacture capacity. This situation can be determined by comparing medicine sales and production.

## **5.8 Compliance with the proposed framework**

After the review of the different study cases under research, the feasibility of blockchain technology to support the proposed use cases is proved. The study cases revealed that the blockchain technology is creating awareness in many industries, fostering the development of multiple pilots and proofs of concept to explore its future deployment in current SCs. It must be stressed that companies are significantly more interested in the blockchain applications related to trade finance, transportation documentation management, and track and trace solutions due to the largest amount of study cases found related with these solutions in comparison with the others potential use cases proposed. This may be because these industries are in highly competitive markets, which impulse them to finding new ways to gain a competitive advantage. The early adoption of innovations can make them to increase profits and strengthen relationships across the SC.

According with the results obtained, the framework proposed initially is verified by the study cases employed. In all of them, the blockchain technology helps to overcome current SC challenges. Furthermore, the framework must to be updated in order to highlight the abovementioned most promising use cases, being finally configure as the following Figure 25:.



*Figure 25: Blockchain in SCs framework updated with the most relevant use cases*

## **6. BLOCKCHAIN APPLICATION EFFECTS IN SUPPLY CHAINS**

In this section, the effects observed as the result of the application of blockchain technology in the different study cases under research are explained. It has to be notice that only the main effects are outlined in this section.

### **6.1 Transparency and visibility**

All the study cases that have been analyzed lead to the conclusion that the application of blockchain technology increases the overall transparency of the SC. This is especially important due to the direct implications of transparency into making a more effective SCM by gaining end-to-end visibility into the extended SC.

In the study cases under research, the increased SC transparency provides more end-to-end visibility to both businesses and consumers. In the case of the businesses, a greater SC visibility enables companies to improve the efficiency of the whole SC. The transparency in the SC allows companies to closely monitor SC activities, take better-informed decisions and better meet with compliance requirements of the different legal bodies. In addition, the greater SC visibility helps companies to better perform current processes along SC, reducing SC failures and managing risks effectively. This is the case of T&T processes, an increased visibility of the SC enables to better T&T along the entire SC. This is especially important in some industries, where an effective T&T throughout the SC help to identify faster the sources and causes of contamination and improve the recall process. On the other hand, the levels of transparency arising from the blockchain technology also enhance internal visibility into a company, helping to streamline and optimize day-to-day company's internal activities, such as MRO purchasing or inventory management.

In regards to customer's visibility, it helps to build and maintain customer engagement in order to gain competitive advantage. In the face of the ethical, environmental and sustainability claims of customers, the end-to-end visibility of the journey of the product through the SC become a market-driven necessity. This transparency associated with the products gives the opportunity to customers to know more about what they are buying and make an informed choice, enabling customer trust and loyalty. This is the case of the pilots conducted by Provenance (study cases 5,6,7 and 8), whose main objectives are always boost the traceability of products, from the raw of materials to the retailer, giving more insightful information and enabling SC transparency to customers, which ultimately increases the customer value for that offering. Furthermore, this improvement in transparency can suppose the development of new customer services to better satisfy their current

or future necessities. For instance, the maintenance log developed by Renault in the study case 25 in order to provide the customers with a transparent and secure car passport.

Finally, it is necessary emphasize that among the intrinsic features of blockchain, transparency is one of them. In a blockchain network, all the authorized participants have an automatically updated full copy of the history ledger. Thereby, the data shared in the blockchain is always available and visible for all the participants (MarCom, 2017). With the introduction of blockchain technology into current SC processes, an increase of transparency and visibility throughout the SC is expected automatically.

## **6.2 Security**

Given the threats posed by the digitalization of supply chains, the cybersecurity has become one of the most relevant. One example of the dimensions of this risk is the cyber-attack suffered by A.P. Moller Maersk in late June 2017. The company was hit by the ransomware NotPetya, which prevented company's workers from accessing the data unless they paid \$300 in bitcoin. As a result, the cyber-attack costed to the company as much as \$300 million and disrupted operations for 2 weeks (Leovy, 2017; Novet 2017).

Consequently, multiple companies have been working into new solutions to enhance the security in their SCs. The blockchain appears as one of the best technologies to securitizing information systems and data transactions along the SC. Generally, in the majority of the study cases of the research, an improvement in SC security has appeared. In all of them, the implementation of blockchain technology to supporting current SC processes supposed a solution to automatically enhancing SC security.

This results from the fact that the blockchain technology is secure-by-design. The cryptographic hash secures the data recorded in a blockchain with a digital signature, establishing a proof of authenticity (MarCom, 2017). Moreover, each transaction is tied in the chain to previous transaction or records that at the same time are distributed among and accessible by all participants of a blockchain distributed ledger. On the other hand, a single entity cannot create a transaction in the blockchain, it must to be validated by other nodes through consensus algorithms. Thereby, an attempt of hacker attack require change the previous records in the blockchain that are immutable and change the consensus of the blockchain network (Bendor-Samuel, 2017).

