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Scuola di Ingegneria Industriale e dell'Informazione

Master of Science in Management Engineering

An investigation on the adoption of Blockchain Technology in Supply Chain

Supervisor: Prof. Riccardo Mangiaracina

Co-supervisor: Luca Gelsomino

Master Graduation Thesis by:

Claudio RATTI

898702

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Credo che la vita sia fatta di sfide, grandi o piccole che siano.

Per vincere queste sfide ho bisogno di motivazioni, qualcosa che mi dia una spinta.

Io queste motivazioni le trovo nelle persone, perché a loro associo dei sentimenti.

Motivazioni forti vengono da sentimenti forti.

Un “grazie”, quindi, va a tutti voi amici, familiari, compagni di calcio e di università, perché mi fate trovare le motivazioni di cui ho bisogno per vincere le sfide della vita.

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Abbreviations

AI: Artificial Intelligence

API: Application Programming Interface

AR: Augmented Reality

BT: Blockchain

BD: Big Data

BiTA: Blockchain in Transportation Alliance

BLE: Bluetooth Low Energy

CAGR: Compound Annual Growth Rate

CC: Cloud Computing

CSC: Collaborative Supply Chain

CSCMP: Council of Supply Chain Management Professional

CPS: Cyber-Physical System

CPU: Central Processing Unit

DApp: Distributed Application

DAC: Distributed Autonomous Corporation

DAO: Distributed Autonomous Organization

DAS: Distributed Autonomous Society

DLT: Distributed Ledger Technology

DNS: Domain Name Server

DSC: Digital supply chain

EDI: Electronic Data Interchange

EHR: Electronic Health Records

EPC: Electronic Product Code

ERBV: Extended Resource Based View

ERP: Enterprise Resource Planning

F&B: Food & Beverage

FVL: Finished Vehicles Logistics

HW: Hardware

ICT: Information Communication Technology

IOM: Internet of Money

IOT: Internet of Things

IT: Information Technology

IP: Internet Protocol

KPI: Key Performance Indicator

L&T: Logistics & Transportation

LSH: life Sciences & Healthcare

LSP: Logistics Service Provider

MRP: Material Requirement Planning

M2M: Machine-to-Machine

NCPDM: National Council of Physical Distribution Management

NFC: Near-Field Communication

OCT: Order Cycle Time

OEM: Original Equipment Manufacturer

ONS: Object Name Server

PKI: Public Key Infrastructure

PMI: Physical Mobile Interaction

PoC: Proof-of-Concept

PoW: Proof-of-Work

PoS: Proof-of-Stake

P2P: Point-2-Point

RFID: Radio Frequency identification

RQ: Research questions

RV: Relational View

SC: Supply chain

SCC: Supply Chain Collaboration

SCO: Supply Chain Orientation

SCM: Supply chain management

SCF: Supply chain finance

S&OP: Sales & Operations

SME: Small-Medium Enterprise

SOA: Service Oriented Architecture

SW: Software

TCE: Transactions Economics Theory

TTP: Trusted Third Party

USD: United States Dollar

UTXO: Unspent Transaction output

XML: eXtensible Mark-up Language

WC: Working Capital

WSN: Wireless Sensor Network

ABSTRACT

Purpose – The research is aimed to overcome two major gaps of the existing literature: the lack of structured approaches to investigate BT and the unclear cause-effect linkages in the value creation mechanism of BT in supply chain. Consequently, the study was developed according to three key purposes: identifying the variables affecting BT suitability in SC using field-based insights and a structural approach; evaluating them in a comparison with secondary sources and clearly describing BT contribution mechanisms in the realm of SCM.

Design, methodology and approach – In consideration of the exploratory nature of the investigation and the technology novelty, a multiple case study methodology was adopted. 13 interviews were conducted to collect insights from IoT and BT providers, elaborating the research framework afterwards. Ultimately, a content analysis was performed on grey literature regarding 40 selected BT applications, in order to evaluate the framework variables using a different standpoint.

Findings – the research thesis outputs can be summarized as follows: (1) a research framework based on literature and primary sources, containing the set of variables to be addressed when evaluating BT adoption in SC; (2) a deep analysis on how such technology is supposed to add value to SCM dimensions. In particular, the first output is complementary to a detailed analysis conducted on secondary sources, which, overall, provides more consistency and precise observations on BT adoption.

Theoretical and managerial implications – On a theoretical level, this inquiry was developed in the theory-building direction to improve current knowledge of BT adoption in SC. Especially, the greatest contribution is represented by the research framework and the underlying analyses. From a managerial perspective, the research delivers its greatest value by supporting managers with tools and models in the evaluation of BT as a new investment for their companies.

Future research – Primarily, the research could be enlarged engaging with more companies. In general, future investigations are suggested to test the validity of the

research framework by applying it to real-case BT applications. Eventually, further quantitative data should be collected to address actual BT benefits.

ESTRATTO

Scopo – La ricerca vuole superare due principali lacune della moderna letteratura: la mancanza di approcci strutturati per analizzare blockchain e le vaghe correlazioni causa-effetto relative alla creazione di valore da parte di blockchain in supply chain. Conseguentemente, lo studio è articolato secondo tre scopi principali: identificare le variabili che influenzano l'applicabilità di blockchain in supply tramite osservazioni sul campo, analizzarle rispetto a fonti secondarie e descrivere chiaramente i meccanismi di contribuzione nell'ambito di Supply Chain Management.

Design, metodologia e approccio – In considerazione della natura esplorativa dell'indagine e della novità tecnologica, è stata adottata una metodologia di studio di casi multipli. Sono state condotte 13 interviste per raccogliere informazioni da parte di fornitori di Internet of Things e blockchain, elaborando in seguito il quadro di ricerca. Infine, è stata effettuata un'analisi dei contenuti della letteratura grigia relativa a 40 applicazioni blockchain selezionate, al fine di valutare le variabili di ricerca utilizzando un diverso punto di vista.

Risultati – I risultati della tesi di ricerca possono essere riassunti come segue: (1) un quadro di ricerca basato sulla letteratura e sulle fonti primarie, contenente l'insieme di variabili da affrontare nel valutare l'adozione della BT in SC; (2) un'analisi approfondita su come tale tecnologia dovrebbe aggiungere valore alle dimensioni della CSM. In particolare, il primo output è complementare ad un'analisi dettagliata condotta su fonti secondarie, che, nel complesso, fornisce una maggiore coerenza e osservazioni precise sull'adozione della BT.

Implicazioni teoriche e manageriali – A livello teorico, questa indagine è stata sviluppata nella direzione dello sviluppo di nuove teorie per aumentare le attuali conoscenze dell'adozione di BT in SC. In particolare, il contributo maggiore è rappresentato dal quadro di ricerca e dalle relative analisi. Da un punto di vista manageriale, la ricerca offre il massimo valore supportando i manager con strumenti e modelli nella valutazione della blockchain come nuovo investimento per le loro aziende.

Limiti e ricerche future – In primo luogo, la ricerca potrebbe essere ampliata coinvolgendo più aziende. In generale, si suggeriscono indagini future per verificare la validità del quadro di ricerca applicandolo ad applicazioni BT reali. Alla fine, dovrebbero essere raccolti ulteriori dati quantitativi per valutare gli effettivi vantaggi della BT.

EXECUTIVE SUMMARY

This study serves as an investigation on Blockchain Technology (BT) potential within the realm of Supply Chain (SC), with a specific reference to Supply Chain Management (SCM). The development of such assessment has been rooted on a multiple case studies methodology. The leading paragraphs showcase the key research contents.

Introduction

Ever since the first evolutionary steps in the primitive supply chains, information and innovation have always claimed a driving role in the rush for competitive advantage (Vyas et al. 2019). Information exchanges represent the basis for coordination and effectiveness inside and outside the organizational boundaries. On the other turn, technological innovation is a must-have voice in the investment portfolio of a successful company. As the outlook of global supply chain has been recently influenced by ever greater diversification, globalization and harsh competition, business success seems to become a serious feat for companies. In light of these advancements, practitioners still look at information and innovation to keep it up.

In this complex context, Blockchain has lately deserved a lot of attention as mean to solve some of the traditional supply chain issues. After its first appearance as underlying technology of Bitcoin in 2008, Blockchain turned out to have a significant potential when applied to supply chain. As the technology has raised both scepticism and hype, there is a bit of confusion when assessing the meaningfulness of its applications. Consequently, companies still struggle to understand how to make blockchain adoption valuable and financially sustainable.

Literature review

An extensive set of documents has been adopted to frame the key concepts linked to this thesis and to provide it with a consistent theoretical support.

The innovative traits of the technologies set at the basis of this project, Blockchain and IoT, required to also discuss a few technicalities. Despite not being the core of the project, having a rough idea of the dynamics governing their processes has been considered helpful. Made this premise and aiming to offer a broad logical framework, the consulted documents have been clustered in 4 groups:

Supply Chain Management and Digital Supply Chain: for a clear understanding of the implications stemming from BT adoption in SC, it is necessary to clarify these two concepts. While the concept of SC has been widely analysed by previous scholars and practitioners, that of DSC is recent. The progress in digital technologies has occurred rapidly, considerably affecting companies' business models and supply chains' dynamics.

Blockchain technology: since its debut in 2008, scholars have always referred to it as a game-changing technology. Starting from the financial realm, blockchain unveiled its cross-sectoral applicability, moving to many other industries. This part of literature review assesses the history, the functioning and the implications of its adoption.

IoT technology: despite the generality of the concept, it can be addressed as a trend of "smartification of everything". This leads to a future where any physical device will have its digital equivalent, embedding all of them in a real-time connected whole ecosystem. Plus, the combination of BT and IoT is presented by literature as a value-adding solution deserving more investigation.

Methodology: a multiple case studies approach was adopted to collect data. One major source, (Yin, 2003), was consulted to properly stick to the common rules of this methodology. Together with that, other sources have been observed.

Objectives

All the insights stemming from the literature prompt in unison that applying BT to the realm of SC can be advantageous, especially in terms of traceability and visibility. Nevertheless, there is a certain air of mystery on which variables should be evaluated to take a stand on BT. As previously denounced, a remarkable confusion and scepticism linger on blockchain because of the buzzword it recently became. Its rapid cross-sector diffusion occurred before neither practitioners nor academics had a clear picture of how BT should be properly deployed. In detail, two major defaults were identified in modern literature: the lack of structured approaches to investigate BT and the unclear cause-effect linkages in the value creation mechanism of blockchain in supply chain. These considerations convinced the author to structure the inquiry along the following Research Questions (RQ):

RQ.1: WHAT ARE THE VARIABLES THAT SHOULD BE CONSIDERED IN THE ADOPTION OF BT?

Despite the conspicuous number of related papers, up-to-date literature still misses a model able to identify the variables that need to be addressed to evaluate blockchain in inter and intra organization applications. There is no clarity, in fact, on how to approach such technology for industrial purposes. The first goal of this study, then, is to spot and categorize these dimensions in a framework, working on different level of granularity. This will be done by integrating insights from the field, through interviews, with the most valuable evidences from the literature. In particular, interviews will address IoT and BT providers, targeted for their familiarity with the technologies and their accessibility. Once completed, the research framework will be used to analyse how the variables concur among each other and towards the decision of adopting blockchain.

RQ.2: HOW DOES THE RESULTING ADOPTION FRAMEWORK COMPARE TO GREY PRESS PRESENTING EXISTING BT CASES?

The definition of research variables in the framework represents a valid starting point to evaluate BT. Nonetheless, framework results could be biased by the limited viewpoint of BT and IoT providers. Thus, in order to make the research more objective and reach more comprehensive results, firstly a content analysis will be performed on grey literature (made of secondary sources like Web journals and companies' websites) regarding forty selected BT applications. Successively, the outputs of the content analysis will be compared to those of the interviews, contained in the framework. With this parallel, the author will articulate a more exhaustive analysis, making considerations on the observed similarities and divergencies.

<u>RQ.3</u>: HOW DOES THE VALUE CREATION MECHANISM WORK FOR THE ADOPTION OF BT IN SC?

To make the investigation on BT complete, the third objective refers to the identification and discussion of the advantages stemmed from BT and IoT employment. The goal is to examine as much as possible how it creates value, inspecting the SCM dimensions and single companies' operations involved in these processes. To do this, data triangulation will be used by integrating literature sources with the grey literature of forty practical BT applications. The result will be a description of how value is created at SC and organization levels when introducing BT.

Overall, the objective of evaluating BT adoption in SC was framed in a structured research model, reported in Figure 1, which provides readers with a general overview on the research dynamics.

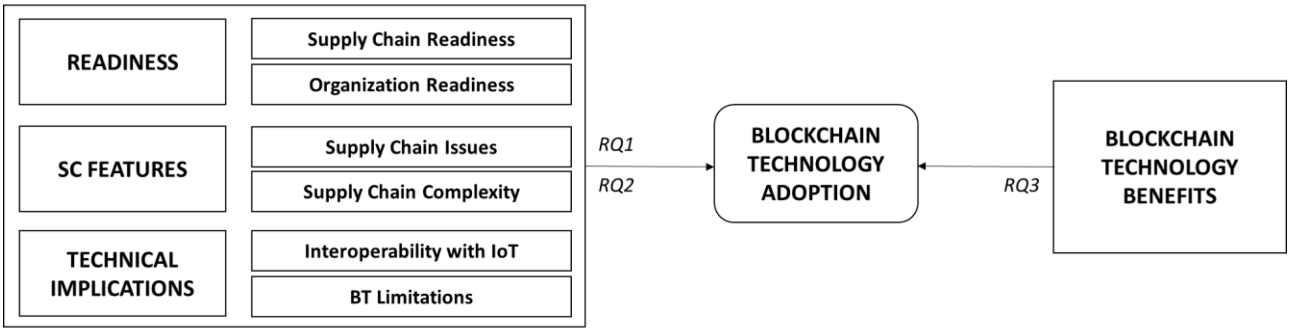


Figure 1: research model (author's elaboration)

The dependent variable, namely the "Blockchain adoption", stands at the hearth of the model, being the central part of this investigation. Beside this, an accurate literature analysis was performed to spot the most relevant variables that could address the research questions. All these variables were then organised into four major research blocks, or micro-variables: Readiness, Supply Chain Features, Technical limitations and BT benefits. Each block can be defined as a conglomerate of several variables, characterized by a different granularity. The research model consists in an outline where these blocks are arranged so that readers can immediately grasp at sight the project rationale. It showcases that BT adoption is a function of four building blocks. In detail, three of them (Readiness, SC Features and Technical Limitation) compose a bigger block which directly influences BT adoption. On the right of the model, the remaining block (BT benefits), alone, also has a direct influence on the dependent variable. The model displays that BT adoption will be firstly assessed through RQ1 and RQ2, investigating the relation with the three building blocks on the left, and then discussed with reference to the befits of BT. Eventually, a comprehensive overview will be provided in the chapter “Conclusions”.

Methodology

Three major methodologies were adopted: a multiple case-study analysis, a content analysis and a comparative analysis.

Since the innovative nature of BT triggers many “how” and ”why” questions, the exploratory investigation was performed with a multiple case study approach, conducting semi-structured interviews with a sample of selected companies. Referring to Yin et al. (2003) and Voss et al. (2002), inputs from single case studies were integrated with each other, addressing single interviews as stand-alone experiments. The sample was composed by 13 BT or/and IoT providers, representing heterogeneous organizations in terms of provenance and size, serving at least one of the research target industries: Food & Beverage (F&B), Logistics & Transportation (L&T). The output of this first methodology based on multiple case studies assessment is a framework containing various levels of variables linked to the suitability of BT adoption.

In order to better evaluate the framework content, a second methodology adopted was the content analysis, consisting in the evaluation of grey literature regarding forty selected applications of BT. Its objective was to assess the levels of evidence of the framework variables in the selected secondary sources. A three-point Likert scale was adopted as categorical indexing, attributing weights to the framework variables depending on their level of evidence in the examined forty applications. Eventually, the content analysis allowed to distinguish between "Evident" and "Not Evident" framework dimensions, considering the perspective of secondary sources.

Finally, a comparative analysis was conducted between the results of the content analysis and the multiple case analysis. In this case, the goal was to compare the levels of evidence attributed to the research variables in the two cases. This enabled the author to grasp further observations on the adoption of BT in SC and to offer insights on how to approach BT.

Eventually, the conclusive part of the research, aimed at investigating BT benefits in SC, relied on data triangulation. Input data was found in a book (Vyas et al. 2019), in seven major sources from the up-to-date literature (later specified) and in the forty BT applications selected for the content analysis.

Findings

In a nutshell, key research findings can be related to three aspects. These are represented in Figure 2 as research parts, in relation to the corresponding RQ and outputs.

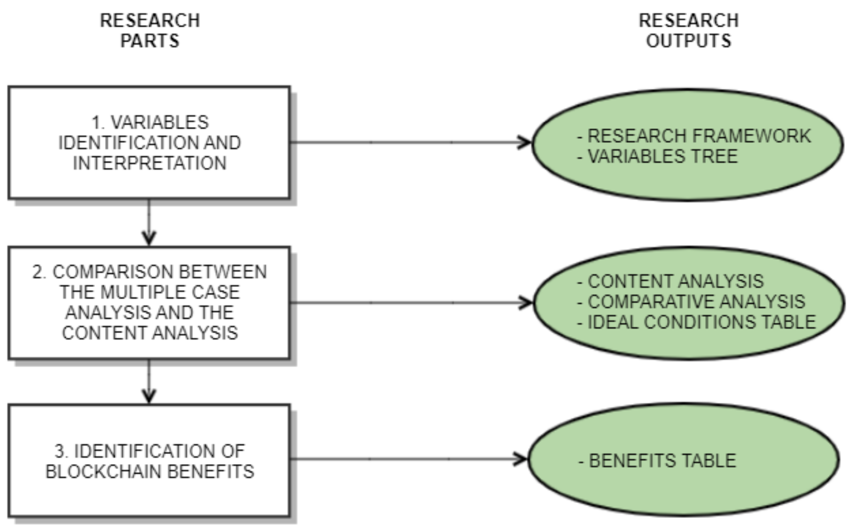


Figure 2: research parts and corresponding outputs (author's elaboration)

1. **<u>Variables identification and interpretation</u>**

A conceptual framework has been created as an attempt to answer to RQ1.

In order to spot variables impacting the suitability of BT adoption in SC, research efforts were organized along two main directions. This search was rooted from one side on the analysis of multiple case studies, used to identify sub-factors, and from the other side, on an extensive usage of up-to-date literature, used to elaborate macro and micro-variables. Parameters, finally, were obtained by merging these two sources. The output was the research framework elaboration, which displays four degrees of variables. Going from the lowest to the highest granularity levels, the framework is structured in macro-variables, micro-variables, parameters and sub-factors.

MACROVARIABLES	MICROVARIABLES	PARAMETERS	SUB-FACTORS
READINESS	SUPPLY CHAIN READINESS	Supply Chain engagement	Willingness to cooperate
			Consortium support
		Complementary IT systems at partners' organization	Interoperability of IT systems at partners' organization
		Innovation stagnancy	Innovation stagnancy
	ORGANIZATION READINESS	Technology	Current IT architecture
		People	Expertise and knowledge on blockchain
		Organization	Current Business Process Architecture
			Organizations' objectives
			Ability to invest
SUPPLY CHAIN FEATURES	SUPPLY CHAIN ISSUES	Data visibility/traceability	Cost-effectiveness of SC information exchange
			Effectiveness of existing communication technologies
			End-to-end visibility along SC operations
			Disputes and frauds creation and management
			Diversity of IT systems
		Process efficiency	Administrative costs
			Inter-company processes accountability and integration

			Visibility on bottlenecks
			Interoperability of corporates' ERPs
			Data integration at SC level
		Demand management	Increased demand for quality, customized and sustainable products
			Level of responsiveness
			Planning and scheduling effectiveness
			Operations transparency
		Tracking, transparency and trust	Effectiveness of assets traceability (losses, thefts and tampering)
			Trust among organizations and customers
			Cost-effectiveness of validation process
	SUPPLY CHAIN COMPLEXITY	Heterogeneity of organizations	Heterogeneity of organizations
		Structure	Structure
TECHNICAL IMPLICATIONS	IOT INTEROPERABILITY	Sensors' features	Dimensions measured
			Sensor typology
			Application level
		Sensors' purposes	Tracking and trace
			Predictive or preventive maintenance
			In-process visibility
			Real-time performance measurement and control
			Avoiding not value-adding activities
		IoT requirements	Data security and validation
			Maintenance cost
			Need for real-time monitoring
			Availability of applications
			Power consumption
			Interoperability with other IoT and Cloud software
	BT LIMITATIONS	Lack of support/trust	Block box
			Platform security
			Zero-status issue
		Implementation issues	Energy consumption
			Technology readiness
			Lack of standards
			Latency
		Strategic issues	No clear ROI
			Added value creation

Table 1: research framework (author's elaboration)

A presentation of the framework variables is reported in the chapter "Results and discussions".

Variables interpretation

The research framework represents the starting point for this second phase. The interpretation of the variables clarifies how they concur among each other and towards the decision of adopting BT. For sake of clarity, a conceptual model (Figure 3) based on mathematical functions is proposed to explain the framework logic.

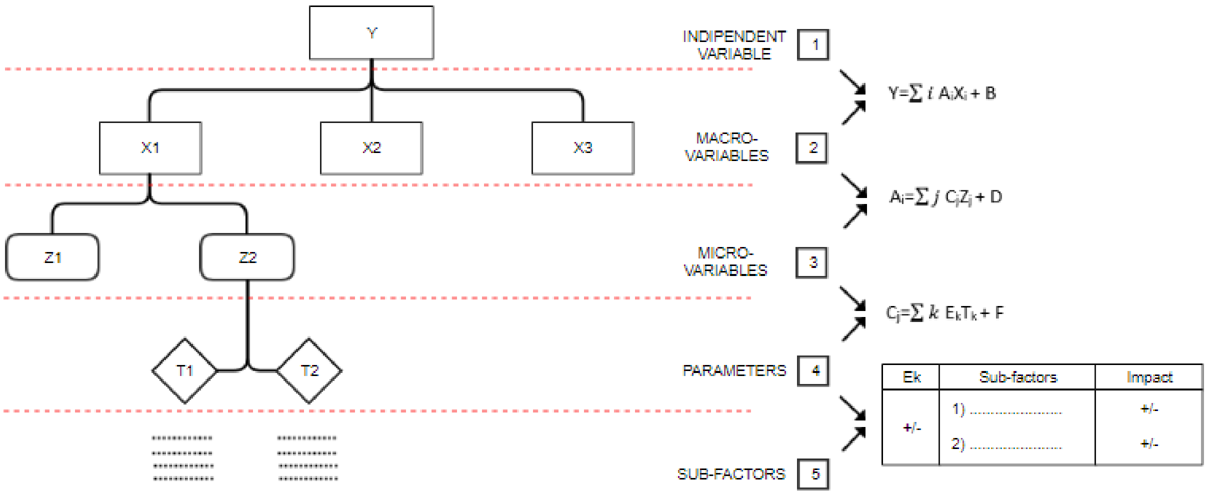


Figure 3: relationships among research variables (author's elaboration)

The relationship existing between the three framework macro-variables and the dependent variable (Blockchain adoption) is a direct proportion, meaning that their positive impact (A_i>0) promotes Blockchain adoption (Y would increase). The mathematical function $Y=\sum i\ A_iX_i + B$ perfectly sums up the nature of this relationship.

On the other turn, a similar link occurs between each macro-variable and its micro-variables, and between each micro-variable and its parameters. Lastly, every single parameter will pay an impact on the micro-variable associated depending on the value of the whole set of sub-factors that parameter is function of.

Apart from the mathematical relationships among variables, which do not fall into the research scope, Figure 3 aims to explain that the convenience of the technology adoption relates to the contribution of any single sub-factors in the framework.

Made this premise, here an application of the research framework is proposed. Should a company evaluate BT as a future investment, the framework would allow the decision maker to use it as a checklist, by climbing it back from the bottom to the top. The tool drafted in the Appendix 6 below is the “variables tree”, which is set to help the user moving along the framework. In this way, organizations can evaluate whether the current status of all the sub-factors promotes or inhibits the technology adoption. By going back up the framework through the different layers of variables and considering the relationships between this layers, one can finally decide whether the as-is situation suits to blockchain introduction.

2. Comparison between the multiple case analysis and the content analysis

The author decided to examine BT adoption with a diverse perspective by conducting a content analysis. Forty BT applications were selected, and the related grey literature was consulted to gather information on them. Afterwards, by comparing the outputs of the content analysis, based on secondary sources, with those of interviews, primary sources, the author intended to critically observe divergencies and similarities to make broader considerations on BT implementation in SC.

Content analysis

The content analysis consisted in the evaluation of grey literature regarding 40 selected forty BT applications. Its goal was to evaluate the research framework variables from a different standpoint.

Secondary sources were analysed to attribute a level of evidence (weight) to each sub-factor in the examined applications depending on their relevance in the specific case, ending up with forty values (one per each BT application) per each sub-factor. Finally, an average value was computed out of these forty to associate a single weight to each sub-factor.

To this purposes, a Likert scale was used as categorical indexing to distinguish between “Evident” (weight=0), “somewhat Evident” (weight=1) and “evident” (weight=2) sub-factors in each specific application, and between “Evident” (average weight>=1) and “Not Evident” (average weight<1) sub-factors at the end of analysis, using the average weights.

Table 2 showcases all these dimensions’ weights, where a red colour is used to highlight the weights associated to the evident dimensions, with white cells identifying the not evident ones.

Willingness to cooperate	1,60	SUPPLY CHAIN ENGAGEMENT	0,95	SUPPLY CHAIN READINESS	0,53
Consortium support	0,30				
Interoperability of IT systems at partners' organization	0,30	COMPLEMENTARITY IT SYSTEMS AT PARTNERS' ORGANIZATIONS	0,30		
Innovation stagnancy	0,33	INNOVATION STAGNANCY	0,33		
Current IT architecture	0,25	TECHNOLOGY	0,25	ORGANIZATION READINESS	0,30
Level of knowledge and expertise on BC technology	0,35	PEOPLE	0,35		
Current Business Process Architecture	0,20	ORGANIZATION	0,30		
Organization's objectives	0,48				
Ability to invest	0,23				
Cost-effectiveness of the SC information exchange	0,95	DATA VISIBILITY	0,84	SUPPLY CHAIN ISSUES	0,82
Adequacy/effectiveness of existing communication technology	0,45				
End-2-end visibility along all SC operations	1,68				
Disputes and frauds creation and management	1,10				
Heterogeneity/diversity of IT systems	0,00				
Administrative costs	0,53	PROCESS EFFICIENCY	0,66		
Inter-company processes accountability / integration	1,00				
Visibility on bottleneck	0,30				
Interoperability of corporates' ERPs	0,05				
Data integration at SC process level	1,43				
Increased demand for quality, customized and sustainable products	1,05	DEMAND MANAGEMENT	0,64		
Level of responsiveness	0,33				
planning/scheduling effectiveness	0,45				
Operations transparency	0,75				
Effectiveness of assets traceability (assets lost, thefts and tampering)	1,50	TRACKING, TRANSPARENCY AND TRUST	1,14		
Trust level among organizations and customers	1,43				
Cost-effectiveness of validation process	0,50				
Heterogeneity of organizations	0,30	HETEROGENEITY OF ORGANIZATIONS	0,30	SUPPLY CHAIN COMLEXITY	0,46
Structure	0,63	STRUCTURE	0,63		
Dimensions measured	0,73	SENSORS' FEATURES	0,52	INTEROPERABILITY WITH IOT	0,49
Sensor typology	0,30				
Application level	0,53				
Tracking and trace	1,20	SENSORS' PURPOSES	0,67		
Predictive or preventive maintenance	0,15				
In-process visibility	1,15				
Real-time performance measurement and control	0,45				
Avoid not value-adding activities	0,38				
Data security and validation	0,10	IOT REQUIREMENTS	0,32		
Relatively low maintenance cost	0,03				
Need for real-time monitoring	0,58				
Availability of applications	0,60				
Efficient power consumption	0,00				
Interoperability with other IoT and Cloud software	0,60				
Black box (meta-trust required)	0,55	LACK OF SUPPORT/TRUST	0,44	BLOCKCHAIN LIMITATION	0,27
Platform security	0,20				
Zero-status issue	0,58				
Energy consumption	0,00	IMPLEMENTATION ISSUES	0,22		
Technology readiness	0,30				
Lack of standards	0,48				
Latency	0,10				
Monetization of the investment (no clear ROI)	0,18	STRATEGIC ISSUES	0,15		
Added value creation	0,13				

Table 2: output of the content analysis (author's elaboration)

Out of the 51 sub-factors listed in the research framework, in fact, only 10 showcased an overall averaged weight above the discriminatory level 1. These 10 dimensions relate to 6 of the 19 framework parameters, namely “Supply Chain Engagement”, “Data Visibility”, “Process Efficiency”, “Demand Management”, “Tracking, Transparency and Trust” and “Sensors’ Purposes”. With reference to the upper layers of the framework, thus, evidences from the examples refer to the micro-variables “Supply Chain Readiness”, “Supply Chain Issues” and “IoT Interoperability”.

Comparison between primary and secondary source

Comparing the levels of evidence of the framework variables resulting from the interviews with those resulting in the content analysis secondary sources’ evidence, the author could highlight convergences and discrepancies across the framework’s variable. A matrix, whose rationale is synthetized in Figure 4, was created to support the comparative analysis. This allowed to underline and – to a certain extent – verify the coherence, alignment and consistency of grey literature in the context of a broader framework expressing a more comprehensive perspective on the adoption of BT.

LEVEL OF EVIDENCE OF THE SUB-FACTOR i IN THE CONTENT ANALYSIS	j ⟶ i ↓	CASE STUDY$_1$	CASE STUDY$_2$		CASE STUDY$_{13}$
X_1	SUB-FACTOR$_1$	$Y_{1\text{-}1}$	$Y_{1\text{-}2}$	. . . . .	$Y_{1\text{-}13}$
X_2	SUB-FACTOR$_2$			. . . . .	$Y_{2\text{-}13}$
⋮	⋮	⋮	⋮	⋮	⋮
X_{51}	SUB-FACTOR$_{51}$			. . . . .	$Y_{51\text{-}13}$

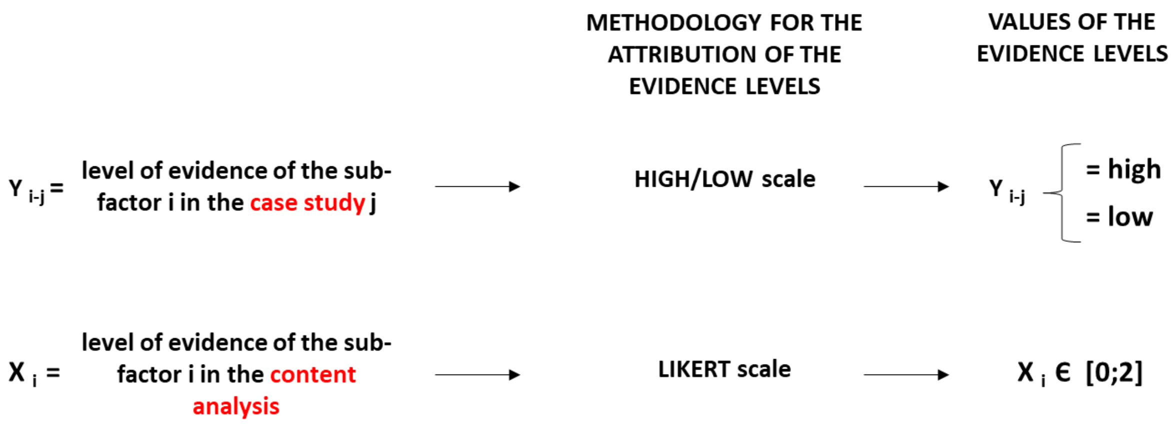


Figure 4: rationale of the matrix supporting the comparative analysis (author's elaboration)

The matrix allowed to shed light on a few aspects of BT:

1. A high interest generally exists on BT, promoted by a diffused concern for digitalization trend. Independently from the specific industry's propension towards innovation, rising stakes for digital technologies create emphasis on blockchain technology.
2. L&T and F&B industries suffer from a set of problems that would benefit from BT introduction. In detail, these supply chains are affected by a deep lack of visibility at industry level, ineffective traceability and unmatched demand for sustainability. Its characteristics and advantages make BT a good solution, especially regarding data management.
3. BT and IoT integration can be a powerful union, as they offer complementary features. From one side, BT platform needs data to manage and share across nodes, on the other side, smart sensors require a common environment where their data can flow into to be managed, elaborated and exploited to create value. In particular, these technologies propose to deliver most of their value in SC with regard to assets traceability and products sustainability, despite a few technical problems need to be addressed.

4. Three major aspects can complicate BT diffusion in these industries. The first is the low engagement shown by many companies, due to the diffused mistrust towards blockchain. The second is the compatibility of the whole industry's IT systems, which could discourage the network to make adjustments to implement BT. The last is represented by two requirements addressed to firms: financial capital and availability to redesign their process architecture.
5. One major guideline emerged from the analyses for those companies interested in BT technology is to join dedicated consortia. Taking part to these groups of entities collaborating on BT, results to be beneficial in three ways. Firstly, it supports the acquisition and development of know-how and skills, as they are typically shared in consortia. Secondly, they help companies in finding the network of players required by BT. Last, they could contribute to set guidelines for a systemic adaptation of IT systems, in case these represented a problem (as reported above).
6. At the moment, the biggest need of potential BT adopters is the initiative of a leader company in applying BT for the abovementioned SC problems. Facilitated by a broader set or resources, this company could trigger market dynamics demonstrating real BT benefits and dragging smaller players to follow their example. This would also contribute to mitigate trust issues associated to such technology.

Finally, this further analysis enabled the author to grasp a complete overview on the framework variables and their ideal configurations. Thus, a new tool was created to support the evaluation of BT. When the framework is used from the top to the bottom, in fact, it could support the definition of the "ideal conditions" required to adopt blockchain. Here, the most suitable "values" of the macro-variables (Readiness, SC features and Technical Implications) are described in the table to permit potential investors to benchmark their starting situation with target conditions. This would help to identify gaps and to possibly support the definition of an action plan for the introduction of blockchain. Hereinafter, the "ideal conditions table" is reported (a more complete version can be found in the "Results and discussions" chapter).

MACRO-VARIABLE	IDEAL CONDITIONS
Readiness	**SC READINESS** - companies within the industry show interest towards BT initiatives and are willing to cooperate and to co-invest to promote blockchain introduction within their processes - dedicated consortia exist to create the network and the know-how for the introduction of BT - the IT systems multiple companies staying at different levels of the chain are not too heterogeneous, rather complementary and interoperable - the industry's risk-taking tendency towards innovation is traditionally high **ORGANIZATION READINESS** - the firm is provided with an IT system that is as interoperable as possible with BT, or that can be easily used in a hybrid form with it - skills and knowledge on BT are internally created or externally acquired - processes within functions are designed so that data automatically flow into the platform, and, vice-versa, the platform smart contracts could directly and autonomously trigger the execution of specific activities in the physical world (such as a payment to a supplier) - enough capital is available and can be flexibly allocated to BT the organization's objectives coincide with the following: reduction in Net Working Capital, assets tracking and traceability, IoT monetization, improvement of data collection and integration process and business model renovation

MACRO-VARIABLE	IDEAL CONDITIONS

Supply Chain Features	**SUPPLY CHAIN PROPERTIES**
	- multi-party environment, where entities taking part are various with different characteristics
	- supply chain structure is complex, made of many layers and many players per each layer
	- many intermediaries operate in transactions within the chain
	
	SUPPLY CHAIN ISSUES
	- when SC displays at least one of the leading problems, BT might have more incentives to be implemented:
	    o lack of visibility on processes involving the whole industry, with consequent disputes, whose management requires time and money
	    o information coming from different actors is not integrated and stakeholders are not aligned or updated. "one up one down" approach is adopted, consisting in dealing only with

	the relationships and data flow of the first upstream and first downstream layer o accountability at systemic level is missing and process inefficiencies increase given the inability to spot bottlenecks in inter-company processes. o High transaction costs associated to the intervention of intermediaries o Wrong or ineffective data management has an influence on companies' ability do properly manage demand forecast and production planning. Uncertainty in the market makes it hard for the players to accurately picture the upcoming demand - end-users require companies to keep a focus on products sustainability, quality and customization, pushing them to adjust their processes. Customers increasingly wish for goods that are 100% compliant to quality standards and environmental certifications.

MACRO-VARIABLE	IDEAL CONDITIONS
Technical Implications	**INTEROPERABILITY WITH IOT**: - smart sensors are already deployed - IoT applied at truck, container or product level to measure real-time performances along the whole handling process, from suppliers to distributors - RFIDs, QR and NFC tags are already deployed - software applications exist to make data measurement, display and analysis user-friendly - Data moving from devices can be easily integrated with the protocols of other Cloud software, like BT - IoT fleet maintenance cost is not prohibitive **BT LIMITATIONS** - decision-makers are aware of the existence of such dimensions - Consortia exist to provide know-how, guidelines, standards and to create the technology network - a big leader company successfully implements BT to create market dynamics, overcome trust issues and drag smaller companies to do the same, after having demonstrated BT benefits

Table 3: Ideal conditions table (author's elaboration)

3. IDENTIFICATION OF BLOCKCHAIN BENEFITS

Data triangulation brought to the identification of the various positive impacts that BT technology could bring when applied in SC. For this specific part of the research, data triangulation has been rooted on the following sources typologies: the research framework, eight recognized papers on the consequences of BT in SC realms and forty BT applications of the content analysis.

By analysing and integrating their contents, a final dashboard was reaped to give a clear and comprehensive overview of the value unleashed. The dashboard is structured in 2 columns, where the first categorizes BT benefits in "SCM objectives" and the second articulates them into "Blockchain roles". The chapter "Results and discussions" completed the table with an accurate description of each impact.

SCM OBJECTIVES	***BLOCKCHAIN ROLES***
COST	- Lowering administrative cost per transaction - Products recall - Paperwork elimination - Lowering regulatory compliance costs - Counterfeit and disputes prevention - Waste and underused assets management through decentralized marketplaces
SPEED	- Enabling fully automated processing of ownership transfer, payment of inventory managed by vendors - Business rules implementation through smart contracts - Securing and streamlining order fulfilment process
DEMAND AND PRODUCTION MANAGEMENT	- Secure decentralized P-2-P collaborative planning and forecasting platform - Forecasts accuracy - Increasing responsiveness to changes and exceptions - Integrating data from 2nd tier to nth tier supply chain members - Providing single source of truth to build SC plans

	- BT-transactions-based vendor selection according to registered (delivery performances) performances
RESILIENCE	- Mitigation of risks associated to middlemen and intermediaries - Data security /and transparency - Super-audit trail to tackle self-reported data - Visibility through exchange of reliable data - Heightened connectivity fostering trust among partners - Only parties mutually accepted in the network can engage in transactions → secure partners and trading identification - Reward SC members for sharing reliable data - Providing real-time secure, validated data to monitor transport conditions - Address holistic sources of risk - Providing data at the lowest possible level of granularity - Counterfeits, losses and damages prevention - Securing order fulfilment process - Cybersecurity → fault tolerance
ASSET MANAGEMENT EFFICIENCY	- Responding to the increasing demand for information from different stakeholders - Securing products' provenance - Enabling sustainable Supply Chain - Providing full products traceability - Providing real-time secure, validated data to monitor transport conditions - Counterfeits, losses and damages prevention during assets management

Table 4: BT benefits (author's elaboration)

Conclusions

In terms of theoretical contributions, the research served to further investigate what emerges as one of the most promising technologies of the next 3-5 years: blockchain. The displayed findings represent a new frontier in the analysis of BT adoption in SC, considering the ***completeness, the structure and granularity*** of the research framework. The latter, in fact, stands as an attempt to approach the evaluation of BT adoption in a structured way, which was missing in the existing literature. The framework variables, indeed, are articulated into various levels of details, promoting an exhaustive analysis. In detail, the implementation of BT is investigated in relation with organization features, supply chain dimensions and IoT interoperability. The added value of the inquiry is finally represented by the field-based insights it is rooted on, making results reliable. Moreover, the comparative analysis brought to light further aspects that enriches the knowledge on blockchain in SC. Specifically, it merged primary and secondary sources to highlight the key drivers, complexities and risk factors. In detail, the analysis explained the key roles of consortia in the development and diffusion of BT, as well as the major need for major initiatives taken from big players to trigger BT-related market dynamics. Furthermore, it evidenced that IT heterogeneity, as well as organizations' reluctancy to adjust their processes architecture, might hinder technology diffusion. At the same time, a few SC problems emerge as potential drivers for the introduction of BT, as they plague multiple firms in both the examined industries. This investigation also contributes to the explanation of the value creation mechanism of BT in SC. The technology advantages, categorized in SCM dimensions, comprehensively report the ways blockchain deliver benefits, with a solid reference to both literature and BT applications. In particular, BT proved to deliver value to the dimensions of cost saving, speed, demand and production management, SC resilience and asset management efficiency.

At a managerial viewpoint, the tools and results of this research represent a solid support for companies that want to evaluate BT as future investment. Despite the key outputs has already been introduced, the author wants to provide readers with a final tool aimed at synthetizing the research content and its practical support. Therefore, the "Model for a comprehensive evaluation of BT" was created.

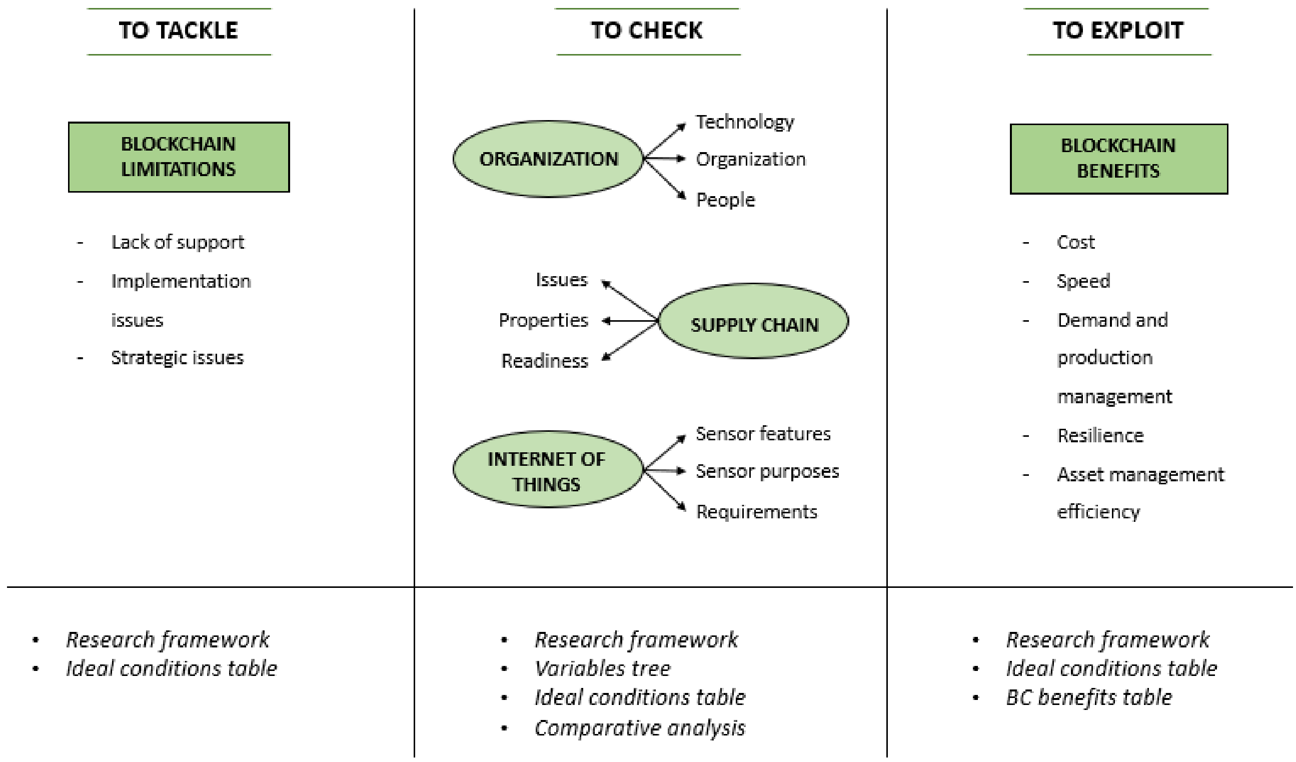


Figure 5: Model for a comprehensive evaluation of blockchain (author's elaboration)

The "Model for a comprehensive evaluation of blockchain" accompanies readers through the evaluative process in three steps.

1) Firstly, the decision maker is invited to check the as-is scenario of the case in examination with the support of both the *research framework* and the *variables tree*. In detail, this first evaluation must be performed along three major directions, that are the organization, the supply chain and the integration with IoT. The research dimensions corresponding to each direction can be found inside the framework, referring respectively to the micro-variables "Organizational Readiness" for the first, "Supply Chain Readiness", "Supply Chain Issues" and "Supply Chain Properties" for the second, and "Interoperability with IoT" for the third. At the beginning, model users should leverage the *ideal conditions table* to grasp information about the best configurations of the framework variables. Keeping them in mind, the *variables tree* must be then used as a checklist to compare the current statuses of the three areas

of analysis (organization, supply chain and internet of things) with the target ones. Consequently, this benchmark should also trigger actions aimed to fill the existing gaps between the as-is and the ideal conditions. Ultimately, the consideration of the comparative analysis results might be helpful too, as it supports companies in correctly approaching the technology.

2) In order to get a better view on the feasibility of BT implementation, the model user should move to the analysis of the BT benefits his case expects to achieve, depending on the company profile, the typology of implementation and the SCM dimension. In this phase, the benefits table should be the reference document.
3) Similarly, the last step, to be conducted in parallel with the second, consists in the assessment of those challenges associated to BT implementation. Combined with the result of step 2, this would assist the definition of pros and cons for the specific application purpose, with the goal of reaching a rational decision. In this regard, the framework micro-variable "Blockchain Limitations" should be the reference document.

Last considerations concern the author's suggestions for the next research steps.

Above all, what is truly necessary is to deepen the quantitative aspects linked to BT adoption in SC. This document provides a model to qualitatively evaluate the technology, but it lacks numbers supporting the rationale underneath. Future investigations, therefore, should collaborate with real-case applications and collect data about those business dimensions improved thanks to the introduction of BT. Sizing its benefits is the only way to understand if and when it makes sense to use blockchain.

Besides that, research results can be deepened and improved by enlarging the sample, possibly engaging with heterogeneous entities to cover all the nine quadrants of the classification matrix for case studies. At the moment, in fact, not all the combinations of IoT and BT providers with L&T and F&B industries are considered, which might limit the analysis results. Potentially, BT adopters might be more available in sharing their projects outputs, which might consistently help with the investigation, especially in delivering quantitative data currently missing.

Similarly, content analysis could be enhanced by expanding the sample of BT applications, making results even more valid. Lastly, grey literature can be complemented with sources possibly released directly from BT adopters examined in the sample.

1. LITERATURE REVIEW

In order to facilitate the reader with the task of understanding the research content and its implications, this first chapter displays the key theoretical basis of the topics regarding SC, SCM, DSC, BT and IOT. Since someone might lack the specific technicalities related to Blockchain and Internet of Things, the author's personal advice is to exploit this review to get a grip on them, for a better and faster comprehension of the subsequent elaborations.

1.1 Supply chain, supply chain management and digital supply chain

Since the focus of this study is linked to the adoption of BT and IoT not for consumer applications, but rather for the supply chain level, it makes sense to briefly introduce the concept of Supply Chain and to examine how it has developed over time.

1.1.1 Supply chain history and definitions

By getting rid of time boundaries and historical periods, it is easy to agree that at the basis of the supply chain idea there is a human need to survive, which happens by getting the required resources. As in most of the cases this search for goods could not be achieved by a single individual, human beings have started cooperating, by exchanging information and goods. In fact, it is possible to date back to the first agriculture-related transactions among farmers (8000 B.C.) the very primitive stages of a supply chain. With the rise of civilization and brain evolution, the kind and size of transactions performed by our ancestors have significantly improved, allowing for the realization of complex systems and infrastructures. Around 2560 B.C., for example, Egyptians managed to construct a 147 meters tall pyramid, by setting up an elaborate production, supply and labour system. Centuries to come, complementary advancements like education improvement and knowledge sharing have furtherly pushed human skills to create more intricate networks of relationships. Lately, wars for trade and commerce have testified how relevant the need and the ability to get the best supply at the best conditions has become (Vyas et al. 2019).

Simultaneously to these events, technological development has always represented the backbone and the driving force for a better and faster movements of goods and people. The wheel, the steam engine, the car. These are all inventions that completely revolutionized the way people could perform different tasks. Closer to our days, containerization is a clear example of how humans' evolution has been adapted to the key necessity of moving materials and goods. Nowadays, the paradigm shows technology innovation as a double edge sword, able to skyrocket revenues of first adopters, as well as to kill the business of late majority and followers. Topics like Artificial Intelligence (AI), Internet of Things, machine learning, 3D printing and CPS should fit into the to-do lists of firms having success and competitive advantage as common denominator.

Where has all of this brought us to? Today's business world is not about firm, is about supply chains. For a long period of time, organizations have restricted their search for competitive advantage and value creation within their own business functions boundaries. The idea was that by making the best in purchasing, production, marketing, financing and logistics, it was possible to reach the best result. Contrary to that, experience teaches not only that this configuration, combined with a lack of cross-functional synergy, can just lead to sub-optimal outputs, but even that extremely better results stem from moving the action and decision-making level to the entire supply chain. In fact, the modern globalized marketplace forces firms to operate not as individual entities, but rather as active members of a more complex competitive system. Made this statement, it is logic to converge to the idea that successful companies discriminate themselves from unsuccessful ones by leveraging their ability to manage, integrate and coordinate the systemic set of linkages with the other supply chain players (Drucker, 2018), (Douglas M. Lambert & Cooper, 2000).

A proof of the SC evolution is documented by its multifarious definitions, adjusted over time. The evolution path has been summarized and reported as follows:

- In 1967, the National Council of Physical Distribution Management (NCPDM) drafted the boundaries of supply chain only within the exchanges of finished products and, eventually, raw materials; defining it as the "efficient movement of finished product from the end of the production line to the consumer". La Londe & Masters (1994) confirmed it by talking of SC as "*the set of firms which pass [these] materials forward*", dragging producers, distributors and retailers in this chain.
- In 1992, M. Christopher introduced the key concept of reverse flows among the SC members, describing that as "*the network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate consumer*".
- In the August 2013, the Council of Supply chain Management Professionals (CSCMP), namely the evolution of the former NCPDM, updated the definition by also considering information as exchange unit: "the material and informational interchanges in the logistical process stretching from acquisition of raw materials to delivery of finished products to the end user. All vendors, service providers and customers are links in the supply chain".

When commenting upon the different definitions, the major variations can be spotted in terms of flow objects and integration. Specifically, the concept ranged from a primitive status almost exclusively focused on the movement of physical goods from producers through distributors (Physical Distribution Management), to a more comprehensive stage where both products, services and information are reversely exchanged along an extended chain. In this last configuration, also customers step into the systemic interchanges.

Despite other up-to-date definitions could be mentioned, practitioners and scholars agree upon the one provided by Coyle et al. (2013): "A series of integrated enterprises that must share information and coordinate physical execution to ensure a smooth, integrated flow of goods, services, information, and cash through the pipeline". Recalling the aforementioned factors of integration and flow objects, this description seems to be the most complete, as it stresses the diversity of the exchanged entities and the coordination required to enterprise within the same supply chain.

Stated this, it should not surprise that many authors have pointed out the integration of firms' operations as major driver for high supply chain performance (Zailani and Rajagopal, 2005),(van der Vaart and van Donk, 2008), (Zhao et al. 2011), (Wong et al. 2013), (Acar and Atadeniz, 2015).

Managing a supply chain, thus, results as a kind of feat. Nevertheless, like in any complex problem-solving process, there have been analyses and standardization efforts providing some helpful insights. First of all, a supply chain assessment should start from the identification of its core dimensions. Reportedly from Lambert and Cooper (2000), a focal company within its SC is characterized by three major factors:

1. the length (horizontal structure) stands as the number of tiers across the supply chain. This dimension generally varies with the product typology and its production process. The less complex the final product (ex. bulk cement), the simpler the chain and the lower the number of tiers.
2. The width (vertical structure) represents the concentration of suppliers or customers in each tier. Decisions like moving from single sourcing to multi sourcing strategies can enlarge the size of a tier, and consequently modify the SC structure.
3. The horizontal position of a company, instead, defines its proximity to the final market or to the supply side.

Once a company's configuration is described in terms of length, width and horizontal position, any change in the SC structure can also be traced back to variations in at least one of the three dimensions. In fact, different firms' decisions might alter this structure: outsourcing logistics, for instance, would influence the first two dimensions of the SC, with an indirect implication even on the third one. Finally, different SC configurations might result in different issues for the members: a company with a focal position in a long and vertical SC might have to face serious issues in terms of visibility over the tier 1.

Mentzer et al. (2001) provide a further specification concerning the complexity degrees of a SC. It is possible to leverage the previously shown concepts of length and width to get a clear understanding of that. The author talks of a "direct supply chain" (Figure 6) to address a short and narrow configuration made of a company, a supplier and a customer, exchanging information, goods, finances and services bottom-up and top-down. An "extended supply chain", on the other turn, is described as longer and larger, as both the immediate supplier's suppliers and the immediate customer's customers are considered. Lastly, the "ultimate supply chain" recalls a complex structure where both length and width are stretched, encompassing all the upstream and downstream organizations, from the ultimate supplier to the ultimate customer. This last configuration can be crowded by further different players, not necessarily acting as suppliers or customers. Financial providers, third party logistics (3PL), market research company and governmental institutions can be involved as well in movements of information, goods, finances and services, raising the complexity degree.

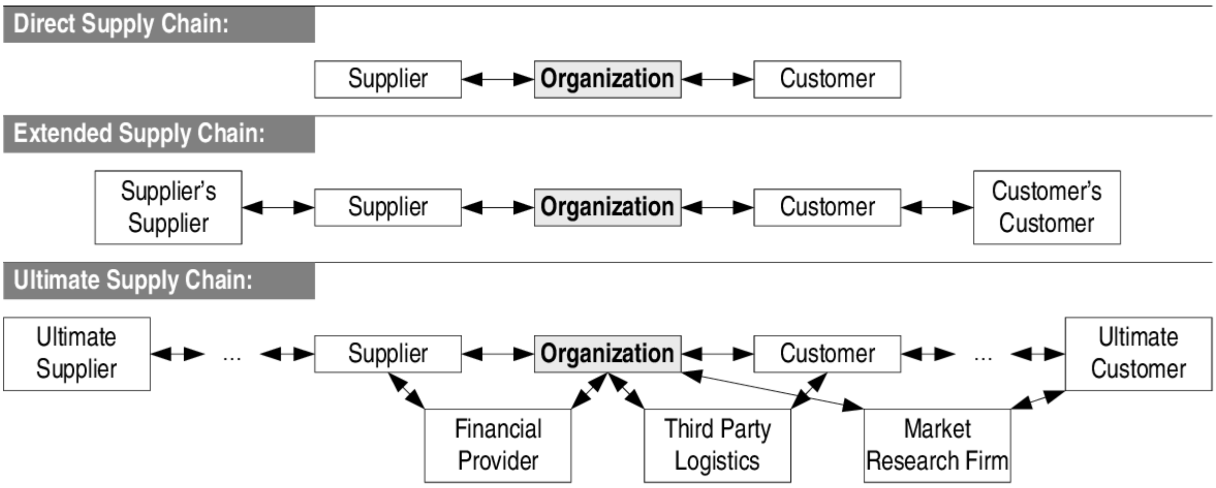


Figure 6: Supply Chain typologies (from Mentzer et al. (2001))

Finally, it is crucial to understand that, regardless the level of coordination, cooperation and integration among players, supply chain as a business phenomenon keeps existing. What marks the difference between supply chain and supply chain management is that in the latter case organizations are required to implement some management efforts within the chain.

1.1.2 Supply chain trends

If we had to pinpoint the most influential force dictating the future behaviours of supply chain members, that would be uncertainty. Indeed, this is an era when supply chain disruptions, being these linked to natural disasters or technology innovation, repetitively force companies to rethink themselves (Li et al. 2010). Ever-increasing globalization and globalized competition make firms compete with players thought innocent or distant so far. Besides that, global political instability requires flexible and resilient organizations to overtake high volatility. By putting all together, the result is a complex external environment foreshadowing blurred and vague perspectives (La Londe & Masters, 1994).

Although, since this situation represents the legacy left by former forces and supply chain dynamics, firms have learnt how to act. Pfeffer and Salanick (1978) promoted the resource dependence theory, stating that, in order to cope with environmental uncertainties and to get strategically relevant resources, inter organization alliances should be the solution. This has always fostered such interactions, but as firms' capabilities and requirements have changed over time, nowadays the most valuable exchanged and required item is data. Confirmed by many authors like Mentzer et al. (2001), Huang et al. (2003) and Pagell (2004), information sharing is a fundamental condition for mutual interactions. Chances are, in fact, that more and better-informed collaborating entities could chalk up important achievements like increased visibility and integration. Nowadays the need for multi-tier data exchange across supply chain is sharper, fostering stricter forms of collaboration.

Fortunately, ICT advancements have made it easier to extract, integrate and share data. Nevertheless, as testified by Auramo et al. (2006), IT has been primarily adopted by firms for intra-organizational operations, rather than for external integrations. Thanks to recent improvements though, diverse companies can now integrate their IT systems to achieve larger scale benefits.

All in all, it is possible to spot two key driving forces that are pushing supply chain players towards a new revolutionary configuration. The need for tighter collaborations from one side and the unbridled ICT innovations from the other side, will conduct supply chain to its new status of Digital Supply Chain (DSC). This has to be meant as a new status where firms interact with each other, moving from an ineffective linear schema to an integrated ecosystem. Abandoning siloes-based supply chains through digitization, it will be possible to unlock great values in terms of visibility. This will be the mean for increased coordination, reduced uncertainty, faster material flows, higher order fulfilment and shorter order cycle times, reduced inventory costs, increased customer satisfaction with fast and reliable delivery, and contribution to overall cost and service level performance (Koçoğlu et al. 2011).

Nevertheless, since the concept of DSC is treated later, the author leaves to the next chapters the goal of further investigating.

1.1.3 Supply Chain Management definitions

As mentioned in the chapter "Supply Chain Definition", it is crucial to keep a clear distinction between the concepts of SC and SCM. Summing up, the latter, which can or cannot be implemented as a consequence of a strategic process, can be roughly described as a set of activities performed by SC members to operate at a systemic level, managing the SC itself, that, at the contrary, always exists as a business phenomenon.

Despite modern practitioners mostly agree on the definition of SCM as the practice of managing the business as a system, avoiding sub-optimal department-to-department optimizations; this has been a long journey. For many years, in fact, lack of clarity and common understanding made the definitions of logistics and SCM diverge.

In 1967, the National Council of Physical Distribution Management described logistics as the "*broad range of activities concerned with efficient movement of finished products from the end of production line to consumer, and in some cases* *includes the movement of raw materials from the source of supply to the beginning of the production line*".

Decades to come, instead, showed the necessity to review the former concept, as other business management activities grew in relevance. Firms operated in a network where interdependence was not just limited to the handling of physical goods but digressed to further forms of collaborations in the domains of purchasing, planning and production. It was after these considerations, around the 90s, that emphasis was moved from the physical distribution idea to that of SCM. Here are some of the most significant definitions, after this separation between logistics and SCM was already spread:

- La Londe and Masters (1994) declared SC strategies to include *"... two or more firms in a supply chain entering into a long-term agreement; ... the development of trust and commitment to the relationship; ... the integration of logistics activities involving the sharing of demand and sales data; ... the potential for a shift in the locus of control of the logistics process*."
- In 1997, Cooper et al. spoke of SCM as *"… an integrative philosophy to manage the total flow of a distribution channel from supplier to the ultimate user*".
- It is possible to date back to 2009 the definition provided by Camerinelli: "*Supply Chain Management is a disciplined blend of time-based practices and technologies that sustain corporate users in the design, planning, sourcing, making, delivery, service and, eventually, return of the goods, information and services delivered to a globalised market*".
- One of the most recent versions of such concept comes from the Council of Supply Chain Management Professionals (CSCMP) (2013): *"Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, supply chain*

> *management integrates supply and demand management within and across companies. Supply Chain Management is an integrating function with primary responsibility for linking major business functions and business processes within and across companies into a cohesive and high-performing business model. It includes all of the logistics management activities noted above, as well as manufacturing operations, and it drives coordination of processes and activities with and across marketing, sales, product design, finance and information technology."*

In light of these descriptions, it is possible to highlight that the concept of SCM has developed in terms of activity coverage and objective performance. In fact, an evident shift has occurred from the more simplistic idea presented by Cooper et al. and restricted to the distribution channel management (Forrester, 1958), to the more integrated vision of the CSCMP. The latter clarifies how the interconnections among firms extend across several types of players and over both logistics and business management operations.