## **6.3 Enhancement of Trustability**

One of the main effects observed in the study cases is the enhanced trustability among SC members. The inclusion of blockchain technology in SCs enable a trust environment, both for the businesses and for the customers.

In regards to the businesses, traditional SCs are characterized by mistrust among partners, preventing them to collaborate adequately in a common information system. This lack of confidence in SCs makes the SC members reluctant to share sensitive business information due to the fear of it can be passed on to competitors. In fact, even if the information is shared, it is not completely trusted due to it could be altered. In this context, trusted central parties are needed in order to operate and maintain common databased of SC information. Moreover, in some business processes, all the transactions must to be processed and verified by a trusted impartial intermediary in order to control and ensure record authenticity.

The incorporation of blockchain into SCs generates an unbroken chain of trust through a common, permanent and shared record of every transaction, where each transaction is time-stamped recorded and appended to the event before. In addition, the cryptology features of the blockchain technology replace the need for trusted intermediaries to control the data or verify the transactions. In a blockchain, all data is synchronizing across the network and accessible by all the authorized participants, who run complex algorithms to verify and certify the integrity of the network. The transparency and security of the blockchain ensure a strong level of trust, facilitating the integration of data sharing and information systems throughout the SC, which ultimately encourage an effective SCM.

As regards of consumers trust, the increase of end-to-end visibility of the products' SC, enabled by the implementation of blockchain technology into SCs, results in a customer trust growth. This effect is of special interest due to the importance of customer trust for maintain and/or increase customer engagement and loyalty. The customer accessibility to more information about the products purchased, not only enhance customer value of the products, but also it has the opportunity to create a trust relationship between customers and businesses, supposing a competitive advantage. Examples of this enhancement of customer trust are found in the digital product labelling of Provenance (study cases 5,6,7 and 8), which allow customers to know more about all the stages of the product's SC.

## **6.4 Reliability**

The introduction of blockchain technology in SC entails the digitalization of current processes, which are mostly manual and paper-based. As a result of the digitalization, a reduction of human errors in data entry and transfer, duplications and documentation misplace in current document management has been noticed in the study cases analyzed.

On the other hand, the blockchain enables databases to be more reliable and accurate. The blockchain is a common distributed ledger among SC partners, entailing a single source of records. Thereby, the same data is accessible by all the SC partners, avoiding the necessity of time and cost-consuming reconciliation processes.

The reliability of SC information is of special interest SC process that are heavily data-based, such as trade finance, T&T processes or MRO, among others.

## **6.5 Fraud prevention**

Nowadays, the complexity of current SCs make them more fraud prone than ever. In this context, the study cases analyzed reach to the conclusion that the transparency-by-design of the blockchain employed contributes to prevent and detect fraud along the SC.

This effect is particularly relevant due the wide range of potential fraud attempts in all the levels of the SC and industries. As is shown in the study cases discussed, key documentation, such as the L/C, is often fake or fraudulent in trade finance, causing double spending of invoices. In goods shipping, not only the freight can be stolen, but also the transportation documentation associated can be falsified and tampered. In MRO processes, the MRO items can be also stolen within the company or along the SC, as well as the maintenance logs can be altered, supposing a safety issue. Similarly occurs with pharma and food industry, whose products are often stolen and fraudulent manipulated, generating counterfeit product problems and safety issues. Finally, in the certification process, the certifications can be falsified as well as the auditing data.

The blockchains used in studied SCs enable to have more end-to-end visibility of the throughout SC, helping to better monitor business transactions or asset movements at any time. On the other hand, the immutability of the blockchain makes it a tamper-proof record of data, being highly reliable for fraud detention. Thereby, the blockchain can help companies to quickly identifying counterfeit or stolen goods by tracking back the transactions, and avoiding potential safety or quality issues while also preventing financial losses. In addition, a better fraud detention reduces or eliminates the impact of counterfeit products for end-users, increasing their confidence.

## **6.6 Enhancement of Efficiency**

In all the study cases discussed, the use of the blockchain technology supposes an overall enhancement of efficiency, both internally within a company and throughout the entire SC. The blockchain enables the digitalization of multiple processes, which many of them are still manual and paper-based with a highly cost and time consuming processing. On the other hand, the use of a blockchain as a shared ledger among SC partners transform how the data is shared and communicated between them, being traditionally highly inefficient. The use of a blockchain improves the efficiency of current processes, mainly by a cost reduction and a processes optimization.

As the blockchain involve a digitalization of administrative processes, it leads to a reduction or elimination of paperwork and other processes associated, such as the data reconciliation. With this technology, these time-consuming processes are optimized, cutting

down the working hours needed to process it. Thereby, the blockchain represents a reduction of administrative costs. In addition, the blockchain feature of elimination of the need for a trusted third party reduces also this cost.