The recent abundant literature on SCM reflects the relevance of such topic. Reasons for that can be spotted in trends like global sourcing and the increasing ambitions in time and quality performances (Mentzer et al. 2001). As organizational procurement has got ever more global, managing to optimize goods, finances and information flows through solid relationships with suppliers has turned crucial. Additionally, increasing competition has raised customers' expectations, leaving on the market only those firms capable of fast delivery and high-quality products. These unstable scenario has shaped supply chain dynamics, dictating for speed and precision (Kuntze et al. 2018). As seldom organizations can survive on their own operations, managing supply chain relations and integrations requires a lot of their resources, reason why SCM concept has recently made a splash. Big names like Hewlett–Packard, IBM, Dell, Procter & Gamble have engaged long-term relationships with their suppliers to cut down transaction costs and to improve their competitive position (Handfield and Bechtel, 2002), (Johnson and Sohi, 2003), (Sheu et al. 2006).

A valuable insight is advanced by Mentzer et al. (2001), who observed a net distinction between SCM philosophy and its realization. In his study "Defining Supply Chain Management", a framework is depicted to show how certain preconditions must be met in order to transform the so-called Supply Chain Orientation (SCO) into the more practical SCM. The difference between the two is said to be that SCM is the hands-on realization of this intention (i.e. orientation) that many players might share within the supply chain. Despite a company might have a SCO, meant as the philosophy of viewing the coordination of SC from a broader system perspective; it might still miss to put it into practice as a real SCM form.

Looking at past studies, the author states that many factors have an impact on the implementation of SCO in SCM. Trust and engagement, according to Morgan and Hunt (1994), stand at the basis of cooperation as they encourage to preserve relationships investments, to resist attractive short-term alternatives and to rely on partners when assessing potentially high-risk actions. Interdependence is what triggers supply chain solidarity (Bowersox et al. 2000) and convince for long-term orientation (Ganesan, 1994). Similarity in corporate cultures and values, as well as complementary goals make organizations compatible, as they prove to have what has been defined as SCO. At the same way, synergies on vision and key processes pay their contribution, as reported by Lambert et al. (1998). Additionally, should an organization play the role of "SC leader", cooperative dynamics would be enforced, provided that this leadership is not too imperative. Finally, a further boost should come from the top management, supposed to provide support and commitment.

Supposed that not all the firms are aligned along these preconditions, SCM cannot be always implemented, as systemic synergies and adhesion are necessary conditions. Nevertheless, once these circumstances are achieved, SCM implementation is demonstrated to supply enormous advantages to single firms' operations. Dwelling on Mentzer et al. (2001), the overall major contribution of SC arrangement can be measured in terms of profitability. Being profitability a function of customer value created by firms and of the ability to gain some competitive advantage, SCM is required to affect both. The SCM dynamics allowing organizations to get ahead can be generally listed as costs optimization at SC level, improved Order Cycle Time (OCT), innovative solutions and increased stock availability. The rationale is that by producing enhanced customer service and minimizing costs, SCM gives off competitive advantage, turning into a higher profitability later, at both SC and individual firm levels.

1.1.4 Supply chain management solutions

Recent authors (Simatupang and Sridharan, 2002), (Martin Christopher and Peck, 2004), (Cao and Zhang, 2011) claim that SCM recalls practices of Collaborative Supply Chain (CSC). Ambiguous external conditions and inter-SC conflicts are suggesting firms to play a team game instead of wrestling with each other. In fact, the dynamic arena of SC is affected by turbulences and frequent changes, requiring the industry to quickly adapt. This need for resiliency, that is the "ability of a system to return to its original status, or to move to a new, more desirable one after being disturbed", has convinced many players to run their businesses in collaboration with their partners. In addition to this, Christopher and Peck (2004) report in their work that organizations are also called to develop agility, to re-engineer SC with a resiliency-driven viewpoint and to develop a SC risk management culture. This last requirement is also stressed by PWC and MIT, whose integrated study drawn up in 2013 highlights how companies should face today's challenges and future opportunities. Still, many efforts should be put in making SC more flexible, agile and adaptable.

Supply Chain Collaboration (SCC) is presented by Cao and Zhang (2011) as a "a partnership process where two or more autonomous firms work closely to plan and execute supply chain operations toward common goals and mutual benefits". The two authors leverage former well-known theories like the Transactions Economics Theory (TCE) and the Extended Resource Based View (ERBV) and the Relational View (RV), to frame the concept. SCC is rooted on business integration and mutual trust to overcome typical blockers of markets and hierarchies. It permits firms to combine resources in such unique ways that competitive advantage arises. Finally, dyadic collaborations serve at merging external and internal resources through network interdependences, resulting in a strong competitive advantage. This latter is addressed as collaborative advantage, which, together with improved firm performances, represents the direct consequence of SCC.

According to Simatupang and Sridharan (2002), SCC is game-changing. Supply chains are generally oppressed by repetitive cost-ineffective conflicts. Such blockers derive from a series of competitive automatisms and selfish company-oriented business operations. The major obastacles are linked to information asymmetry, outdated policies, inappropriate performance measurement metrics and incentive misallignment. The authors, however, structured the table reported in the Table 5 to list the means of intervention to fix these issues out. What is stressed is that in a collaborative supply chain, players build up initiatives and practices in the interest of the whole chain, rather than limiting their actions to their own private scope. Consequentely, they are required to behave in a way that might sound counterintuitive. Practices like information sharing, common policies adoption and incentive allignment allow every member to have a stake in success.

No.	Means of Interventions	Horizon Impact Short-Term	Medium-Term	Long-Term
1.	Mutual objectives	Coping with both usual and unusual demands for products/services	Coping with growing demands for broader market offerings	Coping with growing demands for superior service capabilities
2.	Integrated policies	Matching demand and logistics capability	Matching product design and logistics capability	Matching superior service and logistics capability
3.	Appropriate performance measures	Increased planning capability, improved customer service, shorter order cycles, reliable delivery, assets utilized, reduced inventory, cash flow increase	Increased product variety, effective product life cycles, time to market, reduced overhead cost, flexibility increase	Increased market share, increased human resource capability, increased customer service, reduced overhead costs
4	Decision domain	Customer service requirements, forecasting, inventory, ordering, transportation, replenishment, promotion, pricing	Market segmentation, product development, logistics capability	Business objectives, marketing strategy, capability planning
5.	Information sharing	POS data, the availability of products/services, delivery schedule, promotion schedule, performance status	Customer data, product life cycle plans, costs related data, performance status	Market data, the availability of capabilities, costs related data, performance status
6.	Incentive alignment	Productive behavior-based incentives and pay-for-performance	Equitable compensation	Equitable compensation

Table 5: measures of intervention for SCC blockers (from Simatupang and Sridharan (2002))

Echoing SCM and SCC principles, managing and integrating operations at system level and promoting a collaborative inter-company approach is how firms get rid of unfavourable external conditions, at the same enhancing their own performances. Last but not the least, technology remains a powerful door opener for collaborative practices and an enabler for improved performances. It is by merging the concepts of SCM, SCC and technology innovation that recent researches have predicted a futuristic, seamless and resilient nature of SC, as the next chapter investigates.

1.1.5 Digital Supply Chain introduction

Two distinct trends are putting global supply chains to the test. The first one is the result of many years of advancements and represents an ever-ongoing process itself: digital technology disruptions. What many people struggle to picture is the size of the latest digital evolutions, reason why some numbers might help. In 2008 there were already more “things” than people on the planet, and their number is forecasted to reach 50 billion connected entities by 2020, with an aggregate 19 trillion dollars in cost savings and profits from IoT, reportedly to Cisco research (2011). Back to 2016, Google stated that the 20% of the overall research queries made by consumers were made vocally. Lastly, Gartner conducted a research in 2017, where the number of customers expected to shop in Augmented Reality (AR) by 2020 was said to be close to 100 million.

On the other turn, customer expectations have changed, forcing firms to early spot new hard-to-achieve requirements and to act. For instance, a study from McKinsey & Company (2017) forewarned increased customization and granularization of orders, influenced by globe-wide spread e-channel.

These coupled forces (digital technologies disruption and customer expectations) prompt the leading features of tomorrow’s global supply chain, reshaping also the profile of firms’ business models. As already observed, seemingly, running a business in the modern global supply chain is extremely tough. Firms as stand-alone entities and SC as integrated systems must deliver resiliency and agility if they don’t want to fall short. The problem is that, compared to the latest market evolutions, current supply chains miss some key business requirements, as they result in a series of siloed, discrete and scattered steps (Schrauf and Berttram, 2016). Since this does not get along with recent challenges, a change must be performed, and new technologies are paving new ways for that. The adoption of new solutions like IoT, AI, Big Data, Cloud Computing, Blockchain, Omnichannel and 3D Printing within the world of SC allows for incredibly upgraded possibilities. Eventually, thanks to these latest digital strides, SC turns itself into an evolved form, namely the Digital Supply Chain (DSC). In this new era, walls are brought down by digitization and firms continuously collaborate in vivid ecosystems. If the network is properly modelled and what-if scenarios are frequently created and simulated, collaborating firms within the same industry can be more responsive and adaptable to real-time changes.

1.1.6 Digital Supply Chain definition

Despite the DSC topic has been making headlines only for the last few years, many studies have been conducted to assess it. Gt nexus and Capgemini Consulting, for instance, have interviewed 337 leading executives to investigate about digital transformation in supply chain. Out of them, 75% claimed DSC to be "important or very important", with a 33% of "dissatisfied" answers and a 5% of "very satisfied" feedbacks. Another survey was made by McKinsey in 2013 to get insights from a geographically spread and consistent sample of industries. 850 companies were interviewed, resulting in a rapidly increasing attention towards digital initiatives in their companies from senior executives. Plus, the survey showed that, back to 2013, 30% of interviewees expected to allocate more than 3% of the budget year to digital-business initiatives.

Other hints on the topic have been provided by consultancy companies. Boston Consulting Group for instance drafted a report in 2016 to describe how DSC technologies are allowing organizations to improve their service level while cutting costs. It is stated that three major digital technologies-based strategies are responsible for that. Some companies are using innovative solutions to overcome SC issues conventional approaches would face ineffectively or would not do at all. For instance, RFIDs have been finally deployed by a big European fashion retailer to track products and improve replenishment processes and stock management. Business processes innovation is another strategy practiced by more future-oriented firms to improve performances by combining business process redesign and digital evolution. Advanced organizations are now using cross-functional teams and control-towers to monitor real-time demand, inventory and capacity data. The output still resides in performance advancements in many functions, like planning, demand forecast and distribution. Lastly, some other players manage to disrupt SC by drastically renovating operations, with the usually shared goal of getting closer to the market, decentralizing activities or speeding up deliveries. Amazon, for instance, has developed a mobile 3-D-printing delivery truck, able to print out an order from a data file sent to the closest vehicle, so that warehouse utilization would be optimized. In their conclusions, suggested investments are meant support digital transformation, focusing on four main areas: processes, people and capabilities, structure and systems and tools. Despite a lot of buzzwords fill discussions about DSC and the subject is still unfamiliar to many, Büyüközkan and Göçer (2018) drafted a comprehensive definition of DSC:

"…an intelligent best-fit technological system that is based on the capability of massive data disposal and excellent cooperation and communication for digital hardware, software, and networks to support and synchronize interaction between organizations by making services more valuable, accessible and affordable with consistent, agile and effective outcomes."

The same authors even proposed an integration framework to develop a DSC. This can be found in Figure 7.

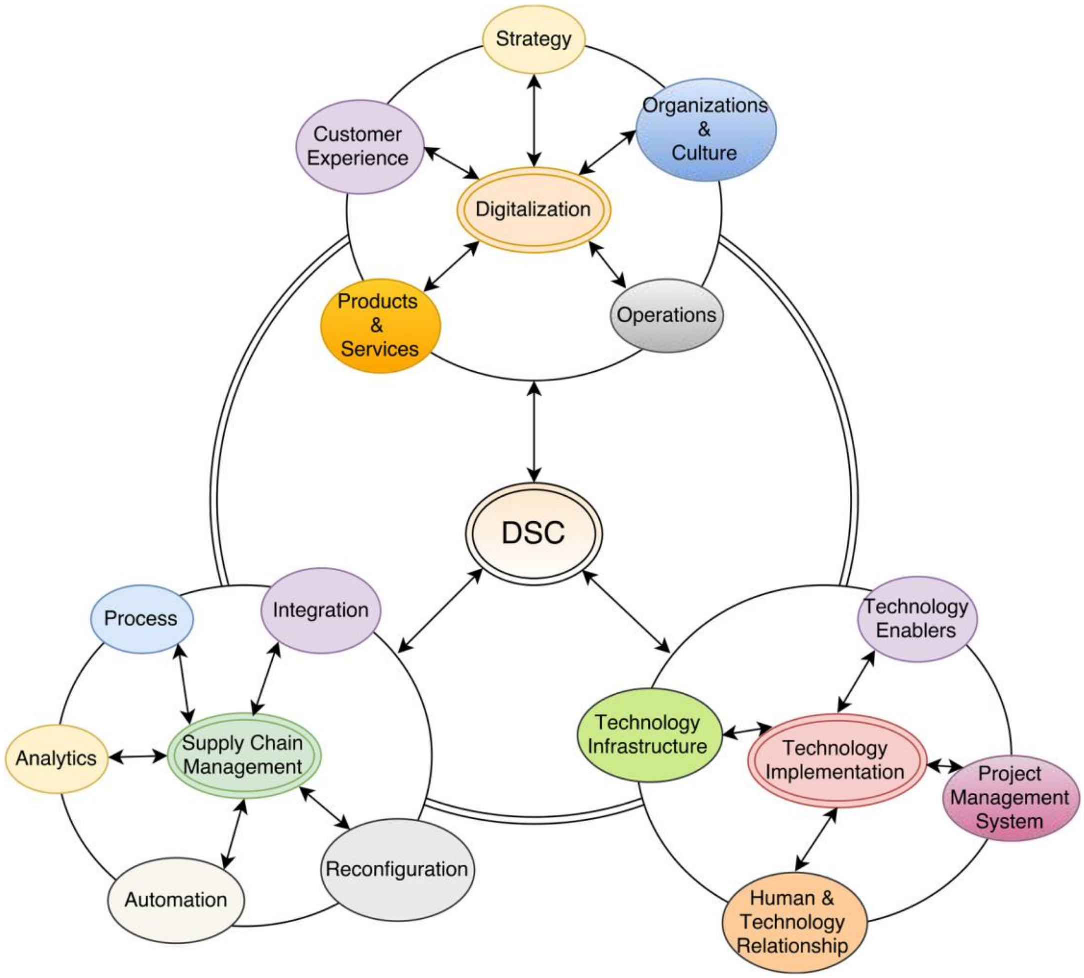


Figure 7: integration framework for DSC introduction (from Büyüközkan and Göçer (2018))

An imperative clarification is that DSC has nothing to do with the physical or digital nature of products and services, rather it is linked to the way SC is managed. Furthermore, it is said to generate more value for individuals then for companies.

All in all, digitization is bringing al lot of benefits to industries. Delivery speed, conceived as delivering more in less time, is improved due to operational agility and flexibility, in a globally connected environment. The orderly slow information flow is disrupted, opening to a real time SC transparency and coordination. Consequently, leveraging the further support of self-learning and autonomous decision-making algorithms, inventory is flexibly adjusted according to reliable updated information. Along with these advantages, DSC deals with a handful of challenges though. Since inter-company relations are key, many risks are associated with interdependences and network dynamics. Lack of collaboration, wrong demand forecasts, lack of integration or information sharing could make such DSC working turbulently. Nonetheless, Alicke et al. (2016) insists that major impacts will be experienced as it concerns inventory and working capital, costs (transport, warehouse and administrative) and customer service.

Outstanding examples of companies trying to operate a DSC are the giants Google, Apple and Amazon. The secret ingredient of their successful businesses is the venturing of many digital areas beyond their core businesses. Amazon Prime Video is a perfect proof of such strategy, as well as the integration of other digital and software services, mobile phones, CC, e-readers, tablets and payments.

Observed that DSC is a game-changing trend, there are a couple of preconditions that still miss to be achieved, in order to perfectly measure up to its promises. What also Schrauf and Philipp (2016) zeroed in on, is that there is no way companies will benefit digitization unless required capabilities are developed or acquired and the right environment is created. Recruiters will have to narrow down their talent searches to higher-level ICT skilled profiles, whilst HR managers will have to undergo employees to new digital courses. At the same time, as the shift to DSC does not emerge autonomously, investments need to be consistently made to keep up with the pace of innovation technology. Therefore, a horizontally integrated function must be deployed within the organization to get ICT skills, to rapidly test, prototype and to implement solutions. In doing that, a start-up-alike approach is required, running pilots, learning by doing and working as incubator.

Finally, authors (Korpela et al. 2017) suggest that four transformations are required to step into a DSC.

1) Business model development: aimed at exploiting digitalization and SC integration services to maximize innovation and effectiveness.
2) Information model platforms: these must be adjusted to other SC members to facilitate information collection, storage and sharing.

3) Business process standards for SC connectivity: SC partners need to be digitally connected to business process transactions.
4) Operator services for data transfer between actors: information stemming from several players has to be consolidated and integrated across systems and entities.

1.1.7 What is the matter with Blockchain?

Despite the still blurred general perception public opinion has of it, Blockchain technology has been extensively praised for its potential contributions to SC. Nonetheless, its enigmatic technical details and some questionable adoptions have brought to controversial feelings.

In order to frame BT share in DSC realm, few key concepts need to be made explicit.

Last chapters have reiterated that modern global supply chains can be thought as multi-stakeholder environments where complementary and heterogeneous entities participate to the value creation process for final customers. Now more than ever, in this complex ecosystem value-added service providers proliferate. Despite performing diverse activities, they all aim at making different systems interoperable within the same SC. These players are adding complexity and increasing the overall SC efficiency at the same time. They are intermediates, logistics service providers (LSPs), ICT companies and financial providers. Regardless they provide cloud solutions or track and trace services during deliveries or lend financial resources, they are grouped in by the intention of making industry's participants collaborating and performing efficiently at system level (Banerjee, 2018).

One major requirement to make this possible is that SC members integrate business transactions and processes in a standardized way. As extensively presented earlier, there have always been attempts to rationalize and manage SC processes. SCM researches and practices have made possible to model and optimize network performances, responding to the increasing necessity of members firms to relate each other and massively collaborate.

To support this managerial and modelling efforts, firms have started adopting software solutions to plan enterprise operations and resources procurement. As a result, Material Requirement Planning (MRP), Manufacturing Resource Planning (MRP II) and Enterprise Resource Planning (ERP) were born in the last 40 years, with the latest advancements flowing into the advanced supply chain planning and operations (APS/APO) software. Out of these last names, ERP has been by far the most impacting on SC business processes, as it permits resources utilization maximization and planning improvement. Its structure conveys insights coming from several departments of the same organization to be unified as a single platform. Consequently, a huge influence is deployed on intra-organization dynamics, improving the way interactions with stakeholders are performed. However, the abundancy in advantages is mostly secluded within the single company's boundaries. In fact, if a systemic perspective is used to evaluate this technology, limitations start to appear. First, as it might seem intuitive, the fact that operations maximization is processed only internally to the company makes the information at SC level fragmented. Additionally, ERP is not applied to inter-firm communications, as other protocols like XML or EDI have always been used and preferred (Banerjee, 2018).

Although ERP might seem the perfect technology solution at a glance, a crucial gap can be spotted: there is no unified network or platform to connect different firms' ERP, regardless their location and domain. This prevents from a standardized integration of business processes, producing consistent frictions along the chain.

In the end, the same technology innovation that has brought us so far, is limiting the achievement of broader systemic results. But how can things be changed? In globally competitive supply chains, collaborative and frequent transactions are commonplace. These must be run smoothly, minimizing the high transaction costs. Because of this, siloed ERPs and troubled information flows need to be overcome.

It is in such a tormented scenario that Blockchain technology stands out. In a nutshell, it can be outlined as a distributed ledger database capable of minimizing third party intermediates and related costs. Simply put, it is a cloud platform allowing for Big Data integration and sharing among different participants. It represents a successful model of many-to-many integration, way more effective than the previous forms of firms' interactions. Up to now, in fact, companies used to rely on slow and untrustworthy models: manual transaction integration, EDI business-to-business integration model, hub B2B integration model and cloud B2B integration model. These approaches have been picked up according to different interaction needs, varying from point-2-point (P2P) to one-to-many and many-to-many later. All of them, though, resulted in a series of flaws: slow data transfer, low interoperability of systems, cybersecurity issues and low automation in data exchange causing a lot of computer-paper-computer manual processes. Alongside with this, fourth parties involvement (ex. banks) brings about additional transaction costs and time (Korpela et al., 2017).

These solutions are recognized to be cost-ineffective, but also Blockchain adoption requires consistent changes to single companies. This is why hybrid forms, made of BT and current ERPs systems, can be thought as the basis of new cost-effective solutions, supporting big organizations and small medium enterprises (SMEs) collaborative interactions. Given the complexity of making a complete shift to BT solutions, authors (Wessling, Ehmke, Hesenius, & Gruhn, 2018) realized that exploiting blockchain-based applications (DApps) jointly with existing IT systems could tackle the technical hurdles of such technology, while alleviating SC issues. Hybridization, then, stands as the starting point to set off this promising journey.

To conclude, recent studies suggest that future SC's shape will be rooted on an extensive adoption of the newest digital advancements, crushing the past boundaries of slow, rigid interactions among members and opening up to a SC 4.0. Within these new arenas, BT technology is likely to pay an enormous contribution, mainly providing visibility and avoiding trust issues. Over the next years, BT-ERP hybrid models will possibly make the way to more articulated, complete and large-scale pure BT platforms.

Over the next chapters, literature review will be directed to blockchain technicalities, advantages and disadvantages and SC applications.

2. BLOCKCHAIN TECHNOLOGY

2.1 Historical notes on Blockchain Technology

The first time humanity read about Blockchain was on the 31ST of October 2008, when the paper titled "Bitcoin: A peer-to-peer electronic cash system" was released on the Internet by a person, or more likely a group of people, using the pseudonym of Satoshi Nakomoto. The major contribution of that document was the definition of an algorithm enabling the implementation of a distributed digital currency (Nakamoto, 2008). In fact, in 2009 the revolutionary cryptocurrency Bitcoin was launched on the public community. Since that moment, individuals and organizations started to look at this solution as a new way to boost their business. The success of this first cryptocurrency was associated to its ability to solve the major hurdles with e-commerce. Thanks to the great advancements of the World Wide Web at the beginning of the second millennium, buyers and sellers found a new way to perform transactions in the digital world. Digital payments made these transactions easier and enlarged at a broader geographical span. Nevertheless, three crucial limitations of this system slowly started to emerge. The first lies in the buyer and seller's need to agree on a unique shared and trusted intermediary validating the payment. The presence of Trusted Third Parties (TTP) from one side eases transactions by getting over trust-related issues, but from the other side adds complexity and fees. The second deals with the privacy issues on personal data of the entities involved in the transaction, as credit cards details could be stolen and unfairly used. Besides this, a major concern was raised on the so-called double spending phenomenon. As the currency is digital, the risk is that coins are copied, as they are just not counterfeit-resistant sequences of bits.

In light of these troubles, Bitcoin successfully emerged as a powerful mean to make digital payments secure, exploiting the distributed nature of the supporting technology. The peer-to-peer electronic cash does not rely on trust, as done before, but, rather, on a cryptographic proof, removing intermediaries from buyer-seller interactions. Specifically, transactions are made secure as electronic cash results as a sequence (or chain) of digital signatures. Any Bitcoin owner, when moving cash to others, has to digitally sign both the hash related to the previous transaction and the public key of the future owner. Once the digital signatures are performed, they are added to the end of the chain. By drawing on digital signatures, crypto keys, hashing functions and proof-of-work, Blockchain technology enabled for the first time secure, tamper-resistant and peer-to-peer digital payments, revolutionizing the traditional financial habits (Nakamoto, 2008).

Since this initial debut, many other cryptocurrencies have been launched, as in 2018 they were said to be 1600 and counting. Among all of them, Ethereum stands as the most consistent and further developed alternative to Bitcoin. This has to be traced back to 2013, when Vitalik Buterin, co-founder of Ethereum and Bitcoin magazine, decided to run a new public Blockchain, introducing an additional feature. Ethereum, in fact, was the first BT solution supporting the transactions of assets different from coins, like contracts or loans. The insertion of smart contracts made Ethereum even more flexible in terms of adoption, dispatching it to high market share in the cryptocurrency realm. (Marr Bernard, 2018 “Blockchain: A Very Short History Of Ethereum Everyone Should Read”, The Forbes)

Swan (2015) suggests that Bitcoin could evolve to enable the so-called “Internet of Money” (IoM), a system that would enable to connect finances as the Internet of Things connects things. The deriving benefits are emblematic, it is enough to think of the reduction in the worldwide credit cards merchant payment fees from 3 to below 1 per cent. As the concept of IoM gets bigger, even more ambitious scenarios could be set up, where BT could support the decentralized trading of different resources, even beyond currencies and payments.

Data coming from market capitalization confirm the increasing climax of interest towards digital currencies. In July 2019, in fact, Bitcoin and Ethereum are reported to have a market cap of 170 and 22 trillion dollars respectively. Other relevant alternatives are Ripple and Tether (CoinMarketCap, accessed July 2019).

Outside the debated cryptocurrencies realm, where Blockchain has always been recognized as the underlying enabling software, innovative applications of the same technology have been continuously proposed from scattered and different sectors. A simple research of the term Blockchain on the Google Trend research engine gave the result pictured in Figure 8 (July 2019), testifying an enormous hype on the topic over the last three years. The reason for this peak must be led back to the growth in interest shown by the public opinion.

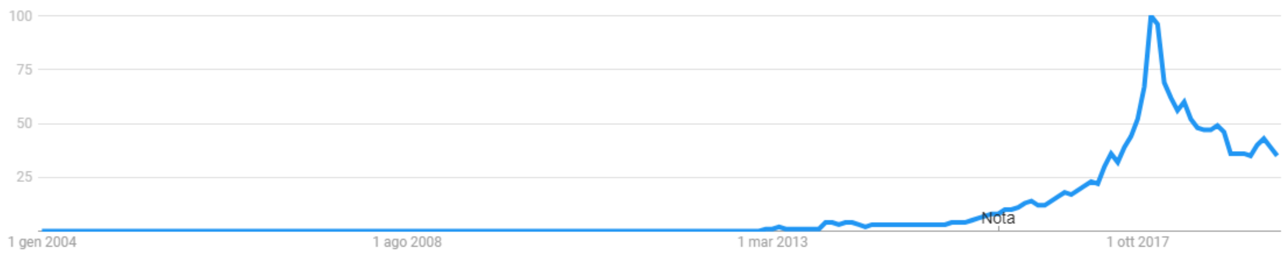


Figure 8: result of the search "Blockchain" on Google Trend research engine

After Bitcoin's launch in 2008, it did not take too long for entrepreneurs to try adopting Blockchain for other purposes. The idea and the nature of such technology made it extremely versatile, convincing companies to make it fit to supply chains, healthcare, insurances, voting systems and others. The point is that Blockchain seems to behave like the Internet technology at its dawning:

"Blockchain is to Bitcoin, what the internet is to email. A big electronic system, on top of which you can build applications. Currency is just one,"

-Sally Davies, Financial Times Technology reporter.

Treiblmaier (2018) properly drafted this parallel. The author suggested that, as the Internet has taken till the 1990s to unveil its full commercial potential, Blockchain might be doomed to the same development. Many applications of the Internet, some more meaningful than others, have been developed over the first years of its adoption. Despite that, later large-scale applications had significant impacts on SCM.

Other authors (Iansiti & Lakhani, 2017) assessed the similarities with the TCP/IP technology, predecessor of the World Wide Web, even in technical terms. Both technologies, in fact, represent an open, distributed and shared system, aimed to reduce costs: connection costs were the target of TCP/IP introduction, while transaction costs decrease is the objective of BT adoption. Furthermore, the development and adoption curve of the former, started from a single use case uptake and finished with a redefinition of the global economic basis, may be replicated by the latter. Indeed, despite the TCP/IP concept was originally brought into businesses to enable direct and fast communications between companies, it ended up with redesigning the rules of making business and creating value. This evolution happened gradually, involving cross-sectoral entities and investments. After its debut in 1972 as email-enabler tool, in fact, the technology firstly moved to a broader adoption in the mid of the 1990s, when localized private network were built up within organizations. The public Internet was the following step, reached through the creation of hardware, software and services to get easy access to this new network. Once complementary applications and services were developed, attracting new users, this network soon achieved the critical mass, making connectivity even cheaper. Since that moment in time, existing businesses changed, and the following generations' companies started digital-rooted models.

In the same way, Blockchain comes with high expectations because of its potential as network-based enabling technology. The authors prompted that BT might be characterized by a development path similar to the above-mentioned one. Considering the level of complexity and coordination required by the technology for a meaningful adoption, and its degree of novelty, Iansiti and Lakhani (2017) clustered four possible future scenarios. Sticking to the adoption model of the TCP/IP technology, BT will possibly go through the same stages: single use case, localization, substitution and transformation.

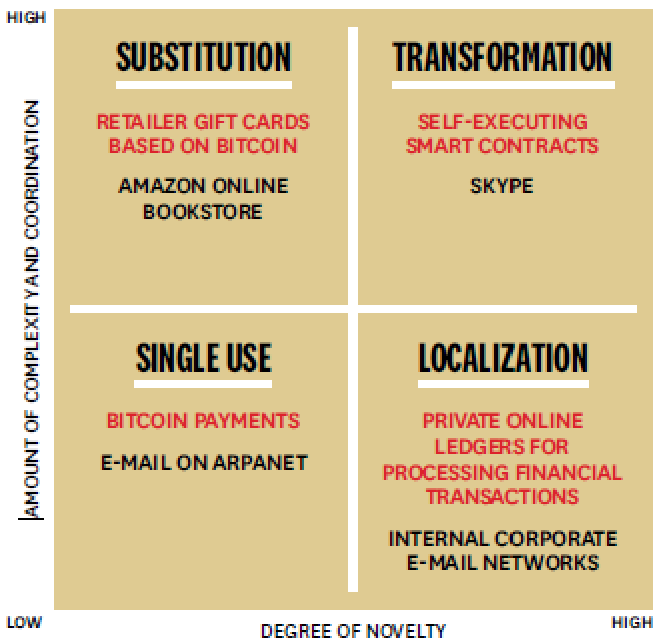


Figure 9: future scenarios of BT (from Iansiti and Lakhani (2017))

Companies eager to get to know BT may start with a single use like introducing Bitcoin as a financial tool to process payments or using blockchain as a database for digital or physical assets. This would not require a broad collaboration with many players, still bringing value to the company. Localized applications can be found in the financial services sector, with major actors like JP Morgan, Bank of America and The New York Stock Exchange testing it to reduce paper-based and manual tasks in some of their functions. Modern new cryptocurrencies, instead, can be depicted as an attempt to substitute existing business, turning to many players, customers included. Lastly, BT could literally transform business as it is successfully applied in a novel area, drawing on a diffuse participation. In these cases, smart contracts stand as a very powerful driver. They are specific applications made of algorithms, run on BT, that enable the automation of payments and other contractual terms. Designing smart contracts is very hard and requires standardization efforts, therefore institutions are claimed to help out. The plan is that members of the same complex SC join the BT platform, so that contractual terms in buyer-supplier linkages are made digital and automated via smart contracts. Payments, for instance, could be processed automatically as the shipment coming from the supplier reaches the point of destination. GPS and other smart sensors placed on the shipment would allow the platform to know whether contractual terms have been met, consequently processing or delaying the payment.

2.2 The Blockchain Technology market

Few steps have already been made by worldwide companies towards blockchain. What is interesting to notice is a set of statistics on the future of this market. According to a research released by marketsandmarkets.com in 2018 (marketsandmarkets.com, "Blockchain market"), a Compound Annual Growth Rate (CAGR) of 80.2% will drive the global blockchain market growth, moving from USD 1.2 billion in 2018 to USD 23.3 billion in 2023. Further clues state that smart contracts are doomed to gain growing stakes over the period of analysis especially across industry verticals, as they aim to reduce costs ought to verification, execution and fraud prevention activities. Smart contracts offer a valid solution to the risk of data tampering and hacking. Additionally, blockchain market is projected to witness to a massive growth by SMEs and to the largest share held by the Banking, financial services and insurances (BFSI) industry. Efforts have been recently taken by large players like Microsoft, IBM and SAP. In October 2018 the latter, for instance, provided new services allowing customers and partners to integrate blockchain infrastructures.

Similar promising outlook emerges when the same analysis is performed on the blockchain IoT market. Indeed, relevant trends like the broad adoption of IoT, the major concerns on IoT security and operational efficiency in business processes, are said to push for an ever-closer integration of these technologies. Reports suggest that over the six years long period between 2018 and 2023, this market will observe an annual growth of 92.92%, measured as CAGR.

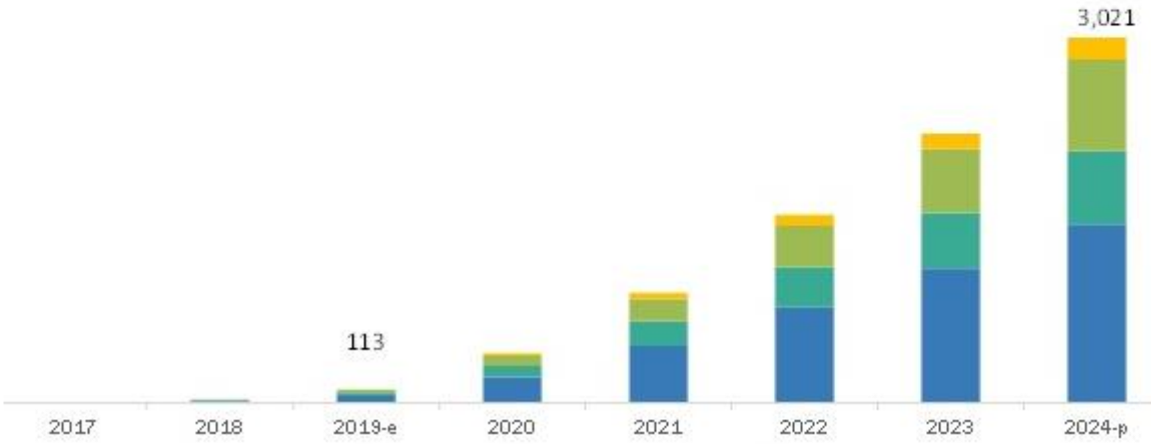


Figure 10: BT-IoT market in USD million (from the research "Blockchain Market", on marketsandmarkets.com (2018))

This sector is enlivened by key players like IBM Corporation, Microsoft Corporation, Intel Corporation and Cisco Systems, collaborating with other entities like Maersk, Tata Consultancy Services and Interswitch Group to develop successful blockchain IoT solutions.

2.3 General description of Blockchain Technology

An important premise needs to be done at the beginning of this chapter: Blockchain is not a single technology, rather it consists in an umbrella of diverse technologies and principles jointly adopted to put in place distributed ledgers. This umbrella concept can be articulated into three major layers: the first is called Blockchain 1.0 and relates to cryptocurrencies like Bitcoin, whose major functions are all linked to cash. Blockchain 2.0 refers to the whole set of applications going beyond simple cash movements, like smart property and contracts. The last layer of BT technology does not regard financial usages, but rather specific areas like science, health and governments (Swan, 2015). Nevertheless, literature seems to ignore such distinction, using the term Blockchain as a general concept.

Blockchain is generally framed as one of the disruptive technology forces that are shaping the industry of the next 3-4 years, as mentioned in the "Logistics Trend Radar" (DHL Trend Research, 2019).

This technology can be addressed as a decentralized database shared by many nodes in a network, where a complex validation mechanism and crypto-related tools allow for the elimination of intermediaries. When data is uploaded on this kind of database, each of the nodes the platform is made of, owns a version of it. It is a public registry of "who owns what" and "who transacts what". The major innovation compared to traditional databases lies in the absence of a central governance entity in charge of both data and transactions management. As disintermediation and decentralization of all global-wide transactions between parties are achieved (Swan, 2015), Blockchain results as a peer-to-peer network where data is uniformly stored. A single version of the truth is ensured by the proof-of-work (PoW) (Pai et al. 2018) and transactions are made permanent as they are stored and sequentially added to the chain through time-stamped blocks of data (Babich & Hilary, 2018). In a nutshell, data on Blockchain can be defined as:

- Consensually shared, as the distributed configuration of the network delivers the same data to all the nodes;
- Tamper-resistant, since any attempt to modify existing data is prevented by the hashing functions and time-stamping mechanism;
- Crypto-secured, thanks to the adoption of crypto public and private keys enabling P-2-P transactions on the network.

One of the most value-adding contributions embedded into Blockchain revolution is the resolution of trust issues in bilateral and multi-party relationships. In a traditional system relying on a central authority, the mistrust between the involved entities is counterbalanced by the role of intermediaries. By putting themselves in between, they reassure both sides (seller and buyer) to transact even when dealing with untrustworthy and unreliable partners. This intervention absorbs time and money, though, making relationships slow and ineffective. Plus, in centrally controlled transactions the parties lose visibility on information and eventually physical flows, at least for a part of this interaction. Therefore, data flowing through the TTPs can be easily tampered with even if trust issues are solved between players looking for trust and those looking to be trusted.

With BT this model is literally turned upside-down. Digital contents, being these financial or informational, flow from one side to the other with no resource-consuming steps along the way. Information is immediately recorded and easily available.

It is possible to think of this technology as a platform like Wikipedia. The latter, in fact, has an open architecture where words, images and their potential changes are recorded and stored over time. Like Wikipedia, Blockchain can keep track of any change and transaction occurred, with the difference that multiple typologies of assets can be transacted. Titles of ownership, contracts, loans can be all made digitally and handled securely.

2.4 Blockchain technicalities and properties

Many terms have been mentioned more times due to their affinity to the analysed technology. Since the examination of its technicalities could be of great help for a comprehensive understanding of the project, the following part of the paragraph is set to clarify how BT works.

As repeated more times, Blockchain technology represents a mechanism allowing unreliable peers belonging to the same network to perform transactions in a verified way. These actors retain the same version of the truth in a distributed database, as they can openly access and consult all the transactions already occurred. This distributed ledger, where any actor stands as a "node", is transparent, secure and auditable (erisindustriees.com, accessed March 2019).

In order to fully understand the dynamics of its functioning, it is necessary to better address the concepts of transactions, blocks, nodes, transactions validation and mining process.

Blockchain technology supports the exchange of digital assets and information among a group of actors. Each of these ***transactions*** must be meant as the record of a network's activity, where a network activity could be a transfer of money. Every member of the network represents a ***node***, and a Public Key Infrastructure (PKI) is associated to each node. A PKI is a cybersecurity framework for authenticating users in the digital world where one public key and one private key identify one specific user. Users (i.e. nodes) use their private key to sign their own transactions, while they are addressable on the network via their public key, for instance when they receive digital assets from other peers. Specifically, an encrypted message can be sent using the receiver's public key, who in turn will use its private key to decrypt the message. This asymmetric key cryptography is the basis for one-to-one relations in the network, as pairs of keys are mathematically linked. The reason for this is that PKI allows the creation and usage of ***digital signature*** for any node: a message encrypted with the sender's private key can be decrypted by anyone else with their own public keys. Therefore, anyone can verify who sent the message. Lastly, combining digital signatures with hashing, it is even possible to verify that the message has not been tampered with, making transactions on the Blockchain platform secure (Lele, 2019).

On the Blockchain, transactions are assembled into ***blocks***. Therefore, blocks result as a timestamped set of transactions where they are added if proved to be valid. In fact, each of these blocks hosts a batch of timestamped transactions and carries a hash[1] to the previous block. Hash functions are pointers that link together consecutive data blocks, thus creating a chain of blocks (so-called blockchain). The hash pointer of a data block does not only contain the address of the previous block, but even the hash of the data inside it. This makes Blockchain a secure distributed database, since a hypothetical malicious node should modify all the data blocks previously linked to the target one. The model reported in Figure 11, taken from Christidis & Devetsikiotis (2016), showcases how this chain of blocks is structured. Before being added to a data block, though, transactions must be validated. This validation process is application-specific, meaning that different BT networks may have different validation processes. Regardless the process type, a transaction is validated only if it sticks to the specific rules.

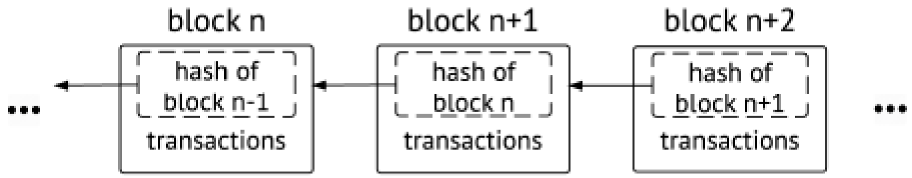


Figure 11: structure of a chain of blocks (from Christidis and Devetsikiotis (2016))

The process of collecting and validating transactions is called ***mining*** and it relates to the validation system mechanism. For instance, a famous validation mechanism is the Proof-of-work (PoW) used by Bitcoin (Christidis & Devetsikiotis, 2016). This is described by Reyna et al. (2018) as "a computationally intensive task that is necessary for the generation of blocks". The PoW is a puzzle resolution requiring a high computational power. In order to solve this puzzle, the "miner" has to find the right random number (nonce) in the block's header that will make its hash (the hash of the header) have an amount of zeroes equal to the one expected by the network. Nodes are called miners as they are incentivized with rewards to run the hash calculations. Generally speaking, mining means to figure out the right "nonce" that makes the block pointed by that hash meet the requirements defined by the validation system. In the case of PoW, for instance, the requirement imposed by the validation system is, indeed, that the hash output must have a specific number of "zeroes". All in all, the overall mining process aims at checking the previous transactions to:

- evaluate whether a network user is entitled to perform that transaction, i.e. transferring a given amount of cryptocurrency;
- solve a computational-intensive mathematical puzzle when adding a new data block to the chain.

PoW and other ***consensus mechanisms*** are put in place to avoid forks and data tamper. A fork occurs when the concurrent generation of blocks in the network bears temporarily different branches, deriving from different miners. As a unique truth must be shared along the whole distributed ledger, forks need to be prevented. Speaking of which, a "pick the longest blockchain" policy is pursued. This makes mining nodes prefer to add blocks to the longest chain, i.e. to the chain with the highest number of blocks. PoW is quite successful in this task as it makes data alteration way too expensive in terms of computational power.

Data alteration represents another problem as well, since the risk is that a single entity joins the network with multiple identities, managing to gain control of it. This event, called Sybil attack, is countered by the nature itself of the examined consensus mechanism. By making computationally expensive the mining process to the nodes, PoW prevents any entity from getting most of the network computational power. Finally, in the PoW development, mining nodes are called miners as they are incentivized with rewards to run the hash calculation.

Alternative to the PoW is the Proof-of-Stake (PoS), which makes mining less CPU-consuming, as the chances of the nodes to mine are proportional to the nodes' balance in terms of cryptocurrencies.

Since the descriptive definition of BT functioning might result confusing, especially for those readers not familiar with cybersecurity, here follows an example adjusted from Christidis and Devetsikiotis (2016).

A blockchain platform works as a distributed database enabling transactions among entities. Its dynamics can be better understood by comparing them to the way a traditional bank's centralized database works. The latter's outlook is a table pointing out the aggregate balances of each customer. Imagine this table as made of two columns: the asset type (ex. USD) and the amount of asset detained by the owner (ex. "100"). Suppose a case where Anna, who owns 100 USD, transfers 10 USD to Barney's account, empty so far. When this transaction takes place, the "quantities" of the asset type detained by the involved owners get updated. Consequently, Anna's account will decrease to 90 and Bob's will increase to 10. What happened was that a digital tokenized asset was transacted. In the Blockchain, this can be made secure, cryptographically verifiable and middleman-free. In this case, the distributed database's outlook would be the same as before, apart from the fact that the owner's name is not displayed in the table, as it is replaced by the public key of the user allowed to edit the row.

Since with BT platform not only digital currencies can be transacted, the asset type in this case will be referred as "X". The starting situation above mentioned where Anna owns 100 units of the asset type is conveyed in the distributed database as a row having "X", Anna's public key and "100" as values. Sticking to the parallel with the previous case, here is how 10 units of X can be transferred by Anna to Barney's account. It is sufficient that Anna signs a transaction to modify her row, moving the amount of X from 100 to 90, and subsequently creates a new row using Barney's public key as "owner", and "X" and "10" as "asset type" and "quantity" respectively. As shown in Figure 12, the creation of a new row assigned to Barney by Anna allowed the transfer of the digital asset.

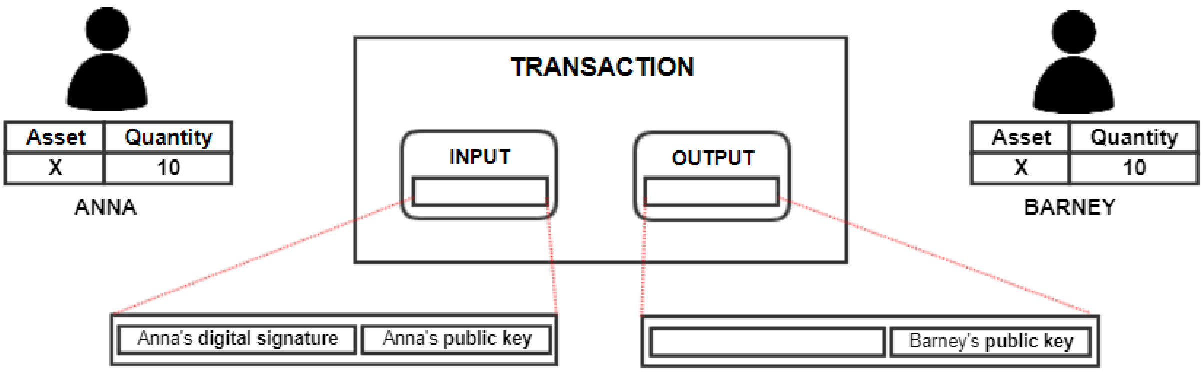


Figure 12: asset transfer on BT (adjusted from Christidis and Devetsikiotis (2016))

At any moment, both users' accounts can be computed as the aggregate of all the rows having their public keys as "owner". Moving beyond this simplistic example, the authors remind that a transaction can involve several existing rows rather than just one. In Bitcoin, these existing rows, created by earlier transactions in the system, go under the name of unspent transaction outputs (UTXO), on the contrary the UTXO consumed are called inputs. Thus, transacting means to delete a set of existing rows (UTXO) and creating new ones (UTXO).

2.4.1 Smart contracts

As time proved Blockchain to be a perfect supporting technology for digital currencies exchange, new evidences and findings brought it to the next level. In fact, as reported by Gatteschi et al. (2018), Blockchain 2.0 disclosed when researchers realized that different assets types besides digital money could be stored on blockchain. Therefore, as pieces of code turned out to be storable as well, the birth of smart contracts occurred.

Despite the term has been used since 1994, when the computer scientist Nick Szabo introduced it for the first time, smart contracts reached the peak only with the rise of BT. Szabo described them as “computerized transaction protocols that execute the terms of a contract''. He prompted that a great value could be unveiled when contractual terms are translated into code and embedded into hardware or software. The initial idea was that smart contracts automatic execution could decrease the dependence on intermediaries in traditional transactions and prevent malicious or accidental exceptions (Szabo, 1997). Reyna et al. (2018) stated that this purpose has been technologically unviable as long as blockchain did not exist. When smart contracts began to be coupled to blockchain technology, in fact, promising possibilities emerged. Matching the trusted environment and disintermediation provided by blockchain with the automatic execution of contractual clauses has represented the starting point of Blockchain 2.0.

Crypto security and verifiability of the network, in fact, made it feasible to code programmable contracts. As a result, these smart contracts became algorithmic codes of contractual terms to be run on BT. When all of these terms are met, these algorithms independently and automatically execute the prescribed outputs. Since smart contracts are stored as scripts on blockchain, they have their own public cryptographic key. Thus, any user of the network can trigger a smart contract simply by addressing the transaction to it.

All in all, smart contracts coded on a blockchain platform are nothing but autonomous actors. Their usefulness to the network is represented by their ability to express business logic in code. This means that when a smart contract is addressed by users, if and only if the contractual terms agreed-upon are achieved, the execution of the contract occurs. The behaviour of these autonomous actors is:

- completely predictable and verifiable, as all the transactions required to execute them are digitally signed;
- deterministic, meaning that the same outputs will always be produced by the same inputs. This condition is essential as otherwise forks would occur in the network, and different versions of the truth would be triggered by different random outputs of the contracts.

Thanks to the programming capability delivered by smart contracts, blockchain matches the requirements of a broad set of further applications, going from domain registration to voting system. For instance, a person could make use of blockchain to manage the inheritance to posterity, by expressing his/her will as a coded smart contract. In this case, information coming even from external sources (like death records), would trigger the transfer of money to the set beneficiary. Lastly, additional conditions might be put in place through smart contracts, like the possibility to transfer assets only after the beneficiary comes of age.

Nevertheless, not all the blockchain platform suit to smart contract coding and execution. Literature in unison points at Ethereum as the platform which best supports smart contracts adoption (Buterin, 2014).

Authors Christidis and Devetsikiotis (2016) still managed to clarify how smart contracts operate on blockchain. The leading example is rearranged from their paper.

Imagine a blockchain network where two digital assets types, X and Y, are traded. Exchanges are made among Anna, Barney and Chris and a smart contract is deployed. Functions of this contract are:

1) “deposit”, allowing to consign units of X into the contract;
2) “trade”, enabling to get 1 unit of X for every 3 units of Y deposited into the contract;
3) “withdraw”, allowing Barney to take back from all the units of any asset types held by the contract.

Functions 1 and 3 are coded so that Barney is the only one allowed to call them, being the contract’s owner. The described smart contract may work like follows.

- Barney address a transaction to the contract’s function “deposit” to move 3 units of X into the contract.
- Anna, instead, addresses the contract’s function “trade” to get back 4 units of X out of the 12 units of Y moved to the contract’s account.
- Finally, Barney calls the function “withdraw” to get all the assets contained in the contract. This function is performed only after the digital signature of the owner is checked.

Each of these transactions is recorded on blockchain as it occurs.

Out of this example it is possible to notice few relevant features. Smart contracts have their own “address” on the network, represented by their public key. They are triggered by users’ messages/transactions that are cryptographically signed and verifiable. A contract can take custody over assets on the network, behaving in a deterministic way. Coherently, a smart contract must be written to properly describe any possible outcome, as exceptions must be avoided.

As already outlined, smart contracts need some agreed upon conditions to be achieved before automatically execute. In order to verify whether it happened or not, smart contracts hark back to the existing information on blockchain. Logically, the network needs some specific external entities to record data from the physical world and report it in the digital realm. These entities or services are called “oracles” and they can be grouped into 4 categories. The software oracles look at the Web as main source of information, differently from hardware ones which are connected to physical sensors. The distinction between inbound and outbound oracles, instead, relates to the information flow direction. If the oracle delivers information to the blockchain it can be addressed as inbound, otherwise as outbound (Dourlens, J. 2017, October 9. “Oracles: bringing data to the blockchain”). Being the information sources standing at the basis of smart contracts execution, inbound oracles play a massive role in the economy of blockchain. Indeed, the aggregate data delivered by all the inbound oracles define whether a smart contract can be processed or not. Considering which, double-checking or verification processes on oracles are frequently put in place by companies as a form of risk management.

2.4.2 DApps, DAOs, DACs and DASs

Few existing projects anticipate what smart contracts may look like in the very next future. Swan (2015) stated that smart contracts are becoming “more like self-contained entities, conducting pre-programmed and eventually self-programmed operations linked to a blockchain”. The author intended those forms of upgraded contracts called Dapps, DAOs, DACs and DASs, respectively standing for decentralized applications, decentralized autonomous organizations, decentralized autonomous corporations and decentralized autonomous societies.

A Dapp is described as an application running on blockchain, a distributed ledger, where information is securely protected, and the execution of the operations is spread across all the nodes of the network. Examples of Dapps can be observed in LaZooz and OpenBazaar. The former is a community-owned platform insisting on resources utilization maximization in transportation. The idea, that might be the decentralized equivalent of Uber’s business model, relies on sharing free seats while driving to a any place, in exchange for a specific reward in cryptocoin. The reward system is based on a “Fair Fare” that is computed depending on the typology of service provided. OpenBazaar, in its turn, is a peer-to-peer online marketplace where anyone can register. Here, users buy and sell literally anything, varying from music to clothes and short-term rentals, exchanging cryptocurrencies. The gain is the complete disintermediation, slamming middlemen and banks out of the game.

In order to move from a Dapp to a DAO/DAC, two additional properties are required. Firstly, the governance must be publicly explained as a sort of constitution. Secondly, the distributed organization needs to provide itself a financing source, like a crowdfunding. In addition to that, DAOs fully rely on smart contracts for the execution of preapproved operations, as ideally the objective is to set up a working corporation where no human intervention is recognizable. Storj is one of the few existing cases of DAOs: it is a decentralized platform enabling peers to buy and sell cloud storage space in return for tokens. The goal is to leverage a monopolized market, headed by Dropbox and Google, where users are forced to overpay for further data storage.

A major development of these decentralized concepts is embodied by the DASs, that are agglomerates of integrated DApps and DAOs working as a stand-alone autonomous society. Here automation starts from the crowdfunding phase and finishes with dividends distribution, involving feedbacks and voting system.

The ideal destination point of the development path of such technologies is represented by the automatic markets, where resources are unitized and autonomously transacted in the basis of both real-time conditions and predefined rules. An example is given by the smart energy grids, where units of energy can be automatically interchanged, sold and purchased among nodes according to system-specific dynamics.

2.4.3 Platform typologies

Blockchain platforms are, yet, not all equivalent. Depending on the circumstances, selecting a specific typology rather than another might save money and enhance performances. Literature showcases a clear diffused distinction between Public and Private platforms. Pai et al. (2018) outlines in their report that a public (or permissionless) blockchain can be joined by anyone. Here any member can write and transact as well, with no need for permission. In a private platform, whereas, only a whitelist of designated members is allowed to perform specific operations. In line with these permissions, the members of blockchain platform might be enabled to read, write and transact. Wust and Gervais (2018) link the choice of platform typology to the verifiability level, the number and the identity of writers. If no selection is needed on the possibility of verifying (reading) data and transactions, a public blockchain is a good solution. Similarly, if the number of writers varies and their identities are not known, still permissionless platforms represent the best option. The authors evidence how different the performances of a centralized database are compared to the ones of a DLT. What emerges as relevant when evaluating BT adoption is the trade-off between decentralization and throughput. In fact, despite blockchain platforms increasingly catching appreciations, centralized databases still prevail when it comes to latency and throughput. The latter indeed processes a higher number of transactions per second compared to the blockchain solutions (Bitcoin only processes seven transactions per second, while Visa manages to sustain more than fifty thousand in the same time). Further discrepancies between centralized and decentralized database are mentioned in Figure 13.

	Permissionless Blockchain	Permissioned Blockchain	Central Database
Throughput	Low	High	Very High
Latency	Slow	Medium	Fast
Number of readers	High	High	High
Number of writers	High	Low	High
Number of untrusted writers	High	Low	0
Consensus mechanism	Mainly PoW, some PoS	BFT protocols (e.g. PBFT [5])	None
Centrally managed	No	Yes	Yes

Figure 13: differences between multiple typologies of BT platform (Wust and Gervais (2018))

Despite the platform typologies are interchangeable at an architecture viewpoint, a more accurate selection is required when it comes to supply chain applications. In Pai et al. (2018), few factors are pointed out as implications of such decisions. Generally, a licensing mechanism on the access activity is required by permissioned platforms, as well as a much higher emphasis needs to be stressed concerning data privacy and security. In fact, security needs to be guaranteed throughout all the layers, starting from the access management to the infrastructure the platform is deployed upon. Moreover, the platform requires to be integrated with the enterprise system. To these terms, APIs (Application Programming Interface) serve as trait d'union between the current configuration of an enterprise and the blockchain processes. Lastly, to overcome the apparent complexity of such technology, developers should work to build up friendly user interfaces.

At the end of the day, it is possible to synthetize the differences between private and public blockchain as follows. Permissionless platforms, like Bitcoin and Ethereum, are self-sustained, meaning that infrastructure costs are totally avoided. Nevertheless, the lack of a licensing system forces to put in place a stronger consensus mechanism, requiring high computational power. Coherently with that, permissioned blockchains like the HyperLedger can run with lower requirements of computational power and higher transactions per second.

One last clarification on the platform categories is given by Casino et al. (2019), that is where the definition of a federated blockchain comes from. The latter is addressed as the result of a hybridization process between public and private platforms, despite logical differences still exist. Federated blockchains draw on a set of leader nodes for the verification of transactions. The readers should remember that such process is carried out by all the nodes in a public version and by single entity in a permissioned one. Further distinctions among the three mentioned types of blockchain are reported in the Figures 14 and 15.

Property	Public
Consensus Mechanism	• Costly PoW • All miners
Identity Anonymity	• (Pseudo) Anonymous • Malicious?
Protocol Efficiency & Consumption	• Low efficiency • High energy
Immutability	• Almost impossible
Ownership & Management	• Public • Permissionless
Transaction Approval	• Order of minutes

Figure 14: differences between public and private BT platforms (Casino, Dasaklis and Patsakis, (2019))

Private	Federated
• Light PoW • Centralised organisation	• Light PoW • Leader node set
• Identified users • Trusted	• Identified users • Trusted
• High efficiency • Low energy	• High efficiency • Low energy
• Collusion attacks	• Collusion attacks
• Centralised • Permissioned whitelist	• Semi-Centralised • Permissioned nodes
• Order of milliseconds	• Order of milliseconds

Figure 15: differences between private and federated BT platforms (Casino, Dasaklis and Patsakis, (2019))

Summing up, six major features stand out when dealing with this peer-to-peer multi-field network: decentralization, transparency, immutability, autonomy, anonymity and open source (Siyal et al. 2019). Data in the network can be accessed, monitored, stored and updated on the distributed connected nodes. This happens transparently, meaning that any potential user has visibility on data storage and recording, so that data alteration and theft are prevented, and update is easy. Immutability is another relevant feature, as recorded data cannot be altered or modified once stored on Blockchain, unless more than 51% of the computing power is held by a single node. Additionally, as already mentioned, a crucial characteristic is that the all network-related services like data access, storage, transfer and update are provided in a reliable way with no middleman acting in between. This provides autonomy and independency from external actors. Concluding, additional value is delivered considering that users are kept anonymous, as transactions occur among nodes, identified with public and private keys. No individuals' names or personal details spill-over can happen on the Blockchain, proving greater reliability than other networks. Ultimately, since this is an open-source technology, users can not only publicly access records, but even develop new applications.

2.5 Strengths and weaknesses of Blockchain Technology

Now that the key technicalities have been discussed and the readers hopefully have a better understanding of a blockchain platform dynamics, it is easier to point out its major advantages and drawbacks. All the concepts faced so far are of crucial relevance, as they allow for a better comprehension of the reasons why blockchain is not a silver bullet for any situation. Peer-to-peer network, distributed ledger, consensus mechanisms, mining process, basic cryptographic logics and smart contracts are all topics standing at the basis of a comprehensive vision of BT.

The first focus of this paragraph is on the strengths of BT technology. These are listed as follows:

1) **Visibility and transparency**: any platform participants can read and verify the occurred transactions, unless explicitly encrypted. When brought into SCM terms, this is a game-changing mechanism, as participating entities can have a full overview on the whole journey of a product/item along the chain. The accessibility of data within the platform enables end-to-end traceability, so far not feasible for the

existing information sharing dynamics (Gatteschi et al. 2018). SC members using blockchain can therefore extend their understanding of the processes at systemic level, adjusting and optimizing their operations at enterprise level, like improving demand forecasting. Abandoning the antique OUOD (One Up One Down) approach, typically adopted by companies to get a grip on the first upstream and downstream layer of players; organizations can leverage a more exhaustive visibility on the supply chain (Insolar, 2019).

Nevertheless, data encryption operated via cryptographic keys is a mean to keep information exchanges confidential (Vyas et al., 2019).

2) **Decentralization**: the innovative configuration of DLTs is the entry door for a set of unique features. First of all, a certain degree of robustness is achieved by taking centralized entities out. Since the system is shared among multiple peers, there will no longer be a single point of failure, but as many as the number of nodes. This makes the database more resilient and tolerant of nodes failures (Babich & Hilary, 2018). Furthermore, the elimination of intermediaries allows peers not to have to trust any entity, except for the platform itself. The maintenance of the platform does not rely on the actions of a TTP, letting transactions be performed smoothly and frictionless (Treiblmaier, 2018). The other way around, decentralization permits to gather and aggregate information from a myriad of sources.

3) **Data validation and immutability**: the existence of a stored transaction on the distributed database is a warranty itself of its validity (Babich & Hilary, 2018). In fact, the robust identity management process combined with the consensus mechanisms make these transactions secure. A further proof of the system resiliency is provided by the immutability of the stored data. Blockchain is an add-only, temporally ordered database, where hashes and the distributed nature make it almost impossible to tamper with the information. Information auditability, lastly, prevents disputes that otherwise would require time and money to be solved (Wang et al. 2019).