On the other hand, the blockchain helps to streamline SC processes, enabling to speed them up to new levels. In the case of trade finance, the transaction processing time can be strongly reduced. In the study case 10, BBVA and Wave minimized the time required to send, verify and authorize an international trade transaction, which normally takes from seven to ten days, was reduced to just 2.5 hours (Fernández Espinosa, 2017). This improvement of this kind of processes can expedite the payment processes, reducing also cash-to-cash cycles.

The blockchain also notably improve T&T processes, such as the removal of non-compliance products. One example of this is the proof of concept undertook by Walmart and IBM (study case 11) that demonstrated the ability to reduce the tracking down time of a defective product from over 30 days to merely just 2.2 seconds.

Moreover, the automatization of certain processes by smart contracts also enable an improved efficiency, reducing the cost and time of low-value added processes. In addition, the increment of secure and trustworthy information accessible for authorized SC partners allow to reengineer key processes, such as route optimization in deliveries or better on-shelf-life management.

Thereby, the enhancement of efficiency due to blockchain generates an improvement in asset management and service quality, while reduces SC costs. This effect is of great interest because of it provides a source of effective SCM.

## **6.7 Auditability**

One of the main characteristics observed in the study cases analyzed is the blockchain ability to facilitate auditability and accountability in SC processes. By design, blockchains are inherently resistant to modification of any stored data, implying that every transaction in the blockchain is inherently immutable and irrevocable recorded. Thereby, every transaction is perfectly traceable within the ledger with reliability (Psaila, 2017).

This feature is of great interest for certification, where current certification audit processes are highly problematic. Traditional systems are expensive, highly inefficient and technically challenging due to paper-based databases and information systems working as a siloes. Moreover, these inefficient systems are associated with data errors, misunderstanding and potential compromised information. With the use of a blockchain network, each transaction or operation is immutably recorded in the ledger, and can be easily visible for all the authorized parties of the network. This audit trail established by a blockchain allows improving current audit process and driving cost and time efficiencies, as



well as to quickly identify sources of non-compliance with the standards or certification schemes.

On the other hand, the improvement in auditability generated by the blockchain is also significant for every process that need to be verified or inspected, such as in trade finance, logistics, etc.

## **6.8 Product safety**

In the study cases related with products that have to meet with safety standards, the blockchain technology appears as a mechanism to improve product safety along the SC. The transparency-by-design of the blockchain enables to obtain information associated with the product at each stage in the SC, from the origin to the retailer. This information become especially useful in food and pharma industries, where customers are increasingly searching integrity in the products they buy, and a defective item can generate a disease outbreak.

Nowadays, when there is a product recall, the companies have to track down the source of contamination and restore customers' confidence in product safety, process that usually takes weeks. With the blockchain, the track down process can be carried out in just a few seconds, helping to identify faster the sources and causes of contamination and improve the recall process, and ultimately increasing product safety. In addition, the transparency and auditability of blockchain ledgers allow proving the compliance of the product with the regulations.

## **6.9 Sustainability**

The enhanced level of SC transparency provided by the introduction of blockchain technology in the SCs not only increases SC efficiency, but also helps to ensure SC sustainability. The study cases conducted by Provenance (study cases 5,6,7 and 8) serve as an evidence of the suitability of blockchain solutions to clarify and bring more visibility to sustainability claims in SC.

The blockchain is a distributed digital ledger of transactions, where information gathered along the journey of a product through the SC can be securely and immutably recorded. The blockchain serves as a verified database by which social, ethical and environmental issues associated with a product can be tracked down. Thereby, it offers an opportunity to facilitate the flow of information and enabling prove fair trade, sustainable manufacturing practices or environment-friendly processes, among others.

If this information is accessible to the end-customers, it will help to ensure them the sustainability of their purchase. Moreover, this increment of the customers' end-to-end visibility of the SC enables choice differentiation and conscientious consumption, increasing customer value that ultimately enhance competitive advantage.