4) **Automation and efficiency**: blockchain offers the possibility to digitally translate and code business rules for the government of expected dynamics. The codification of contractual terms occurs via smart contracts and it is the first step for the creation of DApps, DAOs or furtherly developed forms (Swan, 2019). When all the terms reported within the smart contracts are met, the upon agreed actions are automatically executed, bypassing time-consuming approvals and steps. This results in a much higher efficiency, for instance when automatic payments between suppliers and buyers make operations faster but still reliable

As far as it concerns its weaknesses, this is what the existing literature has to say on blockchain. The next bullet list is a comprehensive summary of them all.

1) **Technical issues**: due to the consistent complexity level embedded within blockchain, many practical challenges pop up. The following list aims to clarify them.
   - **Throughput, size and latency**: as previously mentioned, the number of transactions per second sustained by blockchain has nothing to do with the standards of other transactions processing networks. The throughput capacity of blockchain is estimated to be equal to the 0.35% and 0.14% of respectively Visa and Twitter capacity. Practitioners claim that such limitation can be treated by enlarging the "block" size, meaning to put more transactions (data) in the same block. About that, problems already exist regarding the system latency. As it currently works, any transactions block requires at least 10 minutes to be confirmed, and this time proportionally increases with the target security level and the size of the transfer.
     On the other turn, though, concerns are raised regarding the topic of necessary data storage. Swan (2019) computed that in order to level off with Twitter's throughput standards (typically around 5000 tps), a blockchain network would ask for 214 PB/year, which is otherworldly. This is the reason why future researches need to be focused on innovative compression algorithms or further enhancements of the so-called APIs, that are applications automatically calling and connecting to Blockchain. Until these issues will remain unsolved, any blockchain application could hardly reach large-scale dimensions.

- **Energy consumption**: statistics about the amount of energy required by blockchain are astonishing. Digiconomist.net showcase the estimated energy consumption of Bitcoin, as in the Figure 16 below.

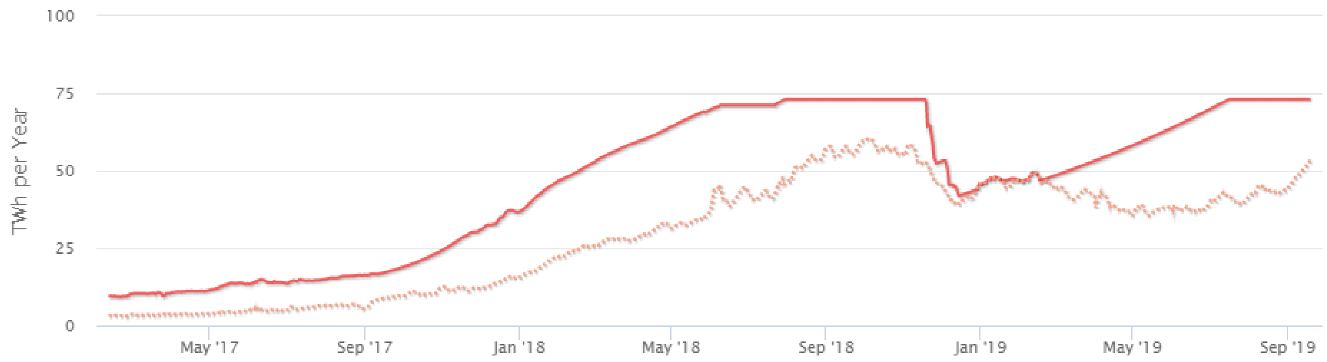


Figure 16: Bitcoin energy consumption (from Digiconomist.net)

The same website quantifies the environmental impact of Bitcoin through a series of benchmarks. The annual carbon footprint of Bitcoin is comparable to the one of Denmark, while it looks like Austria consumes the same yearly amount of electrical energy as Bitcoin. Furthermore, despite the comparison between Visa and blockchain is strongly unbalanced towards the former in terms of throughput, a transaction conducted on BT has the same carbon footprint as 731,291 transactions on Visa (equivalent to 48,753 hours of watching YouTube). Maintaining the distributed ledger and, above all, mining are the key reasons for this need for computing power. The signature verification required by any transaction with cryptographic scheme is what triggers the energy requirement. In a blockchain network, in fact, every node has to validate every transaction, resulting in a huge aggregate energy consumption (Min, 2019).

- **Network security**: like any network running on the Internet, blockchain can potentially become the victim of hack attacks. These are diverse, numerous and linked to the type of consensus mechanism (Bitfuri, 2016). Despite technically possible, most of them are extremely improbable. Here is a list:
    - 51% attack: it is a consequence of the network democratic functioning. It happens when a group of miners manage to get the majority of

computational power (at least 51%, as the name suggests). A major prevention against this kind of attack is the adoption of permissioned blockchains, where all the members are known and constrained by a licensing system. The key threat is the tendency in centralizing the mining process into few mining pools that end up controlling most of the transactions (Golosova & Romanovs, 2018).

- Sybil's attack: it still relates to permissionless platforms, where the adoption of PoW as consensus mechanism can mitigate its effects though. This attack consists in the creation of spurious nodes to get the control of a system, but can be counterattacked by imposing a computational cost (Vyas et al., 2019).
- Double-spending: it occurs when a malicious entity spends the same asset twice by sending multiple orders in rapid succession. Technically, double-spending is prevented by time-stamping transactions and agglomerating them into blocks.

Regardless the attack typology, one common output of a distributed network malfunctioning is the creation of forks. It occurs when the chain of blocks is split. Possible reasons for this are the update of the software or when multiple miners mine the same block at the same time, triggering the creation of two or more different versions of the blockchain. Differences between the two types of forks, hard and soft, are linked to the compatibility of the two (or more) versions of the software. In case of hard fork, these are incompatible as typically changes in consensus rules are brought. Logically, soft forks produce software versions that are still compatible (Medium.com, September 5, 2019).

2) **<u>Legal issues</u>**: there are a lot of open questions regarding the regulatory sphere of blockchain technology. Many governments still lag behind digital innovation, as BT rise has found a lot of them unprepared to adapt or manage such a potentially impacting technology. Especially, Swan (2015) put emphasis on a few aspects like taxation, economic performances measurement and business models. With blockchain predicted to revolutionize financial services and payments, a first major governments' concern is to make it stick to taxes regulation. The possibility of developing decentralized P2P sharing economy, merging Airbnb-like features with BT opportunities, is perceived by regulatory authorities as a challenge, as new practices and ruling systems must be put in place. The diffusion of cryptocurrencies, also considering the nimbus of mistrust surrounding them, must be carefully handled by governments. Moreover, traditional schemes for measuring economic performances must be reviewed as well, as they contemplate consumption as the only criterion to evaluate countries' GDP.

Similarly, governments still have to understand how to assimilate BT and deal with it. Swan (2015) underlines that there could be a positive integration between them, as one might make use of the other to simplify daily processes. In particular, blockchain technology is claimed to support governments in their record-keeping activities of information. In the new era of big data, in fact, governments are called to reshape their value propositions and business models to cope with the enormous data flow. The shift to blockchain-based governments is also argued to possibly contribute to the elimination of entire costly public services. Nonetheless, the path to a successful integration is still long and intrigued, worsened by uncertainties linked to the technology itself.

Regulatory concerns also exist in the context of technology standards. Babich and Hillary (2018) reason that BT development must be handled more structurally, as nowadays the diversity of protocols is a big obstacle. So far, blockchain applications have developed flexibly, sustained by their exploratory rationale. Nevertheless, now companies need to approach it in an organized and legally secure way. Past protocols have made it difficult to set guidelines for harmonized BT implementations, since they have developed independently.

3) **Trust issues**: another consistent hinder for BT is that, due to current uncertainty about its future evolution and to past events, a general scepticism has developed. Besides its technical imperfections, in fact, blockchain must deal with cautious industries, mainly interested in the economic return, and fearful Individuals, threatened by misgivings related to data privacy. Overall, this negative perception

can be attributed to the idea that "crypto is bad". The association of BT to cryptocurrencies is a primary reason of such mistrust, due to multiple scandals in recent years (Yeoh, 2017). An example of such failures is represented by Liberty Reserve, a Costa Rica-based provider of anonymous virtual money transfer services, associated to the money laundering activities. Liberty Reserve was used to support 55 million criminal transactions, contributing to generate an estimated worth of 6 billion USD.

Potential users are massively frightened by leakages in terms of data privacy. Zheng et al. (2018) stressed that despite the common believe on BT safety, sustained by the possibility to transact with virtual addresses rather than real identities, transactional privacy is not guaranteed. This means that all the transactions values and balances are visible for each public keys, which might be used to discover users' information. When the same address is used by users for multiple transactions, in fact, it is possible to associate addresses to users. Mixing is named as a possible solution, consisting in a service which "provides anonymity by transferring funds from multiple input addresses to multiple output addresses".

Alongside with these factors, Babich and Hillary (2018) discussed the concept of black box, in association to BT. In their paper, authors indicate that, in SC domains, while from one side it enables disintermediation, on the other side blockchain requires meta-trust. They questioned that, despite users are freed from the duty of trusting a counterparty or a middleman, with blockchain they are asked to trust a platform and its processes, whose technicalities are a black box. This contributes to generate uncertainty and to further hinder BT diffusion, especially in industrial realms.

Still referring to industrial scenarios, the GIGO phenomenon is reported as a problem. In the attempt to link the physical world with the digital one, challenges may emerge. Firstly, data flowing into BT platforms from physical oracles might be incorrect or tampered with, as generally devices can be easily hacked. Thus, this issue, called "state-zero" problem, must be carefully treated, since no or limited countermeasures exist to tackle it at its origins. Secondly, transferring data from the real world to a BT platform might be problematic if data in the real-world changes but its digital version is not kept updated. A solution to this can be the adoption of smart devices, capable of a continuous interaction and automatic data updates. In this case, though, the investment required to develop a fleet of smart sensors and to maintain it can be prohibitive for some companies.

2.6 Blockchain Technology applications

A considerable abundancy in BT applications has been registered in several fields. This testifies how broadly its potential could be exploited. Despite this research univocally relates to the industries of Logistics and Transportation (L&T) and Food and Beverage (F&B), having the big picture on the whole set of scattered BT adoptions is helpful to get an idea of this innovation diffusion. Different usages come from finance, banking sector, government, insurance, gaming and many others. Still, automotive and mobility, Life Sciences & Healthcare (LSH) and Retail & Consumer (Ret&Co) are said to be the most promising industries. Having said that, global trade seems to be the perfect match with BT, as this solution has the potential to increase global GDP by 5% and global trade by 15%, through supply chain barriers reduction (DHL Trend Research, 2019).

Here is a list of wide-ranging applications, clustered in different sectors.

1) in LSH, Blockchain has proved to offer valuable alternatives to Electronic Health Records (EHR), clinical research, medical fraud detection, neuroscience research and pharmaceutical industry and research. All of these usages leverage the mechanism of data set stabilization, allowing users to interact through different types of transactions. As sensitive data linked to patients' medical records are handled, the capacity of BT to make the movement of this assets secure reveals to be extremely precious. For instance, provided that patients are prone to leave their medical records scattered all over multiple institutions, solutions like "MedRec" deserve high stakes. It is a Blockchain prototype aimed at providing patients with their detailed and immutable records regardless the provider detaining that information. This

patient is the only owner of the entire history and can decide where this data can eventually be moved (Siyal et al., 2019).

In the pharma industry, drugs authentication has always been a great deal. Potential drugs' production process must be monitored and evaluated, as well as transportation and final delivery conditions (Mettler, 2016). Furthermore, counterfeit drugs production and distribution deliver fake drugs to the market, under the eyes of powerless controlling authorities. Even in this case, Blockchain can be a best-fit solution. As testimony to this fact, a pilot project has been jointly launched by Sanofi, Pfizer and Amgen to inspect new drugs via blockchain-based digital drug control system, as reported by CoinDesk.com (2018). The same website reported that Canadian firm Boehringer Ingelheim started to partner with IBM in 2019, leveraging tech giant's BT platform to improve clinical trials.

2) In Finance and Banking, intermediation role played by banks and other financial institutions has always raised controversy. Blockchain and cryptocurrencies stand as a new hope due to the promise of taking over these players in financial transactions. Recent digital business developments paved the basis for a model where transaction costs are demolished and money transfers are fast and cheap. Celsius Network is an example of these new blockchain-enabled financial solutions, where depositors' concerns come before institutions' profits and interest rates. Celsius Network is a decentralized interest income and lending platform, easily accessible via mobile app. Differently from the traditional banking dynamics, where institutions just pay back less than 1% interest to customers, Celsius Network manages to take this value to 7.1%. Despite scepticism is obviously lingering around this model, the drivers are reported to be the use of BT and the achievement of the critical mass, besides the desertion of the unfair common financial system. The network developers argue that banks can provide better interest rates as well, they just don't want to renounce their current profit model, accounting as the 80% of their return on capital (Medium.com, September 8, 2019. "Celsius Network Interest Rates, Explained").

   Another renowned instance is Batavia, a global trade finance platform running on Blockchain. In 2016, IBM, Erste Group, Commerzbank, CaixaBank, UBS and the Bank of Montreal joined their forces to create an integrated service provider for shipment-related activities, from warehouse to the point of destination. The objective was to overcome the traditional ineffective model, where hundreds of transactions occur between dozens of players. In this last solution, paper-based processes and manual work, together with a scarce visibility on the whole shipment processes were the reason of slow financial flows and difficulty in providing loans. Batavia platform solved most of these challenges, enabling sellers, buyers, inspectors, banks, transporters and regulators to share and store documents permanently. Transparency and all-length visibility were the major advantages, opening to easier access to trade finance solutions and to consistent savings in time and money (Brink et al. 2018).

The International Data Corporation (IDC) report affirmed that the financial services one is the sector with the highest investments, 552 million dollars, in blockchain projects in 2018.

3) In Governmental and public sectors, BT has already been tested as enabler of faster, more friendly and digitalized services. The literature, in this case, prompts some insights. Forbes (2017, “Dubai Sets Its Sights On Becoming The World's First Blockchain-Powered Government”) announced ambitious plans of Dubai to become the first ever Blockchain-powered Government. The project wants an equivalent amount of 100 million documents per year running only on blockchain. Moving visa applications, license renewals and bill payments to a digital world is forecasted to worth 1.5 billion dollars per year, as paper-based related activities would be avoided. A further testimony of BT usefulness and adoption rate is given by the decision taken by the Estonian Government to issue digital identities for every Estonian citizen. E-identity allows people to digitally sign by using their ID-card, Mobile-ID or Smart-ID, thus accessing e-services with no troubles. Practically, this shift to digitalization, permitted by Blockchain platform, positively affects citizens’ lives. They can exploit their digital identity for the national health insurance, for I-voting, to use e-Prescriptions (e-estonia.com, 2019).

Furthermore, 2018 was the year when Sweden's land registry authority collaborated with a set of banks and start-ups to move land registrations on Blockchain. ChromaWay is the Blockchain startup driving the pilot, with SBAB Bank and Landshypotek are the financial firms actively participating (Kim, C. 2018, June 15. "Sweden's Land Registry Demos Live Transaction on a Blockchain" from CoinDesk.com).

4) Blockchain technology also contributes to build up new business possibilities in the future. Indeed, the marketplace-based solutions are said to become more common with the raise of Blockchain. Online marketplaces, in fact, may leverage at full its transparent connectivity and network to foster their performances. Tokenization features powered by BT would allow users to exchange diverse typologies of assets, pushing buyer-seller relationships to a new level and delivering new economic solutions. A quick intuitive example of these marketplaces user-friendliness can be found in Facebook's Online Marketplace. This is a way to make the most of the network power, exploiting connections to transact value, but literature has extensively discussed related possibilities.

   An example of Blockchain-based marketplace is Slock.it, a public network where properties and services sharing is made secure and fast. The platform relies on smart electronic locks, called Slocks, which can be timely accessed through mobile app. From one side assets owners define prices for a timed usage. On the other side, by purchasing the associated tokens on the Ethereum blockchain, users can unlock these Slocks to access assets or services. This solution is likely to find applications in rentals of cars and houses, as the two sides of a transaction can easily communicate and interact. Peer-to-peer secured connections provided by blockchain-based platforms are extremely powerful as they suit to different assets exchanges.

   For instance, In New York, TransActive Grid aims at transforming the renewable energy market via blockchain. The concept is to create a network where different nodes (ex. buildings or single apartments and houses) buy and sell the exceeding amount of energy produced by the respective solar panels. Furthermore, energy and financial flows among involved parties would ideally occur automatically via smart contracts (Kshetri, 2018).

A very similar project has been tested in Brooklyn, Germany and Australia under the name of LO3. Still, the core objective was to develop a P2P energy marketplace within a blockchain-enabled network. In this case, microgrids for energy production and storage have been used to allow connected devices operating as platform nodes (Reyna et al., 2018).

One last use case of a similar BT adoption in the energy sector is given by IOTA, a DLT provider, and ElaadNL, innovative Dutch company in the field of Smart Charging. On April the 18th 2018 they jointly launched the first charging station operating Machine-to-Machine transactions with IOTA BT-alike platform. The latter enables fees-free micropayments and secure data transfer, opening to a future where charging cars will just require plugging the pump. In this way transactions occur spontaneously with no charge card or transcription needed (Van den Brink, M. 2018, April 19. "World's first IOTA Smart Charging Station", from Blog.iota.org).

All of these examples may even help the readers to get an idea of the value that combined digital technologies are able to deliver to modern businesses.

5) Insurance companies have recently started looking at blockchain and IoT integration to revolutionize their sector, as testified by the creation of the first blockchain-centred insurance consortium in 2018 (CoinDesk.com, 2018). Despite that, facts are that this technology is a topic still needing for further investigations. Insurance organizations, even more than in other industries, seek for emblematic use cases to proof real benefits. This is the reason why it is not possible to think of massive diffused investments in this sector before the next 3 to 5 years (McKinsey & Company, 2017).

   Anyway, some tested projects and use cases have already proved which contributions could be introduced. Gatteschi et al. (2018) examined them, as reported in the next lines.

   First, claims processing activities can be accelerated and made more reliable by offsetting manual tasks. For instance, refund can be automatically transferred via

smart contracts to customers only if cars are proved to be repaired at certified mechanic. Few policies could suit this autonomy in transactions though, as in many cases an external evaluation by experts is required.
Furthermore, similarly to what has been discussed when dealing with e-identity, BT serves at easily identify individuals. By providing their information only at the first service access, customers would not be required to provide it again or to use an identification document, as their credentials would be automatically recorded on the platform. This would ensure savings in time and cost, just by optimizing data entry and identification procedures.
Although many privacy-related concerns are associated to that, insurance companies may make use of BT technology for premium computation, risk assessment and fraud prevention. This would be achieved by enabling a multiple-source record and sharing of information among insurance agencies, police officers, medical institutions and potentially even wearable devices. By triangulating different information typologies, insurance premiums can be adjusted on the deriving customer's profile and frauds can be prevented. One of the applications that result feasible the most is linked to pay-per-use solutions, where smart contracts and IoT integration would allow, for instance, to collect premiums when specific conditions are matched. A practical example is represented by an insurance premium starting from the moment a customer is picked up by a Uber driver. Lastly, Peer-to-Peer insurances are discussed as the next-generation formula, as DAOs hard-coding and adoption would help to overcome existing obstacles.
The authors even built up a SWOT analysis that generalises the key features of BT technology.

	Positive	Negative
Internal	Strengths - Fast and low-cost money transfers - No need for intermediaries - Automation (by means of smart contracts) - Accessible worldwide - Transparency - Platform for data analytics - No data loss/modification/falsification - Non-repudiation	Weaknesses - Scalability - Low performance - Energy consumption - Reduced users' privacy - Autonomous code is "candy for hackers" - Need to rely to external oracles - No intermediary to contact in case of loss of users' credentials - Volatility of cryptocurrencies - Still in an early stage (no "winning" blockchain, need of programming skills to read code, blockchain concepts difficult to be mastered) - Same results achieved with well-mastered technologies
External	Opportunities - Competitive advantage (if efforts to reduce/hide the complexity behind blockchain are successful, or in case of diffusion of IoT) - Possibility to address new markets (e.g., supporting car and house sharing, disk storage rental, etc.) - Availability of a huge amount of heterogeneous data, pushed in the blockchain by different actors	Threats - Could be perceived as unsecure/unreliable - Low adoption from external actors means lack of information - Governments could consider blockchain and smart contracts "dangerous" - Medium-long term investment - Not suitable for all existing processes - Customers would still consider personal interaction important

Figure 17: SWOT analysis on BT (Gatteschi et al. (2018))

Despite the mentioned applications may sound extremely appealing; proof of concepts, prototypes and large-scale testing are required to truly evaluate their feasibility. In fact, the numerousness of the involved actors, some serious privacy-linked issues and architectural challenges may make either organizations or customers reluctant.

Obviously, many of the most valuable BT-based applications refer to the industries of L&T and F&B, which will be directly analysed in during the research development.

3. INTERNET OF THINGS

3.1 Historical notes of Internet of Things

The birth of the so-called Internet of Thigs phenomenon comes as a new chapter of the human attempt to connect things to the Internet, after its invention in 1989. At the beginning it was simply about activating a toaster via Internet, but enormous advancements followed up. 1997 was when the first description of sensors was introduced by Paul Saffo. In the middle of the 1990s, the idea was to create an "embedded Internet", as defined by Intel, leveraging some crash-proof computers embedded into products of daily usage to expand connectivity to unthinkable levels. eventually, the term "IoT", which did not reach a mainstream adoption till the second decade of 2000, was coined by Kevin Ashton in 1999. During one of his works at Procter&Gamble, while talking about the introduction of RFIDs in supply chain, Ashton named his presentation "Internet of Things", by making reference to the hottest concept of that time, the Internet. Among the first forms of "Things" were the RFIDs, whose adoption skyrocketed in 2003, when the US Army started using them. It is after that, and above all after the launch of IPv6 in 2011 that the IoT covered a lot of ground (Suresh et al. 2014).

As mentioned, the epithet got lost for more than a decade, when in 2011 Gartner, a company famous for its "hype-cycle for emerging technologies", introduced the Internet of Things as a new emerging phenomenon. Since then, the name has made headlines, entering the traditional vocabulary of relevant tech-savvy magazines, authorities and practitioners. Despite this, a sort of confusion is associated with the term Internet of Things due to the lack of a formally and universally recognized definition. Many other terms, in fact, have been widely used to mean concepts somehow related, but not equivalent, to the IoT. Some examples are Machine-to-Machine (M2M), Industry 4.0, Smart systems and Pervasive computing.

During its diffusion, the IoT found significative linkages with the concept of "smart environment". The latter was defined by Mark Weiser, the forefather of the Ubiquitous Computing, as "the physical world that is richly and invisibly interwoven with sensors, actuators, displays and computational elements, embedded seamlessly in the everyday objects of our lives, and connected through a continuous network". As Weiser suggested, there was the need to rethink of the role of Human-to-human and human-to-computer interactions, being the PC too complex and isolated at that time. The hint, giving rise to the idea of smart environment, intended to frame humanity within a world of ever-lasting connectivity, where anything is connected through the Internet. To this matter, Caceres and Friday (2012) identified two technologies necessary for the ubicomp (Ubiquitous Computing) to materialize. From one side, the authors spotted in the wireless sensor network (WSN) the hardware infrastructure capable of generating and exchanging data for the ubicomp. Such network was thought to be the result of the latest advancements in miniature devices, digital electronics and wireless communication. On the other turn, Cloud Computing was appointed as the best-suit technology for its digitalised storage capacity and, above all, for its ability to interpret and visualize data coming from the sensing side.

The result is the triad Sensor-Actuator-Internet that the authors describe as the core framework supporting the creation of a smart environment.

It is after such evolution that nowadays the IoT stays for a world where communication and information systems are invisibly embedded in the physical world, generating huge amount of data. The geographical dispersion of different "things" -RFIDs, smart sensors, smart devices, etc.- allows for continuous and enlarged interactions, where data flows timely and seamlessly. In this new reality of enhanced connectivity, Cloud Computing does work as the digital infrastructure to transform the integrated data, coming from multiple sources, through services. Finally, the provision of such services is reported to follow a traditional commodity-alike model, where businesses and users can make use of on-demand applications (Gubbi et al. 2013).

3.2 Internet of Things market

Statistics about the Internet of Things leave no doubt about the size and relevance of such technological trend. What firstly impresses is that forecasts report an astonishing rise in the number of IoT connections. The GSM Association Report "The mobile economy" (2019) recently foresaw that more than 16 billion new IoT global connections are expected within 2025, advancing the overall value to 25,2 billion. The same source evidences how most of the market value deriving from IoT actually relies on the applications, platforms and services layer. Almost the 65% of the overall value was linked to this layer, with increasing forecasts increasing up to 69%, amounting to $754 billion. Such boost is mostly attributable to the encouraging related investments in Smart homes and Smart buildings, contributing to zoom in the hot topic of Smart Cities.

Further numbers describing the market value hidden behind the IoT realms have been found on marketsandmarkets.com (accessed in October 2019). Here some reports give specific clues on consumer IoT market and the industrial domain.

As for the former, a CAGR of 17,39% is estimated to be responsible for a vertical growth on a 6-year period of analysis, starting in 2018. At the end of this time window, in 2023, this market section is said to generate a value of $104,4 billion. Main reasons for this boost were identified in the increasing number of Internet users and more widespread adoption of smart devices, together with a particularly higher awareness about fitness.

A slightly weaker growth rate (7,4%) will push the industrial IoT market to a remarkable peak of $91,4 billion in 2023. In this domain, major contributions are expected from few big American players (Cisco, GE, Intel and IBM) and other major names like ABB, Siemens, Bosch and Huawei. In this case, the main evolution drivers are indicated in the diffusion of Cloud-based platforms as alternatives to PC-based models and the proliferation of smart devices.

3.3 Internet of Things definitions

As already verified, authors still struggle to agree upon an ultimate definition around the concept of Internet of Things. What appears clear from the review of the state-of-art literature is that, like ascertained by the IEEE (2015), the definition is author-biased. The diversity in the descriptions, in fact, has to be attributed to the asset typology the authors are more interested in. The vastity of the IoT concept permits different writers to put the emphasis on a particular nuance rather than on others.

Despite this, it was possible to pinpoint few comprehensive and objective definitions. As it might be obvious from the preview, they cannot proof unanimity over the examined argument. Nevertheless, the understanding of the underlying differences is presented to get a comprehension of the IoT as exhaustive as possible.

- Atzori et al. (2010) tackled the multidisciplinary nature of the topic by identifying the three paradigms IoT is articulated into. These are: the semantic-oriented paradigm (knowledge), the things-oriented paradigm (sensors) and the internet-oriented paradigm (middleware). Despite this discrimination has the merit to distinguish between different stakeholders' needs and interests, it needs to be stressed that IoT results particularly meaningful at the intersection of all the three paradigms.
- Forrester (2010) contributed to the clarification of IoT as associated to the idea of smart environment. The author, possibly biased by his field of interest -smart cities-, states that smart environments use "*information and communications technologies to make the critical infrastructure components and services of a city administration, education, healthcare, public safety, real estate, transportation and utilities more aware, interactive and efficient*".
- Later in time, Gubbi et al. (2013) offered a definition that is intentionally detached from any protocol. With the intention of delivering a more user-centric presentation, the authors talk about the IoT as the "*Interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications. This is achieved by*

seamless large-scale sensing, data analytics and information representation using cutting edge ubiquitous sensing and cloud computing".

- Lastly, the IEEE proposed their vision of the Internet of Things. The latter seems to be the most comprehensive as well as the most complex available from the literature; addressing it like *"Internet of Things envisions a self-configuring, adaptive, complex network that interconnects 'things' to the Internet through the use of standard communication protocols. The interconnected things have physical or virtual representation in the digital world, sensing/actuation capability, a programmability feature and are uniquely identifiable. The representation contains information including the thing's identity, status, location or any other business, social or privately relevant information. The things offer services, with or without human intervention, through the exploitation of unique identification, data capture and communication, and actuation capability. The service is exploited through the use of intelligent interfaces and is made available anywhere, anytime, and for anything taking security into consideration.*"

Out of these four characterizations of the IoT, the one provided by the IEEE gives most of the specifications. Such definition strongly relies on the distinction between small and large environments, with a better suit to the second ones. The discriminative criterion between the two is represented by the level of complexity of the IoT system. In the first case, system complexity is low as "Things" are presented as uniquely identifiable, with sensing/actuation capabilities and programmability features. The previously reported definition, instead, refers to an IoT system characterized by a high number of things and multiple "administrative domains". In order to cope with such complexity, some additional properties become relevant, such as system scalability and distributed logics. Since both the cases showcase a set of technologies that are uniquely identifiable, programmable, with sensing/actuation capabilities and ubiquity, the major difference between the IoT in small and large environments turns out to be the provision of services in complex systems. In the latter, in fact, things are not only there to grant access to data sources, but they exploit all the pre-listed properties to deliver services through intelligent interfaces.

3.4 Internet of Things technicalities and properties

A fundamental premise to be made before investigating its structural aspects is that IoT must be distinguished from other two similar topics: Cyber-Physical Systems (CPS) and Wireless Sensor Networks (WSN).

As for CPS, despite similarities are not negligible concerning collaborative activities among sensors and actuators for a specific goal achievement, connectivity to the internet is missing. Since operating on the Internet is a major feature of IoT, the analogy with CPS stops at the univocal identifications, sensing and actuation abilities and collaboration between things. In the end, thus, at an application viewpoint CPS identifies a set of objects networking for a common objective.

Whereas, similar discrepancies can be found between the WSN and the IoT. Literature makes it clear that the wireless sensor networks can be thought as a part of the IoT environment, specifically providing the sensors that in the IoT are typically inserted in the same network to collaborate. WSN is just a *"spatially distributed network of autonomous sensors that monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and cooperatively pass their data through the network to a central location".* What is missing to the WSN to advance at the IoT level is that same "smartness" property that contributed to discriminate between WSN and PCS.

Made these premises, it is now possible to examine the architectures of this emerging technology. Despite there is no concurrence on a univocal definition, authors mainly agree when it comes to the architectural side. The common belief is that the Internet of Things draws on a 3-layer structure:

1. The first layer, the things-oriented paradigm as Atzori et al. (2010) would name it, is made of the large set of ***technologies responsible for identification, sensing and communication***. The achievement of the so-called ubiquity, namely the capacity of

a network to be available anywhere and anytime, is the final goal of the layer. In this context, many components can take part to the layer, especially considering the evolution towards smaller, lighter and less power-intensive objects. At the top of the list it is likely to find the category of RFID systems, that are made of one or more readers and multiple RFID tags, with the latter being tiny microchips embedded to an antenna. Considering their functioning, RFID systems are suitable for real-time monitoring of the real world. Since each tag has a unique identifier, when the readers generate the tag-specific signal, tag transmission is triggered, so that the reader can receive information about the tag's ID (ex. location). When physical assets are embedded with RFID tags, this procedure allows for a fast and effective management, by creating a link between the digital and real worlds. Virtual entities and physical entities are, therefore, paired together, with the two being their own reciprocal extension.

Alongside with RFID systems, sensor networks can powerfully support the IoT, providing complementary or additional information with respect to the one delivered by RFID. The difference between the two technologies is that sensor networks are spatially distributed devices reporting information about location, temperature, etc. to a set of pre-defined nodes -called sinks. Further dissimilarity is given by the impossibility of sensor networks to seamlessly integrate its nodes into the Internet. In light of the possible integration of sensing technologies into passive RFID tags, it is possible to evidence three major solutions for this layer: RFID systems, WSN and RFID sensor networks (aimed to support sensing, communication and computing abilities in a passive way).

In more general terms, the IEEE (2015) describes this hardware layer as composed by few principal object typologies: tags, interrogators or readers, sensors and actuators.

2. The second architectural level is occupied by the ***middleware***. As the name suggests, it represents an in-between layer bridging together the purely software layers of applications and the purely hardware one of sensing, communication and identification devices. The functions of this layer are crucial: it generally integrates

information from several sources (Eschenauer and Gligor, 2002) and facilitates the development of new services, by hiding the different oracles/technologies details. In this way, programmers typically working at the upper layer can exclusively focus on the creation of new applications, without questioning features that are out of their preparation field.

A key mechanism associated to the middleware is the Service Oriented Architecture (SOA) approach, which embodies the principles governing the middleware functioning. According to the SOA, applications are built on a modular logic, by dynamically aggregating multiple elementary and well-defined components, i.e. the individual services. The advantage of such configuration is to support complex environments in evolving contexts. Therefore, the SOA is explained as a software architecture that disaggregates business objects “monolithic” into structured agglomerates of services, whose functionalities are specifically designed on the changing business needs. In the IoT context, the implementation of the SOA approach is a key enabler for sharing or reusing the same isolate resources among the same applications (Gubbi et al. 2013).

Through the adoption of standard protocols and common interfaces, the multifaceted enterprise system is addressed horizontally. This enables simple interactions within the fragmented enterprise structure, providing a high-level flexibility towards the evolving market conditions.

Among various other benefits deriving from the SOA approach, particularly valuable for the IoT are the reusability of single components (services), as agreed by Atzori et al. (2010), and the interoperability of different platforms through a common language.

A sketch (Figure 18) of the middleware functioning is proposed by the authors to foster a clear comprehension. Since this functioning deeply relies on the participation of the application layer, its explanation will be presented soon after.

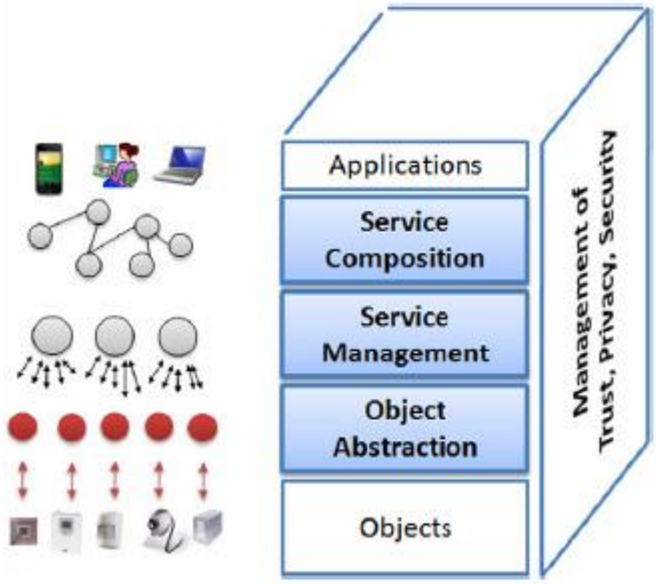


Figure 18: SOA-based architecture for the IoT middleware (Atzori et al. (2010))

3. The last layer composing the IoT architecture is that of the ***applications***. Its major goal is to move the data collected by the first layer and elaborated and integrated by the second, to the final user. This role, which is a crucial link between distributed systems and applications, typically encompasses visualisation activities to report the content.

   Moving a step back to the SOA-based architecture, it immediately looks evident that for the creation of application and the existence of the correspondent layer, the service composition layer is essential. This is where the functionalities for composed services can be found and the system flexibility comes from. In fact, the development of composed services is done in function of the design and representation of complex business processes. Here, Web Service operations make possible for business processes to interact with external entities, but no notion to any physical device is made.

   Soon below, the service management pays its contribution to the middleware architecture. Here, a consistent support is provided by a Web Repository whose scope is to show the list of services associated to the various devices across the network. This functionality is relevant for the upper layer as it enables the development of the composed services, roots of the final applications. Upon the service management layer, new single components (services) can be originated to address emerging case-specific interests. This process typically adopts software components (resources) that can be subdivided into two classes: on-device resources and network resources. The level of their availability marks the distinction between the two categories, with the first locally deployed on the device and the second accessible somewhere at network level. A separate category is, whereas, represented by storage resources, that similarly can be distinguished in two clusters though: on-device and network-based storages (IEEE, 2015)

Shifting to the layer below, abstraction efforts are required to grant an easy access to the various devices. Being the limitation represented by the heterogeneity of the devices, each characterized by its own dialect, the abstraction layer serves at creating common language and procedures to get over them.

Eventually, provided that the SOA-based architecture makes it possible to extract data from the myriad of devices to transform it into properly visualized integrated content, the diffusion of automatically communicating objects can be a pain-point at the levels of trust, privacy and security. When data is unknowingly transferred within the network of devices, it is possible to breach personal privacy by executing a sort of surveillance mechanism.

Leaving the architecture aside, the upcoming part is set to clarify the underlying properties of IoT. The unique features making it such a relevant potentially game-changing paradigm are:

- univocal identifiability
- programmability
- virtualization

First of all, the possibility to univocally identify the single objects is crucial for data extraction as well as their connectivity to the Internet. This condition to address and control via Internet individual devices simply relies on specific addressing schemes, namely the IPv6 and the EPC.

The first scheme works by attributing to every object an Internet Protocol (IP) to enable a network connection. Considering the high number of devices, though, the IPv6 version (128-bit addresses) has recently emerged as the best matching. The existence of an IP at object-level, on one side, enables the objects themselves to access the Internet and its applications; on the other side it makes them addressable from anywhere.

A few limitations, though, have made controversies arise. The attribution of an IP to any device cannot get along with the required processor capacity and energy, and the consequently consistent costs. This has convinced practitioners to prefer indirect connections via gateways and proxies, sacrificing some advanced end-to-end functionalities.

The alternative to sustain univocal addressability is to adopt Electronic Product Code (EPC), a Auto-IDCenter invention that looks like in Figure 19.

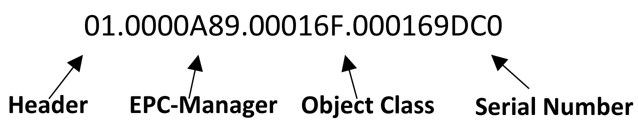


Figure 19: EPC structure (author's elaboration)

In the structure above, four parts can be easily recognized: the header stays for the EPC version used, the second part is the identifier associating the EPC number to the device, the Object Class serves at discriminating the object type and the last sub-series distinguishes a specific product from others of the same class.

When deciding whether adopting the IPv6 or the EPC, some reasonings should be made. (Lee et al. 2007) extensively discussed the differences between the two schemes, concluding by advising a combined deployment. In fact, since the IPv6 works as routing address but not as item identifier and the EPC works the other way around, the best-suit decision is to simultaneously adopt together to enable unique identifiability and connectivity.

Programmability was mentioned as the second property making the IoT a rising technological concept in modern times. Such feature is generally addressed as the ability of a device to automatically adjust its behaviour depending on the inputs coming from the users' side. When thinking of the future world, one of the first visions is a dynamic environment where individual entities are constantly in contact with each other to reciprocally coordinate. Devices programmability is a step forward towards easier and more comfortable lives, where even those not tech-savvy final users are able to control smart objects. Reciprocal and fast interaction among devices promises to open to interesting applications, where lighting systems of a hotel room adjust on the customer's preferences and a gym's machines automatically recognize each users' workout schedule.

In favour of programmability is the rise of smartphones, offering a unique and standardised platform to interact with devices. An emblematic example of programmability is the "If-This-Then-That" (IFTTT) system, that allows end-users to coordinate more than 100 Web services through pre-programmed and automatically triggered conditions. This allows, for instance, to receive an email on the personal Gmail account with the weather update if the connected Weather Channel foresees rain for tomorrow.

The third and last IoT property of those cited is virtualization, which stands at the roots of the duality created by IoT between the physical world and the digital one. Assets virtualization is relevant not only as far as it concerns connectivity, but it also plays other roles. Primarily, in a world where small-to-medium systems are reciprocally connected via Internet, often they are likely to step up to a multi-function configuration. The deriving implication is that, considering the intrigued twine of sensors and clouds, data may face some security and privacy concerns.

In fact, when a multitude of devices can reciprocally interact, data management within these networks is tough, as the "attack surfaces" (which represents the expansion of the networks in terms of connected elements) increase and security risk advances. To prevent malicious or unfair data handling, devices networks are connected to a digital cloud-based network, as discussed by Botta et al. (2016). This connection, that has sometimes suggested to replace the IoT with the "Cloud of Things", are commonly used to operate with various paradigms like "Applications as a Service", "Platform as a Service" and "Infrastructure and Network as a Service" to create more controllable private virtual device networks.

3.5 Strengths and weaknesses of Internet of Things

Like any other innovative technology, the IoT does not play the role of silver bullet for any type of problem. Some of its applications are more meaningful when favouring context-dependent conditions are there, but still in some cases IoT's disadvantages are not balanced by adequate benefits.
In the next lines readers will be able to go through the miscellaneous traits of IoT, facing both pros and cons.

As it will clearly emerge in the next paragraph "Internet of Things applications", real cases testify how good such technology is in specific domains. Brought to general terms, here is what the current literature has to say on the **IoT benefits**.

1) Above all, the greatest value unlocked is linked to ***data usage***. This broad concept relates to the ability of IoT to collect data from a large series of sources, to integrate and elaborate it afterwards with the final goal of making end-users properly visualize it. Lee and Lee (2015) highlighted that the act of sensing a specific event, typically related to multiple actors, is the first step to collaborate. When an event like a delivery from a supplier is performed, many players have interest in knowing what and how it happened. Therefore, when IoT is used to gather multi-source data in a multi-party network, its capacity of integrating and effectively showing data is of particular evidence. Information is managed in a timely, precise and shared way never possible before. This is enabled by the continuous connectivity among sensors that are repeatedly interacting in a seamless M2M way, creating a huge amount of data (Khan et al. 2012). In a broader context, the key benefit is the systemic visibility on SC operations, allowing involved stakeholders to improve their decisions.

2) Together with data handling, further value is associated to IoT due to the possibility to ***automate*** some tasks. Especially when some predefined coded software programs are designed to run upon the data coming from the physical smart world, activities can be moved to the machine side (Evans, 2011). Consequently, as the human workload is lightened by technological automation, life gets more comfortable. Communication among devices works with no human intervention and foster organizational productivity. In particular, when the smart devices are combined with cloud-based or distributed software technologies, automability drives to new possibilities like smart contracts activated by RFIDs working as oracles.

3) Undoubtedly, one of the greatest contributions of the IoT is identifiable in the ***advanced monitoring and control***. Embedding items, or even entire environments, with smart objects grants a steady government of target parameters. Knowing anything of an environment conditions is crucial to prevent malfunctions, as well as a comprehensive overview of the assets status allows for a better management, potentially improved by predictive maintenance. Successful monitoring unveils areas of improvement and hard-to-spot process patterns. Simultaneously, a full awareness like the one enabled by IoT is a promoter for cost savings and resources optimization. It is sufficient to think of the money saved when an automatic switching system of the domestic lighting network is set up. Generally, the benefits of relying on a smart controlled environment are higher than the financial cost required to build up such a monitoring system.

4) The ability to keep track of the assets in a ubiquitous way stands at the heart of a powerful ***end-to-end traceability***. Locations and key parameters of assets can be accessed anytime by multiple stakeholders, so that frauds or losses are prevented. As it will be discussed later on, by combining this data flows with the proper database, IoT can be used to prove the origins of a good, to check out all the regulatory compliances and generally to let the demand side know what has happened till that QR code is scanned.

When talking about the **challenges** encountered by IoT, literature seems to offer more material as authors generally converge on the same issues' categories.

In this research, six major classes have been identified: architecture problems, privacy and security, energy efficiency, data management, interoperability and standardization and addressability.

1) Firstly, as seen, IoT consists in a wide set of technologies that are claimed to communicate with each other. Depending on the application needs, the ***technology architecture*** may vary, introducing some problems related to interoperability. Since communication systems and protocols are frequently made ad-hoc to increase effectiveness, the integration of data coming from different environments results difficult. Despite Raza et al. (2013) suggested that a single open architecture should be defined to increase the interoperability between different systems, later (Chen et al. 2014), after confirming the need for open infrastructures, specified that a single reference architecture could not suit heterogeneous applications. Therefore, diverse open architectures need to exist to effectively match different applications' requirements, but still following standards.

2) Gubbi et al. (2013), for instance, pointed at a cloud-based architecture as the best suit for cost-based services, recognizing its limited applicability though.

   Another IoT limitation that finds a lot of consensus among several authors is the ***energy efficiency***. The vastity and diffusion of IoT ecosystems is very power-demanding as most of the devices are not charged by unlimited supply sources. Therefore, WSN and low-power technologies have to be considered in the design phase. Obviously, the energy demand is directly proportional to the numerosity of connected objects. This, in light of the forecasted increase in connections, should foster new greener innovations.

3) Another IoT-related trouble that seems to raise homogeneous concern in multiple sources is linked to ***privacy and security***. The latter, in particular, creates a lot of

attention, besides the need for further investigations of new solutions. When talking about network technologies, security constantly emerges as a problem category. IoT, though, turns out to be extremely vulnerable due both to its hardware component and to the cloud-based solution. Chen et al. (2014) evidenced that, compared to traditional network technologies, IoT should be addressed with advanced care owing to the need to cover a vast set of management devices and levels. Literature states that all the three hardware types are vulnerable to malicious attackers, with major worries associated to RFIDs (Gubbi et al. 2013). Since most of them are passive and it is commonly not possible to intervene with a high intelligence, RFIDs represent a serious threat to the IoT users, who may also be localised through them. Further security issues are evident in the cloud, with particular reference to the hybrid clouds adopted by businesses, being them public or private (Atzori et al. 2010).

Lee and Lee (2015) reported an interesting part of the study carried out by Hewlett Packard in 2014, revealing that 70% of the most adopted IoT devices show evident vulnerabilities, with an average of 25 holes (or risk sources) per device.

The solutions predominantly claimed as the best are encryption and message authentication codes. The former is more precisely suitable to prevent outsider attacks, while it still strives to tackle insider malicious attacks. In addition, further risks evolve at the data exchange layer from the update of existing sensor applications or when new ones are installed. In these cases, cryptography needs to be used in combination with secure reprogramming protocols like Deluge. System security, in fact, can be put to the test during updates since they typically involve the usage of data dissemination protocols to spread codes to all the nodes with no authentication. (Al-Fuqaha et al. 2015), moreover, added that one side of the security world that is as risky as ignored consists in the exchange of keys among devices, with just an attempt to face it proposed by the Smart Object Lifecycle Architecture for Constrained Environments (SOLACE). Security pitfalls can be tackled by training developers to embed products with dedicated solutions or by convincing final users to make use of the existing security functions in their objects.

What normally comes up with security issues is a set of privacy concerns. When technology is not there to secure sensitive information exchanges, individuals' privacy is frequently violated. Chen at al. (2014) pointed out in their research that necessary remedies are low-cost, M2M-based solutions jointly with low-latency cryptographic algorithms.

4) ***Data management and mining*** correspond to another problem source for IoT. At the heart of the topic is the need to deal with the four Vs (Volume, Velocity, Veracity and Variety) shaping Big Data, with major efforts required to engage Volume and Velocity tremendous amount of data generated (Sahid et al., 2017). In order to leverage IoT benefits, organizations need to cope with the matters arising from its usage and, primarily, with data storage. Gartner (2014) revealed that traditional data centres are not compatible with the heterogeneity and size of IoT data flow. Consequently, data prioritization and data centres redefinition are crucial steps to get over these features. If current data centres are suitable to IoT data type and size, companies need to prioritize data according to needs or value. Alternatively, a shift to distributed systems can represent a valid solution, gaining in processing efficiency above all.

   Furthermore, considering that not all the data consists in structured and discrete content, as part of it comes as videos or images data. Analogously, data from the industrial equipment or complex specialised tools need to be properly managed.

   Such reasonings stress the importance of adopting advanced mathematical and computer model to extract value from various data typologies.

   Data analytics and mining are key requirements to make IoT a value-adding investment. Consequently, analytical skills are required to match this need. To this regard, Manyika et al. (2011) reported a lack of analytical competences in the US to be filled with the injection of 140.000 to 190.000 new workers.

5) ***Interoperability and standardization*** are cited by diverse authors (Al-Fuqaha et al., 2015) (Atzori et al, 2010) (Sahid et al., 2017) as an additional source of risk. Logically, the extreme diversity affecting both the hardware and software sides of IoT creates frictions in the achievement of end-to-end interoperability. The turning point must be the inclusion of interoperability as major design goal for device manufacturers

and application developers. For instance, IoT programmers should create applications where new functions can be added with no side effects. In these terms, though, the heterogeneity of protocols and in the way common standards are differently interpreted by various parties is a decisive hurdle. An unavoidable solution is standardisation, hopefully investigated to smoothly connect users and smart devices, avoiding any type of siloed and monolithic application. The problem is that, since the design phase, manufacturers and developers do not question themselves about making their products accessible by entities or in such ways not equivalent to those predefined. Nevertheless, some groups of the IETF, the premier internet standards organization, are taking remarkable efforts on IPv6 addressability and routing (Sahid et al., 2017). The objective is to uniform or synchronize internet protocols with sensor ones. Further regulatory entities or standards bodies engaged in creating homogenous standards are EPCglobal, ISO, ITU, sections of the Auto.ID Lab, the European Commission and the European Standards Organisations (ETSI and CEN among others).

6) One last complication associated to the Internet of Things world is that of ***addressability***. Many times, it has been mentioned so far that the most relevant feature of IoT is the multitude of connected objects. Dealing with such a vast connected surface requires every single node to be accessible and addressable univocally. This brings to the conclusion that a unique address must be given to any node to promote connectivity and ubiquity. Initially, the IPv4 was appointed as addressing protocol for IoT. Despite that, a shift to the IPv6 was soon performed due to the limited number of available addresses. With the 128-bit length of IPv6, the availability raises up to 10^{38} addresses, covering the huge number of connected things. Problems with addressing protocols get particularly prominent when trying to enable the addressing of RFID tags (commonly standardized as 64-96 bit long) into the IPv6 domain. There have been diverse attempts to get over it, but a unique solution could not be found due to different features of protocols depending on the address length.

Quite a good solution, for instance, was identified for the 64-bit RFID, where gateways were inserted between the hardware and the Internet as a new addressing layer. Such alternative proved to work, but not for the 96-bit RFID addresses.

The last hindrance related to addressing process is the way these addresses are generated. Like it happens with any Internet host with the Domain Name Server (DNS), recovering the IP address of the host by using an input name, the same system is used for IoT objects with the Object Name Server (ONS). The ONS creates a connection between the object description and its RFID tag identifier, on its turn associated to a specific Internet Uniform Reference Locator (URL) containing key information of the thing. The problem with ONS is that two-direction association is not granted. This means that the ONS easily links the object description to its identifier, but the reversal connection is hard to create.

3.6 Internet of Things applications

Being the IoT a multidisciplinary technological reality, readers should not be surprised of observing so many unrelated applications. An analysis of the literature of the last ten-to-fifteen years brought to the conclusion that authors are prone to identify four principal application fields: personal and social domain, healthcare domain, smart environments and supply chain and logistics.

Below, an explanatory list aims to investigate major examples and use-case typologies.

1) In the ***personal and social domain***, noteworthy usages relate to the possibility to connect people besides devices, or better *through* devices. To these terms, smart objects participating in a network are addressed to provide updates about nearby events, personal activities or to figure out past trends by analysing device-recorded events.

   Atzori et al. (2010), later sustained by Gubbi et al. (2013) and Sahid et al. (2017), spotted three application typologies over others. The first comes from connecting IoT to social networks, which enables these platforms users to automatically update their social activities or performances they want to share with a pre-defined group of users. A typical example is a run-lover on Facebook sharing his last performance with friends through Apps like Runkeeper or Runtastic. Another category is the exploitation of historical queries for trends spotting and further analysis. Through the aforementioned IFTTT, for instance, one can automatically create a sheet on Google Drive to record how much time he spends in different places or to keep track of the working hours over the weeks. Lastly, IoT deployment can even play a social contribution by helping users to locate lost objects by letting them see the last place they have been spotted at.

Besides these usages, IoT is also proposed as a solution in such domain for an easier digitalized control of the home equipment like washing machines and refrigerators. Overall advantages would derive from an enhanced comfort and lower energy consumption.

2) In the ***healthcare domain***, IoT has the intuitive objective of enhancing life quality by moving some automatable activities to the machine side. In general, devices for personal health monitoring can be made smart to real-time inform doctors and relatives about any significant or worrying alteration (Whitmore et al., 2014).

   Al-Fuqaha et al. (2015) described in their paper some noticeable related use-cases. In the nursing home patient monitoring system, IoT is deployed through vital sign sensors, light sensors and door sensors to monitor health status and activity level of patients. With systems like SmartThings, data from multiple sources are integrated in a unique platform through sensors' APIs to make different nursing stations visualize them via specifically designed applications. The same authors also presented a similar case for the mitigation of eating disorders through IoT adoption. Analogously, Gubbi et al. (2013) beside insisting on the deployment allowing for home monitoring for aged people, recalled the existence of many smartphones applications for various operating systems that contribute to measure various parameters.

3) As for the development of ***Smart Environments***, the IoT is claimed as the key enabling technology. When sensors and actuators are spread all over diverse

physical environments like offices, houses or gyms, human life within them can be made a way easier and more comfortable. The IoT is typically used for the optimization of resources and the enhancement of life quality. To these purposes, smart monitoring systems can be installed in houses or offices to adjust the lighting and heating parameters. This would not only trigger a cost saving by automatically purchasing electricity in off-peak cheaper time windows or switching off lights when not necessary, but it would open up to new opportunities. Lighting system, for instance, can be adjusted either to maximize workers' productivity or to match specific clients' requirements in the Horeca industry.

Similarly, customized and case-specific services can be offered within museums and gyms, enabling more interactive and user-centred experiences. Personal trainers, for example, can register individuals' workout schedule on a unique software connected to all the machines, so that the machinery itself is able to recognize single users via RFID, providing an ad-hoc monitoring service (Atzori et al, 2010)

On top of this domain lays the huge realm of Smart Cities, where the deployment of sensor networks and related technologies is planned to be spread on a large-scale model. Together with cloud computing and big data analytics, IoT is said to be the underlying technology. The shift from traditional city to Smart city is as time and cost expensive as potentially game changing. The development of the required infrastructure, in fact, represents a big opportunity for telecom OEMs and operators as well as for data enterprises. At the same time, though, remarkable requirements cannot be neglected. A Smart City realization comes after three stages, as reported by Chen et al. (2014): "the stage for initial infrastructure construction; the stage for data-processing facility construction; and the stage for end-phase service platform construction".

4) The last domain of IoT application, not for relevance, is that of ***Supply Chain and Logistics***. The technology versatility has contributed to make it spread to multiple industries.

   In agriculture, as it has also been observed via interviews, many start-ups and companies started to rely on IoT to create smart crops, where dimensions monitoring occurs in real-time. Such environmental control favours an improved quality management of products, fostering safety and traceability. With the organized dispersion of smart devices across the agricultural fields, a previously difficult, expensive and not effective monitoring system can be revolutionised. A lot of resources, both physical and financial, can be saved by improving operations. Selective irrigation of dry areas is a real example driving practitioners towards more eco-friendly performances (Suresh et al. 2014).

At an industrial viewpoint, IoT is suitable to wide-ranging applications. Exploiting its advanced monitoring performances, industrial plants can take advantage of the IoT to control the production processes, the product lifecycle, the industrial environment and pollution levels. Simultaneously, assets tracking is another deployment field doomed to be further investigated in connection to IoT. Some practical examples are the monitoring of products rotation in shelves and within warehouse as well as the control of storage conditions for safety compliance.

Lee et al. (2015) described in their paper a couple of case-study to stress the successful role of IoT in enhancing collaboration and information sharing. The first deals with a better resource management: by placing sensors inside refrigerators of a retail store, any malfunction, damage or incorrect usage can be reported to the store's manager by automatically sending a message to his/her device. Similarly, the same manager can select and inform the most appropriate of the currently available employees to solve it out, sending them tasks assignments through the IoT-based device.

Another real case is that of shopBeacon, representing a positive experiment regarding collaboration with shoppers. ShopBeacon is a mobile location-based technology exploiting ultrasound Bluetooth Low Energy (BLE) that is used to better communicate with the users. Via the dedicated app, shoppers can get access to special deals, advices and rewards. Overall, this new proposal results in a better customer experience, characterized by higher satisfaction and engagement, and rewarded with increased revenues.

Finally, Logistics and Smart transportation are other two fields of major interest for the research purposes, IoT can have a positive impact on.

Applying IoT to trucks is particularly advantageous for a wide set of reasons. Firstly, one major contribution of combining GPS and RFID-based devices is to have data enough to minimize transportation costs. A lot of solutions are feasible: routing trucks towards low-price-diesel locations for stops, shifting to rail transportation after a well-structured cost analysis, or sharing trucks and costs with other players. Besides this, transportation can be made "Smart" by revolutionizing modern fleets. Placing sensors on trucks brings benefits at different viewpoints: enabling a cutting-edge monitoring of the environment and a predictive maintenance system. Transportation conditions within trucks can be regulated according to the item typology, being this drug, food or a mechanical part. Various dimensions, then, can be taken under control and optimized, like temperature, humidity, doors opening. Especially for dairy goods, meats and fruits, having extended control over such parameters is crucial. Overall, the food supply chain management, especially the so-called Cold chain management, can seriously benefit from the IoT revolution.

Advantages are not only registered in terms of environment monitoring though. When talking about trucks, expenses are driven by wear and tear, making it precious to predictively manage maintenance interventions. By using sensors, trucking companies can always have a look on the fuel level and tiers conditions, dramatically reducing the downtime. With the IoT-enabled real-time monitoring, exhaustive information on assets status is the driver for a new era of transportation, where routes are adjusted to both trucks and environment conditions.

In this set of value-adding opportunities, IoT plays a major part in delivering a full-scale benefit: end-to-end visibility. Having entire supply chains supported by IoT makes it possible to integrate data from diverse players, conveying a new gust of efficiency. Especially when it comes to synchronize deliveries and production, having a comprehensive knowledge of the correct times and schedules allows for idle time reduction and smoothly run operations. Taking it at systemic level, if the actors participating to the same production and distribution chain keep sharing real-time updates on their operations of interest, the whole value chain can gain in efficiency and effectiveness, delivering a larger value to the final customer.

All the links of a supply chain can move to the IoT, from raw material purchasing to production and transportation of finished or semi-finished goods. This results in a persistent decrease in reaction time, considering it as the time period from the clients' requirements acquisition to the final supply. Literature suggests that companies relying on IoT (like Walmart and Metro) can reduce this time from 120 days to just a few.

Concluding, the progress in information collection and sharing enabled by IoT does not regard only the upstream linkages of the industry, but also the relationship with the final customer. The infinite amount of data can be used to secure a product provenance or to fulfil the emerging need of extensive information from the demand side, or to simply inform about the availability of a product.

One last adoption reported by Atzori et al. (2010) is that of augmented maps.

Phones provided with NFC can read tags inserted in touristic maps to automatically access web services. This would grant access to additional information on facilities and events within the area of interest. Data extractable from a map can be increased via Physical Mobile Interaction (PMI) techniques: multiple tags can be selected or de-selected or a context menu can be displayed if the marker is hovered.

4. OBJECTIVES AND METHODOLOGY

Over the next pages, readers will be provided with a more precise description of the research scope, the research questions and the underlying literature gaps that were previously introduced. Lastly, a clear description of the underlying methodology is reported.

4.1 Literature gaps, research objectives and research questions

Overall, this research is set to investigate the roles, contributions and limitations of Blockchain technology in Supply Chain. Although blockchain can be described as a fresh digital innovation, it has already been a while that literature deals with it

Due to its novel traits, BT has primarily caught the attention of academics for the investigation of its diverse technical features. A few sources assessed blockchain as a supporting technology for industrial applications, and even fewer of them focused on L&T and F&B. In general, what seems to be evident from a literature overview is that technology novelty and lack of large-scale case studies condemn researches to deliver quite vague and imprecise results.

In general, especially within the logistics domain, BT is addressed as one of the biggest disruptive forces nowadays. However, the problem is that, given the multidisciplinarity of BT and its infancy stage, a lot of industries' interest made it a buzzword. Tech-centred journals, governments and companies typically started naming BT inside their headlines and reports, creating a massive confusion of terms and concepts.

All of these factors have made the existing literature on BT for SC as limited as unclear. In fact, despite different authors have written at length on the general features of this technology, just few of them discussed about real-case applications and the possible value created. Out of this little group, exclusively selected sources were particularly valuable for the research scopes.

Overall, despite these authors' attempts to link BT to SC parameters, two dominant flaws were attributed to the literature: the lack of a structured approach based on case studies assessment in some sources and the absence of a clear cause-effect relationship when talking about value creation. The former, combined with missing quantitative assessments and mathematical approaches, is responsible for the weak and frequently not proved conclusions. The latter, on the other turn, contributes to generate confusion when analysing how SC members can practically take advantage of BT. Indeed, even though the impact on a specific SCM parameter exist, most of the times it is not clear how the value is created.

Going beyond the academic domain, this project was also animated by the desire to help practitioners with this rising digital innovation. The purpose is to support managers and decision makers in the evaluation of BT for their own reality.