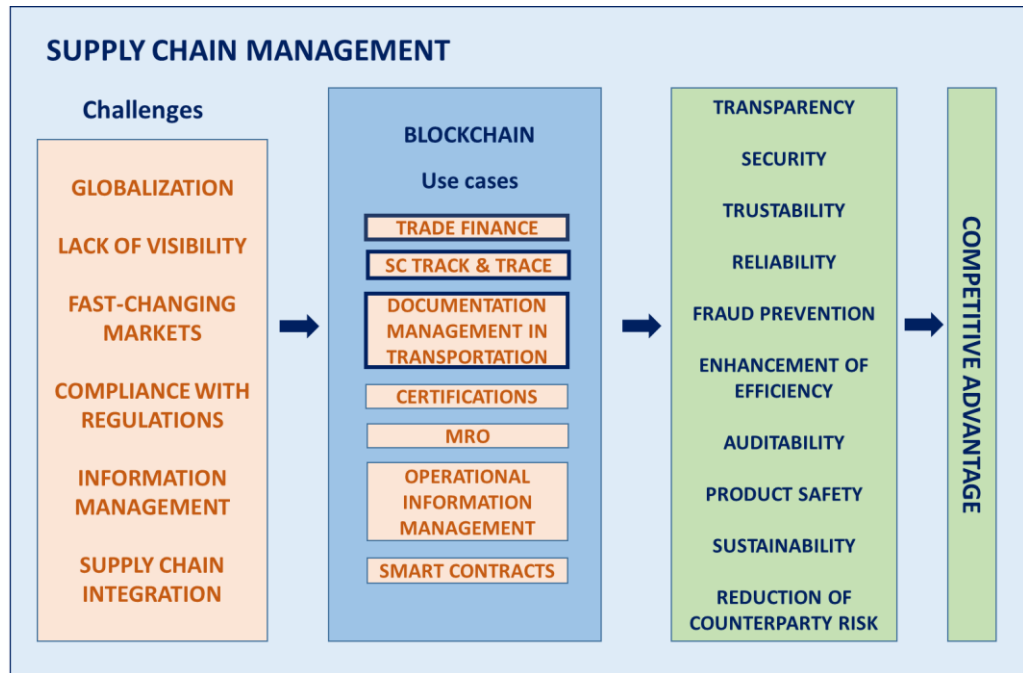
### **6.10 Reduction of counterparty risk**

The counterparty risk is one of the main risk faced by trade partners in SCs. It consists on the risk of not receive the payment after making a delivery to a buyer, meaning a lack of payment security. The blockchain has the potential to reduce this risk by simplifying and making more transparent current trade finance processes. An example is the study case 3 where Agridigital and CBH group explored ways to eliminate the counterparty risk by the implementation of smart contracts in the blockchain. The smart contract consists on match the ownership title with the payment. In a business transaction, the seller has the ownership of the digital asset, representing the physical one, until the payment is received. Thereby, the asset and the payment are securitized and the counterparty risk is reduced.

### **6.11 Compliance with the proposed framework**

In regards with the principal effects observed in the study cases analyzed, they demonstrate the ability of blockchain to overcome the main currently challenges in SCM. The increased end-to-end visibility, security and trustability among SC members enable a better SC integration. These intrinsic features of blockchain technology help to improve the efficiency of current SC processes by streamline them and reducing costs, as well as enhancing product safety and fraud prevention. Moreover, they allow increasing customer value via both better executing existing processes and generating new sources of customer value. All these effects would ultimately give a competitive advantage throughout the SC.

In accordance with the results obtained, the framework proposed must to be updated in order to include all the identified benefits derived of the introduction of blockchain into SCM processes (see Figure 26).



*Figure 26: Blockchain in SCs framework updated with the benefits derived of blockchain introduction into SCs*

## 7. BLOCKCHAIN APPLICATION CHALLENGES IN SUPPLY CHAINS

In this section, the main challenges faced by companies when implement blockchain technology within their SCs are outlined. In addition, the industry leaders' opinion about the introduction of this technology into their businesses is also set out in order to gain more insight into the main challenges and concerns.

### 7.1 Scalability

The scalability is not a specific concern of the blockchain usage in SC, but also signifies a common challenge for the entire blockchain ecosystem. The term scalability means the capability of a system to cope and perform under an increased or expanding workload, referring to scalability as the capacity both in terms of users and transactions. A system that scales well will be able to maintain or even increase its level of performance or efficiency when tested by larger operational demands (Investopedia, 2018). Thereby, the importance of scalability for the blockchain technology lies on the difference between wider adoption of blockchains or limited private use (Bashir, 2017).

In the study cases of blockchain use in SCs analyzed, the scalability has been proven to be a challenge in real implementation. Most of them are still in phase of PoC or small-scale pilots, without addressing large-scale implementations. In order to reach a widely implementation, the blockchain needs to be both technological and social scalable. Technological scalability is related with the number of nodes, amount of data and number of transactions, whereas the social scalability refers to the number and types of users (Ge, et al., 2017).

The scalability issue has been a focus of intense debate and media attention for the last years, promoting the proposal of many solutions to address the scalability problem of blockchain (Bashir, 2017). In regards to social scalability, in the study case 4, the report released by the Wageningen Economic Research and TNO highlighted the importance of blockchain adoption for all SC partners in order to solve social scalability issue, as well as the development of policy recommendations (Ge, et al., 2017).

On the other hand, the technical scalability is more challengeable than in other technology systems due to the blockchain requirement to achieve a target throughput and latency in the presence of increasing workload, without undermining the decentralization (Gencer, 2017). Some solutions approaches are related to the use of other consensus models and algorithms alternative to the proof of work, due to it does not scale well in terms of the

number of transactions. Some models proposed, such as proof of stake or Practical Byzantine Fault Tolerance, have lower latency, require less computational power and waste fewer resources, which enable better scalability. Some of the other issues to deal with include increasing the block size, addressing blockchain bloat, countering vulnerability to 51% mining attacks, and implementing hard forks to the code (Swan, 2015).

## 7.2 Privacy concerns

Despite the blockchain technology enables a tamper-proof and immutable ledger of records, each transaction is visible for all the blockchain nodes (Cagnazzo, 2017). This feature generates many issues of privacy in digital transactions and data-exchange through SC partners.

In public blockchain networks, any transaction is openness and transparent by default so anyone can trace the path of a transaction including the value it holds, and its origin and destination address (Mougayar, 2016). This level of transactions visibility is not viable for blockchain implementations that require a high level of data privacy and confidentiality, such as in finance or health industries (Bashir, 2017). In order to preserve data privacy, the cryptographic technologies grant the verification of transactions without revealing the owners identity, protecting them against information leakage (Mougayar, 2016). Thereby, although the transactions are visible in the blockchain, the off-chain identities are unlinked with the virtual addresses, offering a pseudo-anonymity property (Mercer, 2016). Despite this cryptographic assurance of privacy, the cryptographic keys become associated with individuals' off-chain identities could be stolen or exposed, supposing a privacy issue that need to be addressed.

On the other hand, the compliance of blockchain technology with strong privacy laws is another significant issue to deal with in order to reach a large-scale implementation. The new EU General Data Protection Regulation (GDPR), which will come into effect the 25<sup>th</sup> May 2018, is fundamentally incompatible with blockchain technology. Under the new privacy rule, if an EU citizen requests that their personal data be erased from a company's records, the company will have to obey (Liao, 2018). However, with the blockchain the enforcement of this law is incompatible by its principle of data protection by design (Meyer, 2018). The blockchain is an immutable shared ledger of records distributed across all the nodes, where a transaction in a block is unchangeable, ensuring the reliability of the information stored in the blockchain (Liao, 2018). Technically, it is possible to rewrite the data recorded on a blockchain, but only if most nodes on the network agree to create a new version of the blockchain that includes the changes. This is relatively easy on a private blockchain, but almost impossible on a public blockchain (Meyer, 2018). Thus, most of the current blockchains are incompatible with GDPR, supposing a limitation of applicability and a challenge to overcome in the following years.

### 7.3 Interoperability

The blockchain technology appears as a solution for data and systems interoperability in current SCs. The interoperability is the ability of information systems to work together within and across organizational boundaries, by enabling different information technology systems, and software applications to communicate, exchange data, and use the information that has been exchanged (Grey, 2017). Many already existing SCM systems are still on internal hardware or in private cloud environments of the companies, building data silos that discourage interoperability. The lack of interoperability together with complex processes, lack of transparency, auditability, and control generate difficulties to cover a product's full SC, and are often unable to capture the first mile from the original source (Provenance, 2016).

This technical challenge can be overcome with the introduction of blockchain due to it promises to be a common databases for all the SC partners, where all the participants can access, read and record information without any central monopoly (Ge, et al., 2017) (Provenance, 2016). Thus, the data is interoperable throughout the SC. On the other hand, the interoperability of blockchain with legacy systems of the SC must to be addressed. The availability of standards that enable unconnected systems to communicate using the same language, structures and identifiers are key to eliminate interoperability hurdles SCs (Bashir, 2017).

Finally, in a growing blockchain ecosystem, the interoperability among blockchain systems must to be considered. The existing limitation around interoperability of blockchains results in the development of multiple protocols that can work between different blockchains, as well as the emergence of a number of initiatives by standards organizations to develop standards for blockchain interoperability (Bashir, 2017; Ge, et al., 2017).

### 7.4 Adoption

The blockchain technology is still a relative immature technology, far from mainstream adoption in supply chains. Despite the increasing investment in small-scale pilots in real businesses to prove the feasibility of blockchain for SC processes, there is a gap between technology and investments (Luu, 2018). The early majority adoption only will be real when business drivers are strong, when technology enablers are ready, and when solutions to challenges are found (Mougayar, 2016).

Below are detailed the main threats for blockchain technology adoption in current SCs.

#### 7.4.1 Technical challenges

Before blockchain becomes widespread in SCs, there are several technical challenges that must to be overcome (Alicke, 2018). The underdeveloped ecosystem infrastructure, the

lack of mature applications, the scarcity in developers and immature middleware and tools show that the blockchain technology is still far from being well understood by both technology developers and other parties in the ecosystem (Mougayar, 2016; Ge, et al., 2017).

In addition, the gap between current blockchain technology capacity and SC needed capacity generates scalability issues that must to be resolved to pursue a wider adoption, as it is previously commented. On the other hand, the integration with legacy systems in SCs and the trade-offs with existing databases are also important technical challenges (Mougayar, 2016).