Despite the not negligible number of existing researches on blockchain, still lots of questions remain unsolved or unexplored. At the core of this research, in fact, is the belief that, in order to cope with a complicated technology like BT, a structured and adequately articulated tool needs to be designed to support practitioners.

Alongside with this, the proposed paper aims to set clarity in the description of the value creation mechanism triggered by BT. One of the final objectives, in fact, is to transparently report the several ways in which this advanced technology supports SC actors. Eventually, the purpose is to point out “who for”-“what for” connections between benefit typologies and involved entities. At the end of the research, it will clearly emerge how blockchain generates value for various organizations.

Considering the literature gaps, in line with the reported reasonings and in consideration of the stated research objectives, three research questions could be identified as a project structure. These questions are:

RQ.1: WHAT ARE THE VARIABLES THAT SHOULD BE CONSIDERED IN THE ADOPTION OF BT?

Despite the conspicuous number of related papers, up-to-date literature still misses a model able to identify the variables that need to be addressed to evaluate blockchain in inter and intra organization applications. There is no clarity, in fact, on how to approach such technology for industrial purposes. The first goal of this study, then, is to spot and categorize these dimensions in a framework, working on different level of granularity. This will be done by integrating insights from the field, through interviews, with the most valuable evidences from the literature. In particular, interviews will address IoT and BT providers, targeted for their familiarity with the technologies and their accessibility. Once completed, the research framework will be used to analyse how the variables concur among each other and towards the decision of adopting blockchain.

RQ.2: HOW DOES THE RESULTING ADOPTION FRAMEWORK COMPARE TO GREY PRESS PRESENTING EXISTING BT CASES?

The definition of research variables in the framework represents a valid starting point to evaluate BT. Nonetheless, framework results could be biased by the limited viewpoint of BT and IoT providers. Thus, in order to make the research more objective and reach more comprehensive results, firstly a content analysis will be performed on grey literature (made of secondary sources like Web journals and companies' websites) regarding forty selected BT applications. Successively, the outputs of the content analysis will be compared to those of the interviews, contained in the framework. With this parallel, the author will articulate a more exhaustive analysis, making considerations on the observed similarities and divergencies. BT adoption as well as the framework variables were inspected from technology providers and from the commercial standpoint of technology adopters

RQ.3: HOW DOES THE VALUE CREATION MECHANISM WORK FOR THE ADOPTION OF BT IN SC?

To make the investigation on BT complete, the third objective refers to the identification and discussion of the advantages stemmed from BT and IoT employment. The goal is to examine as much as possible how it creates value, inspecting the SCM dimensions and single companies' operations involved in these processes. To do this, data triangulation will be used by integrating literature sources with the grey literature of forty practical BT applications. The result will be a description of how value is created at SC and organization levels when introducing BT.

4.2 Methodology

A large part of this research project has been performed in strict collaboration with the Supply Chain Finance Research Team of the Windesheim University in Zwolle (the Netherlands), where the author spent a period of 5 months This partnership was particularly beneficial to the research purposes mostly due to two reasons. The first is the unique expertise in BT offered by the research team members, daily involved in local, national and international BT-related projects. Secondly, the time period spent in the Netherlands allowed the writer to perform on-site visits and physical meetings at companies and with profiles extremely competent. In the end, the contribution of such collaboration also resulted in the possibility to leverage a noticeable networking power, which brought to the development of multiple case studies. It was on the basis of such case studies that a first qualitative framework was built up.

Several steps were performed to carry out the research project. Initially, the author reviewed the existing literature, plumbing both practitioners and academics' viewpoints. In order to ground the project on a structured theoretical basis, literature was investigated considering the following major topics:

- Supply chain, supply chain management and digital supply chain
- Blockchain technology
- Internet of Things technology

As previously reported, the key contribution of this phase was the exhaustive understanding of the topics and the identification of gaps. Upon these considerations, the research purposes were heralded, driving to the definition of the RQs. After outlining the research questions, it was possible to smoothly move to the following research steps, having robust objectives in mind.

Since the project purpose consists in developing new theories, a multiple case-study methodology was selected. Such decision was supported by both the generic characteristics of the research and the reasoning made by (Meredith, 1998). In his paper the author explained that case/field research suit to the creation of new theories in Operations Management as "the explanation of quantitative findings and the construction of theory based on those findings will ultimately have to be based on qualitative understanding". Other reasons of the methodology selection could be found in Yin et al. (2003) and (Wacker, 1998).

After the examination of the various case studies ended with the framework draft, a content analysis followed. The objective of this new methodology step was the ascription of a certain evidence degree to each of the framework dimensions. Overall, this aimed to observe whether the framework clues could be confirmed by a benchmark with various applications. Therefore, the grey literature collected on these BT applications was firstly analysed, to lately advance to the weights' attribution. As for the latter, a three-point Likert scale was adopted as categorical indexing, trying to link qualitative data to quantitative methodologies. An enhanced objectivity was also one of this approach's goals.

Once the framework variables were evaluated through the content analysis, the author proceeded with a comparison between its results and those of the multiple case analysis. This task, synthetized by the matrix in the Appendix 4, had the goal of making deeper observations on BT, leveraging the viewpoints provided by both the analyses.

In the end of this extended methodology description, data triangulation can be pointed out as the method that brought to the identification and classification of BT benefits. Indeed, relying on a heterogeneous set of data sources, BT advantages were firstly identified and then clustered according to multiple hints coming from forty BT applications and height major sources taken from the up-to-date literature.

In the leading paragraphs a more precise presentation of the various methodology steps will be provided.

4.2.1 Literature review

The set of documents consulted was primarily selected by accessing library database like Scopus, Science Direct and Google Scholar, with a major adoption of the latter. These were used by typing research keywords like: "Supply Chain", "Supply Chain Management", "Supply Chain solutions", "Digital Supply Chain", "Supply Chain Collaboration", "Collaborative Supply Chain", "Blockchain", "Blockchain Technology", "Internet of Things", "IoT", "IoT applications", "IoT solutions", "Blockchain and IoT integration", "Blockchain applications", "Blockchain solutions", "Blockchain advantages and disadvantages", "Blockchain benefits", "Blockchain in Supply Chain", "Blockchain in SCM", "IoT advantages and disadvantages ", "Case study research", "Qualitative research", "Multiple case analysis". Sources selection also considered a few technical elements to promote a comprehensive understanding of the whole investigation. Mostly, the consulted documents regard four macro-topics:

- Supply Chain, Supply Chain Management and Digital Supply Chain
- Blockchain Technology
- Internet of Things
- Methodology, with a major focus on multiple case analysis

A particular effort was taken to provide the research framework with a robust theoretical support, elaborating the variables with a lower granularity directly from the literature. Eventually, the whole list of sources can be found in the last pages of this paper, in the chapter "Bibliography".

4.2.2 Case studies research

In the attempt to provide a contribution to the assessment of BT in SC, the case study research was judged as the best option. In fact, despite Eisenhardt (1989) outlined the lack of clarity in the inductive process driving to new theories creation from field cases observation, this project leverages the successive evolutions occurred in this domain. In particular, Yin et al. (2003) and Voss et al. (2002), together with (Barratt et al. 2011), managed to provide crucial contributions in terms of research structure, protocols and properties.

Case research can praise some important strength points. Literature indicates the case research for those investigation where variables are still unknown and a full understanding of both the complexity and the nature of the whole phenomenon is still missing. In fact, this methodology allows to answer “why”, “how” and “what” questions by observing actual practices in their natural settings.

Voss et al. (2015) claimed that the analysis of case studies can support several purposes:

- Exploration
- Theory building
- Theory testing
- Theory extension/refinement

The main aspects of each research purpose, namely the related questions and structure, are described in Table 6.

Purpose	Research question	Research structure
Exploration		
Uncover areas for research and theory development	Is there something interesting enough to justify research?	In-depth case studies Unfocused, longitudinal field study
Theory building		
Identify/describe key variables Identify linkages between variables Identify "why" these relationships exist	What are the key variables? What are the patterns or linkages between variables? Why should these relationships exist?	Few focused case studies In-depth field studies Multi-site case studies Best-in-class case studies
Theory testing		
Test the theories developed in the previous stages Predict future outcomes	Are the theories we have generated able to survive the test of empirical data? Did we get the behaviour that was predicted by the theory or did we observe another unanticipated behaviour?	Experiment Quasi-experiment Multiple case studies Large-scale sample of population
Theory extension/refinement		
To better structure the theories in light of the observed results	How generalisable is the theory? Where does the theory apply?	Experiment Quasi-experiment Case studies Large-scale sample of population

Table 6: Matching research purpose with methodology (Voss et al., 2002).

Out of the four categories, that of "theory building" is the one suiting this research context the most. This is because a considerable uncertainty is linked to the definition of constructs and case studies represent a conspicuous prime source of data for new theories creation. Also, the observation of the research questions typology in Table 6 perfectly reminds of this investigation objectives: identifying variables and linking them in a model that would explain the underlying relationships.

Further support comes from Yin et al. (2003), who addressed a case study as "an empirical enquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident". Additionally, the authors confirmed that case study methodology works when "a "how" or "why" question is being asked about a contemporary set of events, over which the investigator has little or no control".

Finally, for sake of clarity, it is worth to specify that the case studies targeted and analysed in this research belong to the category of "exploratory case studies", used as starting inquiry for ideas and questions development. Such category must be distinguished from the other two: "descriptive case studies" and "explanatory case studies". The belonging to the first cluster comes as the result of the inductive and exploratory nature of the research under review.

In order to guide the readers through the next pages and to provide a certain structure, different authors' research processes have been analysed. The Table 7 below can assist readers in the examination of these various processes.

	Eisenhardt (1989)	Stuart et al. (2002)	Voss et al. (2002)	Barratt et al. (2011)
Designing	1. Getting started 2. Selecting cases 3. Crafting instruments and protocols	1. Define the Research Question 2. Instrument development and site selection	1. Rationale for case research 2. Developing the research framework 3. Case selection 4. Developing the research protocol	1. Justification of the research approach 2. Focus of the research and specifying the unit of analysis 3. Research purpose and the role of theory 4. Sampling
Collecting	4. Entering the field	3. Data gathering	5. Conducting the research	5. Data collection and analysis
Analyzing	5. Analyzing data 6. Shaping hypotheses	4. Data analysis	6.Data documentation and coding 7. Data analysis, hypothesis development and testing	
Reporting	7. Enfolding literature 8. Reaching closure	5. Disseminating the research findings		6. Organization of the results 7. Presentation

Table 7: case research processes (Voss et al. 2015)

In order to clearly and exhaustively report the structure and evolution of the research, the author opted for the integration of two sources. The key reference scheme will be the process type presented by Voss et al. (2002), but a few adaptations will be introduced as the contribution of Yin et al. (2003), among the forefathers of this topic.

4.2.2.1 Rationale for case research

Case study research is not a silver bullet, readers might have already got it. A research has to showcase specific characteristics to make this strategy meaningful. In this project, the author has already denounced that literature frequently lacks field-based evidences when talking about BT. Technical features have been comprehensively assessed, but it cannot be stated the same as far as it concerns insights related to its industrial applications.

It is fundamental to face the real-life context, especially when dealing with a fresh innovation like blockchain. Furthermore, the numerosity and complexity of variables emerging when discussing its adoption in SC should furtherly convince to rely on case research. There is no other approach better answering the need of developing new theories, as case studies transparently report a phenomenon evolution and diffusion along the way.

Therefore, considering the extremely limited pragmatism that accompanies BT through the to-date literature and the benefits promised by the case research, it is possible to outline the rationale of this inquiry. This consists in the willingness to exploit an in-depth literature review to find pertinent questions and to try answering them via a real-life pragmatic approach. This will lead to the definition and investigation of several variables to support future breakthroughs in the BT domain.

4.2.2.2 Developing the research model

Since Yin et al. (2003) provided very precise guidelines in the creation of the research framework, this paragraph will relate to both their writing "Case Study Research: Design and Methods" and Voss et al. (2002).

The goal of this project phase is to make the research more structured. The definition of a model provides readers with a general overview on the research dynamics. Eventually, it enables to fully comprehend the logic driving the author from a RQ to the following ones. In the model the linkages among the RQs are framed within a scheme made of variables. The independent variable, namely the "BT adoption", stands at the hearth of the model, being the central part of this investigation. Beside this, an accurate literature analysis was performed to spot the most relevant variables that could address the research questions. All these variables were then organised into four major research blocks.

Overall, the research model consists of an outline where these blocks are arranged so that readers can immediately grasp at sight the project rationale. Additionally, arrows link various parts of the model to make logic connections even more clear.

The research building blocks, or macro-variables, identified through an in-depth literature review are:

- Readiness
- supply chain properties
- technical limitations
- BT benefits.

Each block can be defined as a conglomerate of several variables, characterized by a different granularity. The closer the analysis made on the single block, the higher the level of detail of the variables. What all these blocks and more generic variables have in common is that they can all rely on a strong theoretical support, which is the result of the previously mentioned literature review.

Overall, the research model deriving from the combination of these blocks can be found in Figure 20.

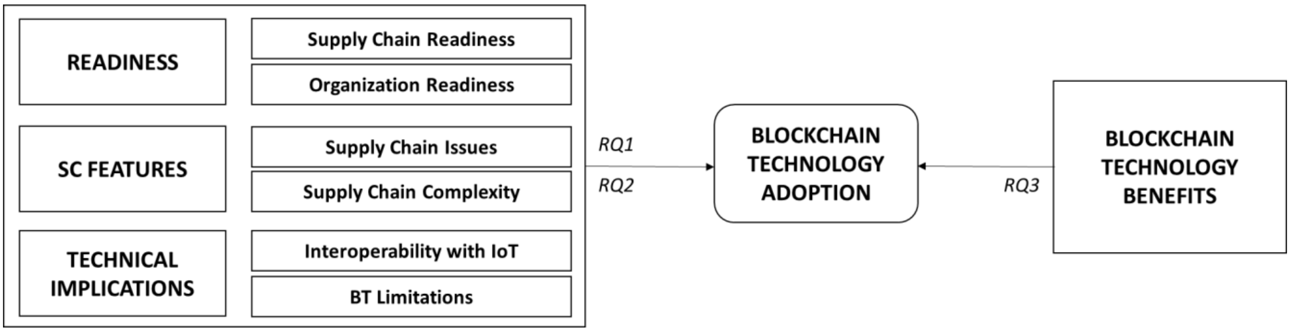


Figure 20: research model (author's elaboration)

The dependent variable, namely the "Blockchain adoption", stands at the hearth of the model, being the central part of this investigation. The research model consists in an outline where these blocks are arranged so that readers can immediately grasp at sight the project rationale. The dependent variable, namely the "Blockchain adoption", stands at the hearth of the model, being the central part of this investigation. The meaning of the model is that BT adoption is a function of four building blocks. In detail, three of them (Readiness, SC Features and Technical Limitation) compose a bigger block which directly influences BT adoption. On the right of the model, the remaining block (BT benefits), alone, also has a direct influence on the dependent variable. The model displays that BT adoption will be firstly assessed through RQ1 and RQ2, investigating the relation with the three building blocks on the left, and then discussed with reference to the befits of BT.

Here comes a list, with the correspondent description, of the four research blocks:

- **Readiness**. What emerged from both scholars and practitioners is that the adoption of a network technology does not only deal with the degree of preparation of the network (Supply Chain Readiness), seen as the set of industry players involved. Rather, the organization that plans to introduce the technology needs to be properly equipped and skilled (Organization Readiness).

MACRO-VARIABLE	MICROVARIABLE	DESCRIPTION	LITERATURE REFERENCES
READINESS	SUPPLY CHAIN READINESS	It represents the level of suitability of the whole industry to the introduction of BT. Literature stresses that, being BT a network technology, the prime condition for its implementation is, logically, the possibility to create a network. This depends on members' willingness to commit to BT-based applications and on the overall industry propensity towards innovative technologies. The latter can be evaluated observing the number of innovators and early adopters in the supply chain, with reference to past innovations. A rough idea of the industry inclination towards BT, then, derives from the number of ongoing or concluded BT-based applications or pilots. Authors prompt it is necessary that members wish to collaborate and start dedicated partnerships, in order to implement the technology in a SC. Ultimately, industry members should demonstrate technical compatibility and interoperability A supply chain is "ready" for BT when companies are eager to engage in shared BT initiatives, industry is not stagnant, but willing to face a certain risk to test innovative solutions, and when IT systems across the industry are interoperable or can be made interoperable with limited efforts.	(Woodside et al. 2017a), (Casino et al. 2019), (Svahn et al. 2017), (Lo et al. 2018), (Wang et al. 2019), (Kshetri, 2018)

	ORGANIZATION READINESS	A company can be mostly ready for a new technology, depending on its suitability to the technology characteristics. Generally, firms need to provide more flexibility to address digital innovations. In particular, companies should check, besides the resources available, whether their objectives are in line with the technology potential. Overall, literature identifies three major dimensions to investigate. At a technological level, the organization readiness is measured in terms of compatibility of BT with the existing IT system. The second dimension is that of human resources, that might require to develop new capabilities. Lastly, BT adoption is also a function of organizational features. Specifically, a company represents a good fit with BT when the adjustments of the process architecture are not prohibitive, as well as when the firm has an available capital and enough flexibility to allocate it to BT.	(Rizzo, 2016), (Woodside et al. 2017), (Holotiuk & Moormann, 2018), (Ebers, 2017), (Svahn et al., 2017)

Table 8: macro-variable "Readiness" (author's elaboration)

- **Supply Chain Features**: Besides the readiness of companies composing the network, BT adoption turns out to be linked to a series of SC characteristics. When the industry displays certain features, a higher predisposition to BT is evident. Alternatively, introducing such technology would result meaningless or it would deliver less advantages.

  These features refer to either problems (Supply Chain Issues) that might affect the system as a whole, like issues due to an ineffective data exchange, or some more structural dimensions (Supply Chain Complexity), like the diversity of involved actors.

MACRO-VARIABLE	MICROVARIABLE	DESCRIPTION	LITERATURE REFERENCES
SUPPLY CHAIN FEATURES	SUPPLY CHAIN ISSUES	This micro-variable relates to the a of SC problems that could be partially or totally solved by BT Literature sources, in fact, state that BT is a powerful solution for industrial pain points like the lack of data visibility along the supply chain and the scarce traceability of assets from origin to destination. Together with them, high administrative costs due to intermediaries, frequent delays and an ineffective communication can be addressed as well. Therefore, the literature review claims that when industries suffer from the problems reported above, the implementation of BT is promoted.	(Lo et al. 2018), (Wang et al. 2019), (Li et al. 2017), (Nakasumi, 2017), (Tapscott, 2016), (Kshetri, 2018), (Kwon & Suh, 2005), (Panayides and Venus Lun, 2009)
	SUPPLY CHAIN COMPLEXITY	Similarly to the previous dimension, the literature identifies a few characteristics of the SC that make BT a best fit. Particularly, the authors consider multi-party and global ecosystems as the best circumstance to implement it. The reported reason is that such ecosystems are typically affected by ineffective and slow information exchanges and by the costly role of middlemen. Alongside with them, also inefficiencies linked to the high number of suppliers and sub-contractors can be mitigated. According to the authors, the adoption of other information systems would be inadequate for complex industries, indicating BT as solution when industry's members are numerous and diversified.	(Abeyratne and Monfared, 2016), (Nakasumi, 2017), (Wang et al.2019)

Table 9: macro-variable "Supply Chain Features" (author's elaboration)

- **Technical implications**: This set of variables assess the technical concerns of BT and opportunities linked to the IOT. The examined authors at unison claim that this technology comes with a cost, which is not only financial but articulated into various forms. Organizations that examine BT as a possible investment should be aware of the challenges hidden behind such a spread hype. Simultaneously, a great value can be reportedly unlocked if BT is combined with the promising reality of smart sensors. New functionalities and enhanced performances seem to be available, provided that these technologies are used for specific purposes and at specific conditions.

MACRO-VARIABLE	MICROVARIABLE	DESCRIPTION	LITERATURE REFERENCES
TECHNICAL IMPLICATIONS	IOT INTEROPERABILITY	This dimension reveals that IoT and BT integration can successfully occur with certain sensors and for specific purposes. Literature proposes many cases to demonstrate the potential value of this union. Examples regard targeted products recall and autonomous transactions triggered by smart contracts. The overall perception is that BT platforms are considered solutions to connect and manage IoT reliably. Nevertheless, authors underline how this integration hinders further complexity, with systems' interoperability and maintenance costs being prime concerns. Above all, finally, the biggest problem remains sensor data security, as devices can be easily manipulated.	(Hackius & Petersen, 2017), (Christidis & Devetsikiotis, 2016), (Reyna et al. 2018)
	BLOCKCHAIN LIMITATIONS	There are diverse obstacles along the path of BT adoption. Recognized by several sources, these challenges are at both company and system level as well as both strategic and technical. Most of the authors	(Woodside et al. 2017), (Casino et al. 2019), (Beck et al. 2016, p. 1), (Holotiuk and Moormann, 2018), (Dos Santos and Chaczko, 2019),

		spot as major issues the energy consumption, data privacy and security, platform latency and the lack of reference use-cases. Moreover, a wide-spread suspicion is appointed as a further obstacle for BT diffusion.	(Sadhya and Sadhya, 2018), (Boucher et al. 2017), (Kshetri, 2018), (Wang et al. 2017)

Table 10: macro-variable "Technical Implications" (author's elaboration)

- **Blockchain benefits**: Literature streams mainly agree on the advantages to attribute to BT. Nevertheless, some taxonomy-related and conceptual issues prevent readers from clearly understanding the real impacts of BT.

  By analysing various sources' viewpoints, the author reorganised all the vastly recognized benefits into five comprehensive categories. These will be described at length in the dedicated research paragraph.

  The definition of the variables reported in this block can also praise the support of the 40 BT applications that have been reviewed. By merging field-based evidences with literature insights, the block is supposed to extensively depict the situation.

MACRO-VARIABLE	MICROVARIABLE	DESCRIPTION	LITERATURE REFERENCES
BLOCKCHAIN BENEFITS	COST	It relates to the various ways BT contributes to cut costs for the company adopting it. Mainly, cost-savings are associated to a reduction in administrative costs, as middlemen's activities can be avoided. Plus, the integration with IoT allows for zero or marginal cost to generate new blockchain codes. Digitalization of documents is a appointed as a further reason, as well as the easier regulatory compliance process through auditable data.	(Kshetri, 2018), (Vyas et al. 2019), (Treiblmaier, 2018), (Babich and Hilary, 2018), (Wang et al. 2019), (Eljazzar et al. 2018), (Pai et al. 2018)

	SPEED	It relates to the various ways BT contributes to increase a company's speed. To this purpose, literature evidenced that BT can digitize digital processes, like payments of suppliers, through smart contracts adoption. Similarly, the disposal of digitally signed documents to validate assets and entities' identity can save time by avoiding physical interactions. Plus, lesser time is spent in waiting for or delivering information, as BT supports a fast and streamlined communication among parties. Lastly, products recall is made faster thanks to the precise identity management system.	(Kshetri, 2018), (Vyas et al. 2019), (Min, 2019), (Babich and Hilary, 2018), (Wang et al. 2019), (Pai et al. 2018)
	DEMAND AND PRODUCTION MANAGEMENT	In this regard, academics highlight how BT can deliver value only if other industry's participants adopt it. If this is the case, companies are said to befit from more precise demand forecasts and operations scheduling thanks to the advanced data exchange. Furthermore, authors recognize that the demand for sustainable products cannot be neglected now that BT can prove the authenticity and the origins of goods. Ultimately, claims are that order fulfilment process is improved and that exceptions can be better handled.	(Vyas et al. 2019), (Babich & Hilary, 2018), (Eljazzar et al. 2018), (Pai et al. 2018)
	RESILIENCE	This is a large dimension embedding diverse benefits linked to SC risk reduction, transparent information sharing and cybersecurity. A diffused opinion among authors is that BT address the holistic sources of risk, since only those parties with a validated identity can engage in transactions. Furthermore, the technology by definition ensures that platform information is tamper-proof,	(Kshetri, 2018), (Vyas et al. 2019), (Min, 2019), (Treiblmaier, 2018), (Babich and Hilary, 2018) (Wang et al. 2019), (Eljazzar et al. 2018), (Pai et al. 2018)

		thanks to the consensus algorithms and crypto keys. Therefore, problems like self-reported data are omitted. Widely recognized advantages of BT are, in fact, data visibility and its append-only nature, making the single version of truth authentic and reliable. Eventually, resilience is enhanced by the technology ability to prevent counterfeits, damages and losses, especially when combined with smart sensors.	
	ASSET MANAGEMENT EFFICIENCY	This is the category where BT is told by authors to deliver value by accurately tracking assets and securing goods' provenance. The strong identity validation and tokenization system permits to create a digital copy of the physical asset, paving the way for a precise handling. In this regard, a key contribution of BT is to authenticate goods' provenance, as the series of operations undertaken by the registered asset at various touchpoints is recorded on the platform as the asset's history. To this purpose, eventually, literature indicates that the combination with IoT should be furtherly exploited.	(Kshetri, 2018) (Vyas et al. 2019) (Min, 2019), (Babich & Hilary, 2018), (Wang et al. 2019), (Pai et al. 2018)

Table 11: macro-variable "Blockchain Benefits" (author's elaboration)

4.2.2.3 Case selection

When dealing with case research, one question is about the number of case studies to use. Going for a single case or a multiple case approach is function of the specific research characteristics. In general, multiple case methodology is addressed as the best, because you can avoid to "put all your eggs in one basket" (Yin et al., 2003). In fact, relying on a single case observation is risky, as it makes the inquiry vulnerable.

Voss et al. (2002) talk about generalisability and biases as the greatest drawbacks of such approach. Yin et al. (2003), in fact, highlight that even with just two case studies, the most relevant benefit of having more observations emerge: the replication logic.

The turning point in such methodology is that, unlike many could think, case studies are necessary not for a sampling logic, but rather for a replication logic. (Barlow, Blanchard et al. 1977) reasoned on the similarity between an investigation made on case studies and another one made on experiments. In fact, the logic is to try replicating a finding from a specific experiment in all the others, by looking for the same evidences but with the possibly different conditions of another experiment. It is only via replication that a finding can be made robust and worthy. All in all, the major benefit of this logic is to enhance the external validity of the research, which is one of the factors it is valued on. Lastly, it was to exploit the exploratory force of the replication logic that multiple case studies were selected.

Such selection was performed with the objective of creating a heterogeneous set of "experiments". Companies displaying diverse conditions were considered allowing the replication logic to work effectively. In fact, both literal and theoretical replication were used as selection criteria, including in the research cases predicting similar results and those "predicting contrasting results but for predictable reasons".

At the basis of the case studies selection is the necessity to specify what the "case" is. For this purpose, it is essential to report what was the unit of analysis along the way and the reasons bringing to it. In this regard, the choice was mainly driven by the research scope, consisting in the investigation of BT adoption in SC. In particular, this project aims to understand when it makes sense for organizations to invest in BT for industrial purposes. Coherently with that, the unit of analysis was identified in the decision-making process conducted by a focal company which is interested in BT as a possible investment. By keeping such unit of analysis, in fact, it was possible to perfectly match the research objective. Furthermore, with this choice it resulted easier to organize data in blocks typically composing the decisional process itself, like benefits and challenges.

For the data collection, the researcher had to cope with the confidentiality of BT projects, since companies with up-and-running or completed BT initiatives are reluctant to share information. The desire to protect the deriving competitive advantage, in fact, convinces them not to divulgate their findings. Therefore, to get proper insights on those variables to consider when assessing blockchain, the author had to target other firms, more accessible and available to disclose data, but still reliable. In consideration of this, the types of companies addressed by the case study analysis were: IoT providers (HW only, SW only or both), or BT providers or BT and IoT providers. This choice is aimed at gathering information from entities that are familiar with BT either because they provide the technology itself, or because they supply IoT-related devices, which, in turn, should make confidence with BT more probable. In addition, this criterion makes the sample populated by technically prepared companies, having a certain expertise and knowledge, contributing for a higher reliability.

A second criterion applied during the sample creation was the industries where the analysed businesses where active in. Being the research focused on the industries of L&T and F&B, the selected entities were inserted in the sample only after proving a connection with at least one of the two domains.

In light of this, heterogeneity was one of the goals of case selection. Referring to two major dimensions, namely the supplier typology and the industries dealt with, companies were chosen to cover most of the combinations. The matrix in Figure 21 represents this situation.

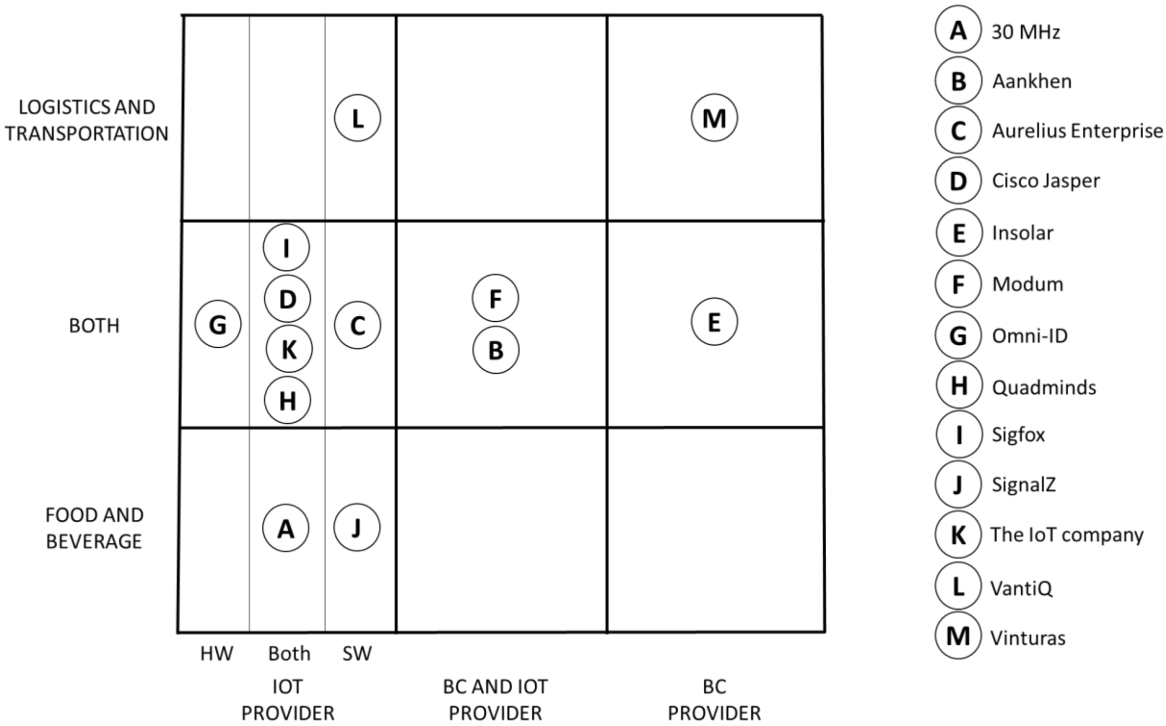


Figure 21: heterogeneity of the sample (author's elaboration)

Putting the two aforementioned dimensions on the X and Y axes correspondingly, the matrix illustrates how companies are displayed across the nine possible matches. The analysis of the distribution testifies the difficulty in engaging with BT companies though, frequently reluctant in sharing information.