Finally, the lack of standards related with the implementation of blockchain technology in SCs would increase the complexities in its adoption. The standards bring with them a number of benefits, including some network effects, easier interoperability, shared implementation knowledge, potential lower costs, and less overall risk (Mougayar, 2016). Nowadays, multiple industry associations appeared with the aim of collectively create a foundation for the future use of blockchain in its industry and develop standards. Some of the most relevant are Blockchain in Transport Alliance (BiTA) and Blockchain for Aviation (BC4A).

#### **7.4.2 Business challenges**

The implementation of blockchains in SCs requires a joint effort of different parties that by default have no trustful relationships among each other. The lack of trust throughout the SCs can prevent them to achieve better SC integration, which ultimately leads a more competitive SC (Ge, et al., 2017). In addition, the low adoption of this technology by industry leaders is slowing down the mainstream adoption due to the industry leaders can generate a network effect and boosting the blockchain technology adoption.

Furthermore, the cost relative to the deployment of blockchain in SCs is one of the main concerns that slow down its introduction. Yet, it is too early to estimate the costs of operating blockchain technology in the SC world, and compare them with other technologies (Alicke, 2018).

#### **7.4.3 Legal and regulatory challenges**

Despite the rapid evolution of the technical and business aspects of blockchain in SC, many legal issues still need to be resolved. As the position of regulatory agents is still no clear, confusion and uncertainty will continue to exist for everyone involved in the blockchain space (Mougayar, 2016).

On one hand, the blockchain deployments in current SCs must to be compliant with general European Union laws, such as General Data Protection Regulation (GDPR), Electronic Identification, Authentication and trust Services (eIDAS) and Payment Services

Directive 2 (PSD2) (Fitzgerald, 2018). However, sometimes the features by design of the blockchain technology are not compatible with the legislation, supposing a great regulatory challenge. For instance, as previously commented in 7.2 section, the blockchain enforcement of the EU's GDPR is incompatible by its principle of transparency by design (Meyer, 2018).

On the other hand, depending on the domain and application area of blockchain implementations in SC, there are many industry-specific legislations required that will need careful consideration (Fitzgerald, 2018).

#### **7.4.4 Behavioral challenges**

The lack of understanding about the basic capabilities of blockchain, as well as the scarcity of blockchain implementation best practices can affect the understanding of its potential value. Thus, trusting on the proper operation of a blockchain network is still a challenge, generating a limited executive vision on this technology (Mougayar, 2016).

On the other hand, the blockchain implementation in SCs entails a business process reengineering, which usually involves gaining new organization competencies and an efficient change management in order to mitigate the resistance to change (Mougayar, 2016).

### **7.5 Industry leaders' concerns**

The adoption of blockchain technology in industry leaders' SCs has the potential to speed up the diffusion process of this disruptive technology. Moreover, by early adopting this technology now, before they become mainstream, companies can gain a significant advantage over their slow-to-react rivals (Curtis, 2018). The lack of understanding about the potential value of the blockchain technology or the issues related to an immature technology are preventing the industry leaders to launch large-scale pilots with this technology in their SCs, constraining wider dissemination.

In order to gain more insight into the main challenges and concerns of industry leaders about the implementation of this technology into their businesses, several questionnaires have been undertaken by multiple organizations. During April 2017, Chain Business Insights conducted a survey to give a response on this issue, being this the first in an ongoing series of industry surveys on blockchain's development and usage in the SC domain (DeCovny, 2017).

The questionnaire was focused on SC professionals of companies with international SCs, including SC practitioners, shipping agents, technology providers and consultants among others. As a result, the survey reflects a relatively high level of awareness of companies about the blockchain, with more than one-third of respondents who are already implementing this technology. The main use cases envisioned by SC professionals are related



with tracking products moving through the SC, sharing information with suppliers and tracking payment information such as purchase orders, all of them focus on improve SC transparency and traceability (DeCovny, 2017).

On the other hand, transparency, transaction cost reduction, trustability between SC partners, security and increased SC velocity are the principal benefits mentioned by the respondents. Despite all the potential benefits as a result of the blockchain implementation in SCs, there are still several hurdles to it adoption. The main obstacles cited by surveyed companies were budget, lack of standards and interoperability, lack of understanding/awareness, do not see the value, lack of industry support and regulatory issues (DeCovny, 2017).

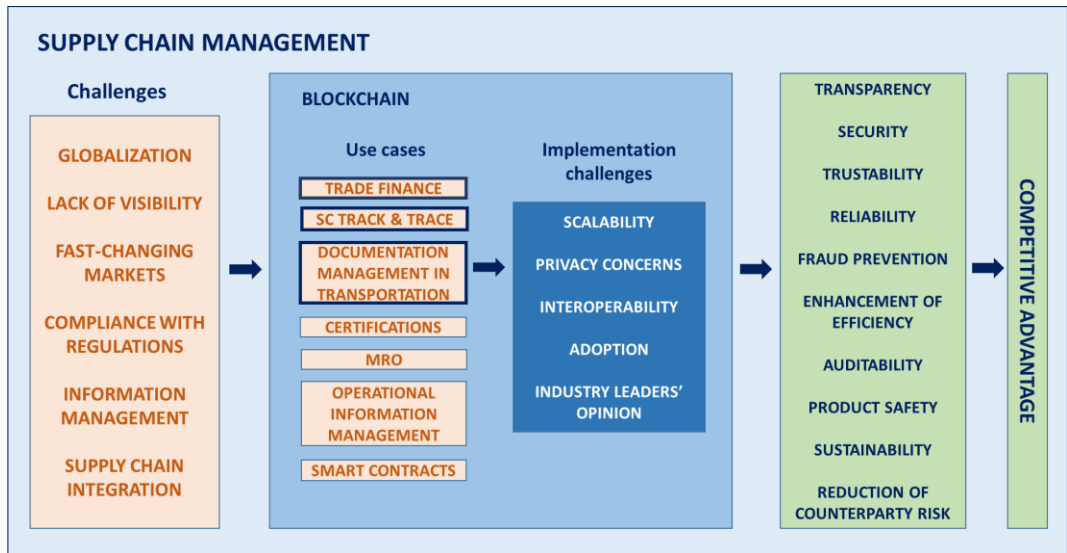
Finally, the companies were asked about the blockchain connectivity and complementary technologies. As it is expected, the most likely technologies to impact their business together with blockchain are Big Data, advanced analytics, IoT and cloud computing. The results of this survey highlight the strategic importance of blockchain technology in SCs, as well as the adoption status of this technology in SCs is still in an initial phase (DeCovny, 2017).

## **7.6 Compliance with the proposed framework**

Despite the proven benefits of the application of blockchain technology to SCs, there are still many challenges to overcome. The innovative feature of the blockchain technology makes more difficult its adoption. As this technology is still under development, there are several technical issues, such as scalability, that must to be addressed in order to be able to spread it diffusion within SCs. In addition, the lack of standardization works against the widely adoption. The lack of best practices to follow by companies in order to implement blockchain technology within their SCs, make them more reluctant to deploy it. This only will be solved with the introduction of blockchain in the SCs of industry leaders, who have the ability to promote the innovation and generate network effects in its adoption.

Although the rapid evolution of the technical and business aspects of blockchain in SCs, many legal issues still need to be resolved. The blockchain application in SCs must to be aligned with current laws and regulation. However, sometimes the features by design of the blockchain technology are no compatible with the legislation, supposing a great regulatory challenge.

In the light of these facts, there is lots of work to be done in order to enable a long-scale application of blockchain technology into current SCs. For this reason, the challenges in the implementation of blockchain in SCs discovered in the study cases analysis must to be added in the proposed framework (see Figure 27).



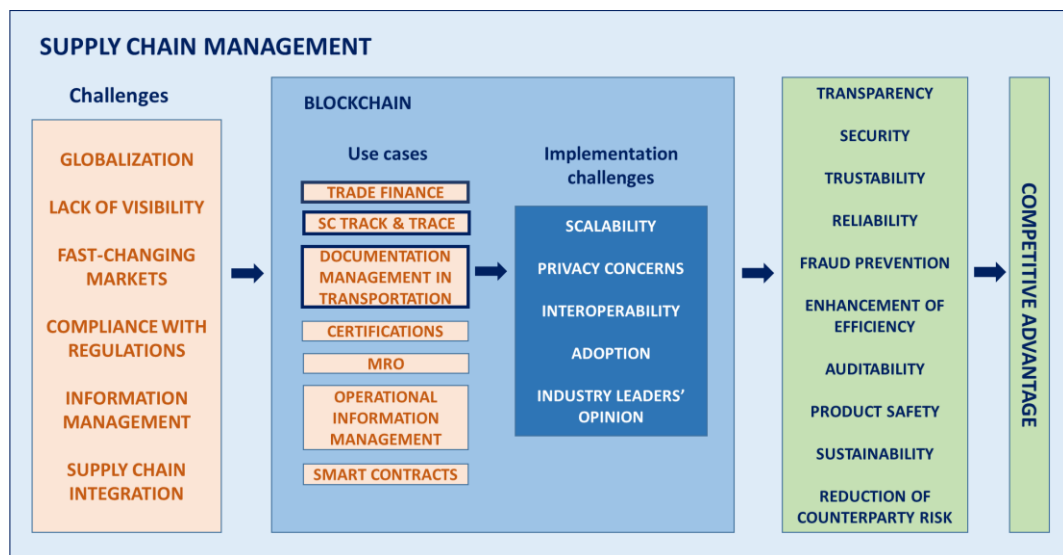
*Figure 27: Blockchain in SCs framework updated with the implementation challenges*

## 8. CONCLUSIONS

In this chapter, the results of this study are summarized. Initially, the main contributions of this thesis to practice and theory of blockchains in SCM are examined. Subsequently, it is analyzed how well the objectives of this study were met. Finally, an evaluation of the research process is undertaken to disclose the limitations of this study, as well as to evaluate the reliability and validity of the results.

### 8.1 Contributions to practice and theory

The main contribution of the thesis to practice and theory of blockchains in SCM is the framework proposed along the study, which is shown in the Figure 28. This theoretical framework provide a general vision of the state of blockchain in SCs, focusing only in the key aspects of (1) why use blockchains, (2) how to use them, (3) what challenges can be expected and (4) what benefits make it implementation worthwhile.



*Figure 28: Blockchain in supply chains framework*

On the other hand, it has been noticed that the study cases analyzed can commonly fit into several use cases proposed in the framework. The flexibility of blockchain design to adapt to specific business processes makes that the studied blockchain applications were supply chain-specific. The blockchain can be shaped in multiple ways to perfectly fit with different processes, network node architectures and participants in a SC. Thereby, it is difficult to generalize about blockchain archetypes for SCs.

## 8.2 Meeting with the research objectives

The objective of this thesis was to bring light on the different potential applications of blockchain technology in supply chain management. In order to achieve it, a theoretical framework was developed progressively in this thesis, incorporating relevant concepts related to the main research questions exposed at the beginning of the work. By this way, the initial framework presented at the end of the theoretical background, which is the initial hypothesis of the thesis, was validated and updated with the findings and results obtained throughout the research until reach the final version.

The first research question was “Why should blockchains be implemented in supply chains?”, which was answered along the theoretical background. The literature review of supply chain management gave me insights of the main challenges that companies face nowadays when try to obtain an effective supply chain management. On the other hand, the literature review of blockchain technology provided me knowledge on the main features of this disruptive technology. By merging the main issues in SCM with the blockchain technology the conclusion reached is the answer to this research question, the reasons why this technology is perfect to overcome current SCM problems, such as the globalization, lack of visibility in current SCs or the SC integration, among others SC challenges. By the intrinsic features of blockchain such as security, transparency, resistant to outages or efficiency, this technology can establish more end-to-end visibility, flexibility, interfered trust, and control along the SC. Thereby, it could derive a more efficient SCM due to the better achievement of SC main goals: a reliable, efficient, trusted and resilient SC.

The second research question was “Which are the applications of blockchain technology in supply chains?”, being answered in the section 5. Through the assessment of the different study cases in relationship with the theoretical framework proposed, the feasibility of blockchain technology to support the proposed use cases was proven. In addition, it was concluded that the most promising blockchain applications are related to trade finance, transportation documentation management, and track and trace solutions.

The third research question was “ Which are the effects of blockchain technology implementation in supply chains?”, whose answer was developed in the section 7. The study cases provided information about the main benefits derived of the use of this technology in the analysed SCs, so this question were adequately answered by studying them. The blockchain technology generally increased the end-to-end visibility, security and trustability among SC members, enabling a better SC integration. Moreover, it helps to improve the efficiency of current SC processes by streamline them and reducing costs, as well as enhancing product safety and fraud prevention. On the other hand, this technology allows increasing customer value via both better executing existing processes and generating new sources of customer value. As a result, all these effects would ultimately give a competitive advantage throughout the SC.

Finally, the last research question was “Which are the challenges in the implementation the blockchain technology in supply chains?”, which was answered in the section 8. In the same way as the third research question, the study cases provisioned information about the main challenges in the implementation of this technology in SCs. As this technology is still under development, there are several technical issues, such as scalability, that must to be addressed in order to be able to spread it diffusion within SCs. In addition, the lack of standardization works against the widely adoption due to the lack of best practices to follow by companies in order to implement blockchain technology within their SCs. On the other hand, many legal issues still need to be resolved, such as the incompatibility of blockchain technology features by design with current legislations.

### **8.3 Evaluation of the research process and results**

This section evaluates the success of research strategy designed in section 2.4. Altogether, the research process was undertaken successfully. As is previously mentioned, the main objective of the thesis was achieved and the research questions under evaluation were answered satisfactorily.

Despite the interesting results achieved in this thesis, there are some limitations. The scarcity of information available due to the sensitive feature of the information for companies limited the depth and scope of the study. This issue was the main reason for selecting the research method employed. Thereby, the results obtained provided an overall vision of the status of blockchain in supply chains, not serving as a guideline for the application in a certain company.

On the other hand, the validity and reliability in the research results are ensured as far as possible. The internal validity is based on the usage of several sources of information for each study case, which is limited by the information available. The external validity is kept as the framework proposed as the result of the study can be easily applied to other companies. Finally, this study is reliable as most of the sources of information come from directly from the companies under study.

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