The Table 8 below, instead, is a more precise description of the sample companies, with details on their geographical scope and HQ position.

SC POSITION	NAME	INDUSTRY	HQ	MARKET	INTERVIEWED PROFILE
IoT provider	30 Mhz	F&B (agrifood)	Amsterdam (NL)	Worldwide	CEO
BC and IoT provider	Aankhen	T&L, F&B	San Jose, CA (US)	Worldwide	CEO
IoT provider	Aurelius Enterprise	T&L, F&B	Amstrerdam (NL)	Worldwide	Project Manager
IoT provider	Cisco Jasper	T&L, F&B	Santa Clara, CA (US)	Worldwide	Sales Leader
BC provider	Insolar	T&L, F&B	Zug (CH)	Worldwide	Head of innovation
BC and IoT provider	Modum	T&L, F&B	Zurich (CH)	Worldwide	Product Manager
IoT provider	Omni-ID	T&L, F&B	New York (US)	Worldwide	Key Account Manager
IoT provider	Quadminds	T&L, F&B	Buenos Aires (ARG)	Worldwide	Product Manager
IoT provider	Sigfox	T&L, F&B	Labège (FR)	Worldwide	Technical director
IoT provider	SignalZ	F&B	Veenendaal (NL)	Worldwide	CEO
IoT provider	The IoT company	T&L, F&B	Rotterdam (NL)	Europe	CEO
IoT provider	VantiQ	L&T	Walnut Creek, California (US)	Worldwide	Director International Pre-Sales
BC provider	Vinturas	L&T	Leek (NL)	Europe	Lead BC architect

Table 12: sample companies' general information (author's elaboration)

4.2.2.4 Developing the research instruments and protocol

Along the evolution of the inquiry in examination, open-ended interviews were performed with various profiles of the selected companies. These interviews referred to a protocol made of various questions and topics. Companies were submitted such questionnaire form and interviews were conducted with a flexible approach, allowing the interviewers to focus on those questions and parts where interviewees demonstrated to deliver more information.

After getting companies onboard and before meeting (or e-meeting) for the interview, selected profiles were addressed with an email introducing the key project aspects (like the purpose, the involved people and sponsor) and the main topics. This was made to grant that interviewed people could come prepared to the interview date.

Despite of the selected organizations heterogeneity, questionnaire was kept the same for all the interviews, with a constant parallel to the aforementioned building blocks. This, if from one side allowed for a more homogeneous data analysis and a more transparent approach, from the other side made it difficult for some profiles to answer to questions oriented to topics they were not confident with. Nonetheless, the research methodology was revealed to deliver precious insights, gathering perspectives form diverse realities.

In short, these are the main content areas of the questionnaire:

- Company overview
- Key business model elements (mission, customers, partners and their needs)
- Served industries characteristics
- Smart sensors deployment
- Relation with blockchain
- Example of an IoT application, if available

In the Appendixes both the questionnaires and the introductive email are reported.

4.2.2.5 Conducting the research

At a broader span, the discussed research is part of a larger and long-term project. As readers already know, the SCF research team based at the Windesheim University of Zwolle provided a great contribution to the author in terms of supporting expertise and network. The thesis project was then inserted in the ambitious plan to build up a consortium for entities interested in BT and IoT. The real objective was, and to-date remains, that of mapping out these companies, reaching them out and convincing them to take part to the LivingLab, a broad and vivid environment made to foster knowledge sharing and BT adoption. This research project attempts to help out with the creation of the LivingLab by identifying new companies active in this domain and gathering information from them.

The investigation was practically performed by interviewing specific profiles within the targeted firms. These people were met either physically during on-site visits or digitally via dedicated programs like Skype or Hangout. The decision on the interview modality depended on his/her availability and geographical location during the data collection time period. When possible, it was always preferred to go for the on-site visits.

Moreover, interviews were conducted by the project author supported, when possible, the representative tutor and colleague Luca Gelsomino. As mentioned by Yin et al. (2003), the inquiry can benefit from a richer participation as for perspective complementarity and information loss prevention.

Interviews duration was always kept between 45 and 70 minutes, in function of the interviewees availability and the exhaustiveness of collected data. At the beginning of the discussion, interviewees were told about the vocal recording activity, furtherly preventing any information loss. During the interviews the author continuously took notes to emphasise the major emerging evidences and, lately, all the interview content was summarily transcribed using the questionnaire outline.

When approaching interviews, the author strived for behaving according to the guidelines drafted by Yin et al. (2003). This consisted in interpreting answers after making good questions, avoiding preconditions while listening to the interviewee and being flexible and adaptable. Alongside with this, the interviewer is invited to get grips on the argument by preparing accordingly and facing the event with no biases. This was extremely important to prevent speakers from perceiving the interview as an attempt to convince them on the BT benefit.

4.2.2.6 Data documentation and analysis

In order to support the documentation process, tape-recording was put in practice. Despite scholars claim that tape-recording may lead the interviewer to misleading behaviours, the researcher still decided to adopt it not to miss information and still focusing on the listening. Risks associated to this activity are the time-consuming transcription task and that of inhibiting interviewees. To prevent information losses, the recorded contents were transcribed in summaries the few hours or the day after the interview took place.

During the entire investigation, particular attention was payed to make the work valid and reliable, as prompted by Yin et al. (2003) and Voss et al. (2002). Construct validity, that is ability to "establish correct operational measures for the concepts being studied", was chased by using secondary sources of information. The interviews content was deepened with data from online material, companies' websites and debates with field experts like Professor Ok Van Megchelen (IoT expert) and Aljosja Beije (BT expert and CEO of BlockLab). A further boost to construct validity came with data triangulation and framework validation (Eisenhardt, 1989). The latter, which will be furtherly discussed in the next paragraphs, relied on a database of forty practical BT applications to proof the interviews evidences.

Additionally, research reliability, that is the ability of repeating a study's operations ending up with the same results, was also a top goal. Efforts to pursue it can be recognized in the creation of a case studies database. In details, a spreadsheet was set up to keep track of the targeted companies and the status of their engagement process.

Data documentation was not backed up by a data coding process. Although it is frequently addressed as a valid method to grasp data out of qualitative dataset, this research does not include it. Reasons for that are the scarcity of material, as coding requires quite large datasets to extract meaningful insights, and the desire for a more furthered analysis.

Data analysis approach, whereas, strongly contributed for an advanced research validity. A two-step process represented the path for assessing data (Eisenhardt, 1989). Firstly, in order to get as more familiar as possible with the single case studies, within case analysis were conducted. As it will be shown later, a standardized and organized display of information allowed to engage in individual cases in a systematic way. This phase committed to the identification of looming evidences and significant patterns within each case. Therefore, sub-factors and parameters were sequentially spotted, case by case, with reference to the categorization made upon literature insights. These within-case analysis can be found in the Appendix 5.

At conclusion of data analysis, the evidences derived from within case inquiries were assessed and integrated across the various cases. Cross-case analysis is an essential step for the recognition of patterns and for making results generalisable. The elaboration of this task made use of the within case results, from which emerging insights were firstly extracted and then sequentially compared with the other cases' patterns. This allowed to observe similarities and differences among various experiments, furtherly enhancing internal validity of the work (Voss et al., 2002).

A scheme of the cross-case study analysis can be found in Figures 9 and 10.

Overall the data analysis process can be envisioned as the bedrock for the achievement of what is supposed to be the real project goal, that is new theories creation. By generating elementary hypothesis from single cases and comparing them within the entire sample, it is possible to test which are the most valid. When this procedure is made iterative, it results in the selection of those theories having a close fit with most of the cases.

Ultimately, literature review is important to corroborate the evidences obtained from data analysis. In fact, a constant reference to the literature protocols was constantly kept, both considering the building blocks identified since the beginning and by keeping a real connection with the existing works on the assessed topics. This was particularly precious to define what is different and what is similar with what claimed by other authors (Voss et al., 2002) (Eisenhardt, 1989).

4.2.3 Content analysis

Conducting qualitative researches puts the authors in front of some conceptual problems. First of all, the lack of quantitative data advances concerns related to the verifiability of conclusions. Qualitative information can be easily handled opportunistically in order to come up with the desired results. Furthermore, where qualitative conclusions come after an individually managed set of processes, their truthfulness is logically questioned.

Mason (2002) claims that the criticism around qualitative research is not fully justified as it frequently comes as a misunderstanding. Diffused preconceptions are that qualitative investigations are necessarily associated to weaknesses like being unsystematic, anecdotal and at best illustrative. The author stresses how qualitative inquiries can destroy this opinion when their authors act with active reflexivity, that is critically evaluating the results and their reasons.

In order to get over these legitimate concerns and to expand the analysis beyond the research framework, a content analysis was put in place. The latter was conceived as an effort to objectively compare the framework's content with other sources. It relies on a so-called categorical indexing, one of the three approaches proposed by Mason (2002) to sort and organize qualitative data. The term "categorical indexing" is described as a tool to devise "a consistent system for indexing the whole of a data set according to a set of common principles and measures". The adoption of such approach is aimed at finding a way to systematically handle predominantly text-based data.

The central idea of the content analysis was to verify whether the framework variables also exist in real-case applications of BT and IoT, and, possibly, their degree of evidence. Consequently, the first step consisted in identifying and selecting a set of initiatives of this kind. Because of the already discussed difficulty in obtaining data from companies directly committed into BT projects, information was collected via grey literature, consisting in secondary sources like web articles and companies' websites. A database was created to keep track of the various projects and the corresponding data sources. The number of applications reported in the database is

40, which is a significantly large sample with some of the most relevant cases known in the world. The spreadsheet can be found in the Appendix 3 at the end of the document.

Once the list of applications and the related material was available, a categorical indexing was selected to treat data. The categorical indexing identification stands at the basis of the successive content analysis, that is the application of the indexing on the collected material. Like Ruhanen (2017) did in her writing "Tourism and Hospitality Panning & Development", a three-point Likert type scale was adopted to define whether the framework variables are evident, somewhat evident or not evident. This decision was taken to assist the research with a higher objectivity, besides to engage with qualitative data in a quantitative way. The method, applied during the content analysis, consisted in assigning a value of 0 ("Not Evident"), 1 ("Somewhat Evident") or 2 ("Evident") to every sub-factor in a specific BT application, depending on the level of evidence the sub-factor showed in the corresponding data sources. In this way, it was possible to observe which sub-factors emerged as relevant in the examined case study. Hence, by repeating this procedure on the entire database, i.e. the 40 applications, the researcher came up with a table showcasing 40 values for each of the framework dimensions. Later on, these values (weights) were used to compute a mathematical average for all the 51 sub-factors, in order to grasp the "average" level of evidence in the 40 cases. After which, in the final step, a discriminatory threshold of 1 was set to discriminate between evident and not evident dimensions, respectively having an overall average weight between 1 and 2 and between 0 and 0.99.

The above-described methodology is represented and synthetized in Figure 22.

j → / i ↓	BT APPLICATION$_1$	BT APPLICATION$_2$		BT APPLICATION$_{40}$	AVERAGE WEIGHT
SUB-FACTOR$_1$	weight $_{1\text{-}1}$	weight $_{1\text{-}2}$	. . . . . .	weight $_{1\text{-}40}$	$\sum_{j=1}^{40}$ weight $_{1\text{-}j}$
SUB-FACTOR$_2$	weight $_{2\text{-}1}$	weight $_{2\text{-}2}$	. . . . . .	weight $_{2\text{-}40}$	$\sum_{j=1}^{40}$ weight $_{2\text{-}j}$
⋮	⋮	⋮	⋮	⋮	⋮
SUB-FACTOR$_{51}$	weight $_{51\text{-}1}$	weight $_{51\text{-}2}$	. . . . . .	weight $_{51\text{-}40}$	$\sum_{j=1}^{40}$ weight $_{51\text{-}j}$

Figure 22: rationale of the content analysis methodology (author's elaboration)

Limitations of a content analysis

Despite the content analysis is not per se ineffective, here some structural and circumstantial characteristics make it difficult to exploit its full potential. This approach works smoothly when rooted on extensive databases, providing an objective and exhaustive amount of data. In this case, though, it was hard to achieve the desired level of data detail and precision for a comprehensive description of the selected BT applications. In fact, the newness of BT technology and its limited number of practical applications from one side, and the paucity of scientific papers to describe them from the other side, represented a challenge to the study. The recent rise of blockchain has allowed only the bravest firms and the first movers to really experience its practical implications, benefits and drawbacks. Consequently, no or few official scientific documents have been released on these applications. Most of the sources used to run the content analysis were part of grey literature, written with an informational or promotional scope and with a commercial nature.

Because of these obstacles, the Likert scale output turns out to be limited, as the generic tone and not exhaustive content of these articles were hardly matchable with the high level of specificity of the sub-factors.

4.2.4 Comparison between the content analysis and the multiple-case analysis

So far, data was collected from both primary sources and secondary sources. The analysis of primary sources, as already observed in the previous paragraphs, mainly referred to the interviews' content. This was triangulated with the analysis of complementary sources regarding the same companies and of the related literature. In the end, this resulted in the formulation of the research framework. Later, the author performed a content analysis on "grey literature", considering the research framework as reference model. Its goal was to understand the level of evidence attributed to the research variables from the grey literature.

Comparing the framework resulting from the interviews with the evidences of the content analysis, the author could highlight convergences and discrepancies across the framework's variable. This allowed to underline and – to a certain extent – verify the coherence, alignment and consistency of grey literature in the context of a broader framework expressing a more comprehensive perspective on the adoption of BT.

Such comparison was supported by a matrix, reported in the Appendix 4, displaying the evidence levels of sub-factors observed in interviews (X axis) and in the content analysis (Y axis). Two different methods were adopted in the attribution of evidence degrees, depending on the type of analysis.

Specifically, the technique used with interviews was chosen in relation to the qualitative nature of their content. In fact, various levels of evidence were attributed based on qualitative and descriptive insights contained in the interviews. Depending on the opinion expressed by the interviewee at the level of a specific dimension, the author discriminated between high and low evidence factors. In addition, descriptive comments were also inserted into the matrix cells, beside the evidence judgement, when interviews' clues were specific. This was performed to prevent rushed conclusions and to support a high-level comparison with the other type of analysis.

About the content analysis, the variables' evidence was evaluated using the Likert scale as categorical indexing, as extensively described in the previous paragraph.

The above-described methodology is represented and synthetized in Figure 23.

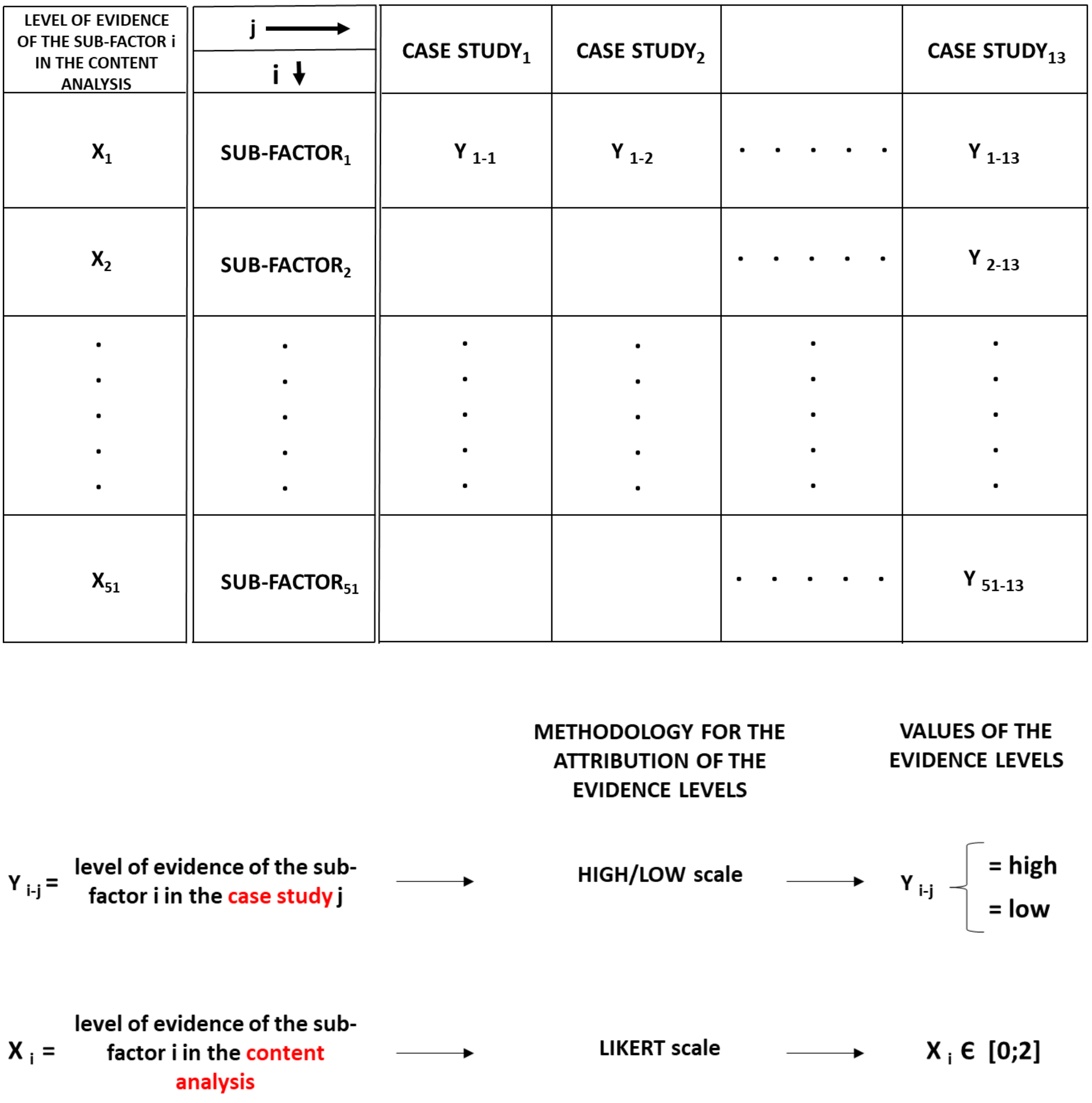


Figure 23: comparative analysis methodology (author's elaboration)

5. RESULTS AND DISCUSSION

The pages below will bring the readers throughout the main results of the three parts the project is made of. The application of the methodologies presented above led to the definition of certain findings that will be accurately showcased. The findings explanation will occur in consideration of the research structure and in form of discussion of the three research questions. Specifically, RQ1 and RQ2 are set to introduce the research variables and their relationship with the independent variable, i.e. the BT adoption. Lastly, along the discussion of RQ3, readers will be provided with the analysis of BT benefits.

5.1 RQ1*: identification and interpretation of the variables impacting the adoption of BT*

A conceptual framework has been created as a first attempt to answer to RQ1.

Aiming to spot the variables affecting the adoption of BT in the examined industries, research efforts were organized along two main directions. From one side, the above-mentioned literature review allowed to point out three theoretical building blocks pertinent to RQ1: Readiness, Supply Chain features and technical implications. This provided a general structure for the research, besides a solid theoretical foundation. On the other turn, the multiple-case methodology was leveraged to extract further impacting dimensions with a lower granularity, namely the sub-factors. For sake of clarity, these dimensions were clustered in the three theoretical building blocks named above, also to keep a constant benchmark with the literature.

To sum up, variables identification was the result of a two-step multiple-case analysis. After the case selection, in fact, variables were defined based on the within-case analysis and a cross-case analysis. While the outputs of the within-case analysis are reported in the Appendixes, those related to the cross-case assessment will be discusses below. The final research framework, coherently with the methodology steps performed, is presented after the cross-case analysis, being this the overall output of the multiple case analysis.

At the end of the paragraph dedicated to RQ1, the author further inspects the relationship concurring among the independent variables and towards the dependent one. Precisely, the "variables tree" is proposed as a practical application of the research framework.

5.1.1 Cross-case analysis

The cross-case analysis was conducted after the within-case analysis to investigate whether the insights coming from a case study could find confirmation in others. Tables 9 and 10, in fact, suits to cross-check which cases contain or relate to a specific dimension (sub-factor). To proceed with the analysis, sub-factors were organized by concept, as suggested by Voss et al. (2002), using the theoretical building blocks as a reference. In this way, it was possible to spot similarities and differences in how various cases address the same macro-topics (Yin et al., 2003).

Overall, this analysis allows to understand whether a factor emerging from a specific case is confirmed by other cases. The tables prompt that insights emerging from a single experiment might be agreed by other cases, to an extent that varies from one dimension to the other. The "X" reported in the tables, in fact, indicates that the sub-factor lying on that row exists (i.e. is confirmed) in the case study corresponding to that column. The inductive inclination of the inquiry brought to consider also those sub-factors showing limited approval across the cases, since every case was analysed as if it was an experiment. Indeed, any time a new pertinent dimension popped up, it was inserted into the pre-existing framework structure, made of the theoretical building blocks.

These tables, besides proving the diffusion of research factors across the case studies, paved the way for the leading part of the investigation, consisting in the comparison with the content analysis. Together with the within-case analysis, in fact, the cross-case assessment was also used to evaluate the "type" of evidence of dimension in the specific cases. Per se, indeed, the cross-case analysis tables do not manage to distinguish between a case where the factor X was presented as highly evident and another case where the same dimension had a low evidence.

			30 MHZ	AANKHEN	AURELIUS ENTERPRISE	CISCO JASPER	INSOLAR	MODUM	OMNI-ID	QUADMINDS	SIGFOX	SIGNALZ	THE IOT COMPANY	VANTIQ	VINTURAS
SUPPLY CHAIN READINESS	SUPPLY CHAIN ENGAGEMENT	Willingness to cooperate	X	X	X	X	X	X	X	X	X	X	X	X	X
		Consortium support		X			X							X	X
	COMPLEMENTARITY IT SYSTEMS AT PARTNERS' ORGANIZATIONS	Interoperability of IT systems at partners' organization				X	X	X		X					X
	INNOVATION STAGNANCY	Innovation stagnancy			X	X	X	X		X			X		X
ORGANIZATION READINESS	TECHNOLOGY	Current IT architecture					X			X					
	PEOPLE	Level of knowledge and expertise on BC technology		X				X				X	X		
	ORGANIZATION	Current Business Process Architecture					X				X				
		Organization's objectives	X		X	X		X	X	X			X		X
		Ability to invest					X			X					
SUPPLY CHAIN ISSUES	DATA VISIBILITY	Cost-effectiveness of the SC information exchange		X		X		X	X	X			X	X	
		Adequacy/effectiveness of existing communication technology								X					X
		End-2-end visibility along all SC operations	X	X	X	X	X	X		X			X	X	X
		Disputes and frauds creation and management		X			X	X				X			X
		Heterogeneity/diversity of IT systems					X								X
	PROCESS EFFICIENCY	Administrative costs				X									X
		Inter-company processes accountability / integration	X	X		X		X		X				X	
		Visibility on bottleneck	X	X	X					X				X	X
		Interoperability of corporates' ERPs					X								
		Data integration at SC process level	X	X	X	X		X	X	X			X	X	X
	DEMAND MANAGEMENT	Increased demand for quality, customized and sustainable products	X		X			X		X		X			
		Level of responsiveness			X										
		planning/scheduling effectiveness			X		X			X				X	
		Operations transparency		X		X						X			
	TRACKING, TRANSPARENCY AND TRUST	Effectiveness of assets traceability (assets lost, thefts and tampering)	X	X		X		X	X	X	X		X	X	X
		Trust level among organizations and customers	X	X		X	X	X		X					
		Cost-effectiveness of validation process		X			X	X	X						

Table 13: Cross-case analysis (author's elaboration)

			30 MHZ	AANKHEN	AURELIUS ENTERPRISE	CISCO JASPER	INSOLAR	MODUM	OMNI-ID	QUADMINDS	SIGFOX	SIGNALZ	THE IOT COMPANY	VANTIQ	VINTURAS
SUPPLY CHAIN COMPLEXITY	HETEROGENEITY OF ORGANIZATIONS	Heterogeneity of organizations					X		X	X	X			X	
	STRUCTURE	Structure					X			X	X			X	X
INTEROPERABILITY WITH IOT	SENSORS' FEATURES	Dimensions measured	X	X		X	X	X	X	X	X	X	X	X	
		Sensor typology	X	X			X	X	X	X	X	X	X	X	
		Application level	X				X	X	X	X	X	X	X	X	
	SENSORS' PURPOSES	Tracking and trace		X	X	X	X	X	X	X	X		X	X	X
		Predictive or preventive maintenance			X		X					X			
		In-process visibility	X	X	X				X	X	X	X			
		Real-time performance measurement and control	X	X	X	X	X	X	X	X	X	X			
		Avoid not value-adding activities	X	X	X										
		Data security and validation		X	X	X			X	X		X			
		Relatively low maintenance cost			X						X	X	X		
		Need for real-time monitoring						X	X	X		X			
		Availability of applications	X		X	X		X	X	X	X			X	
		Efficient power consumption									X				
		Interoperability with other IoT and Cloud software	X	X	X	X		X	X	X	X	X		X	
BLOCKCHAIN LIMITATION	LACK OF SUPPORT/TRUST	Black box (meta-trust required)	X							X	X			X	X
		Platform security	X			X									
		Zero-status issue	X												
	IMPLEMENTATION ISSUES	Energy consumption					X								
		Technology readiness		X				X	X		X				
		Lack of standards		X		X								X	X
		Latency													X
	STRATEGIC ISSUES	Monetization of the investment (no clear ROI)				X		X	X	X	X				
		Added value creation	X	X					X	X		X		X	X

Table 14: Cross-case analysis (author's elaboration)

5.1.2 Research framework presentation

The research framework shown in Table 1 represents the final output of the multiple-case analysis. Here variables are visually represented to be generally described afterwards.

MACROVARIABLES	MICROVARIABLES	PARAMETERS	SUB-FACTORS
READINESS	SUPPLY CHAIN READINESS	Supply Chain engagement	Willingness to cooperate
			Consortium support
		Complementary IT systems at partners' organization	Interoperability of IT systems at partners' organization
		Innovation stagnancy	Innovation stagnancy
	ORGANIZATION READINESS	Technology	Current IT architecture
		People	Expertise and knowledge on blockchain
		Organization	Current Business Process Architecture
			Organizations' objectives
			Ability to invest
SUPPLY CHAIN FEATURES	SUPPLY CHAIN ISSUES	Data visibility/traceability	Cost-effectiveness of SC information exchange
			Effectiveness of existing communication technologies
			End-to-end visibility along SC operations
			Disputes and frauds creation and management
			Diversity of IT systems
		Process efficiency	Administrative costs
			Inter-company processes accountability and integration
			Visibility on bottlenecks
			Interoperability of corporates' ERPs
			Data integration at SC level
		Demand management	Increased demand for quality, customized and sustainable products
			Level of responsiveness
			Planning and scheduling effectiveness
			Operations transparency
		Tracking, transparency and trust	Effectiveness of assets traceability (losses, thefts and tampering)
			Trust among organizations and customers
			Cost-effectiveness of validation process

	SUPPLY CHAIN COMPLEXITY	Heterogeneity of organizations	Heterogeneity of organizations
		Structure	Structure
TECHNICAL IMPLICATIONS	IOT INTEROPERABILITY	Sensors' features	Dimensions measured
			Sensor typology
			Application level
		Sensors' purposes	Tracking and trace
			Predictive or preventive maintenance
			In-process visibility
			Real-time performance measurement and control
			Avoiding not value-adding activities
		Pre-conditions for IoT	Data security and validation
			Maintenance cost
			Need for real-time monitoring
			Availability of applications
			Power consumption
			Interoperability with other IoT and Cloud software
	BT LIMITATIONS	Lack of support/trust	Block box
			Platform security
			Zero-status issue
		Implementation issues	Energy consumption
			Technology readiness
			Lack of standards
			Latency
		Strategic issues	No clear ROI
			Added value creation

Table 1: research framework (author's elaboration)

The leading part is meant to provide readers with an overview of the variables. Their explanation is based on the framework structure, following the categorization mentioned at the beginning of the research.

<u>Readiness</u>

First of all, being this an innovative digital technology, it requires single organizations to properly adapt. The latter, in fact, are asked to bring about changes as far as it concerns organizational processes, people and technology, handling all of them simultaneously through deep dedicated activities of project management (Holotiuk & Moormann, 2018). The introduction of a new technology is a resource and time-consuming event. Therefore, measures taken by companies should be entangled in a comprehensive set.

Regarding the **organization**, since BT is a network solution operating among multiple players, any adopter should adjust its processes so that synergies inter departments and inter organizations are achieved. Moreover, case-study analysis suggested that process architecture should be generally adapted to enable BT introduction. Fostering collaborations with other industry entities is also a valid criterion for this processes redesign. Plus, the engagement of diverse departments and employees may lead to further ideas generation. Alongside with that, a company might find further drivers for this technology adoptions in its objectives. If cost reduction through process optimization, improved visibility on operations, enhanced asset management and innovative business model are among the company's goals, BT can be a powerful ally. Last but not the least, companies should ascertain the required capital availability and verify to be flexible in the capital allocation.

When it comes to **technology**, on the other turn, BT adds some levels of complexity to the IT system, despite being a non-invasive solution at a hardware viewpoint. Many IT providers have already started offering blockchain-based applications, to integrate with the currently existing IT architecture. About this, authors (Banerjee, 2018) suggest hybrid forms made as a mix of BT and ERP features will be mostly adopted in the very next future. Firms should check whether required IT adjustments still make it advantageous to implement BT.

Human resources represent a key possible enabler for blockchain. Novelty and specificity of the technical aspects linked to the new technology need to be counterbalanced by an adequate set of skills and knowledge. Training and hiring are the way to get this familiarity with BT on board, but adaptations may be required as well.

Alongside this, a joint management of all these procedures is promoted as a way to facilitate BT adoption. Specific responsibilities allocation and leadership definition are at the hearth of this managerial approach. Plus, such innovative projects need to be held with a "trial and error" approach, providing flexibility to changes and sequentially moving from Proof of concepts to larger-scale solutions with quick tests and prototypes.

Besides being a disruptive digital innovation, BT is repeatedly reported to suit network situations with a high number of participants. This makes it clear how relevant the whole supply chain readiness level is. Since it is the entire industry to benefit from BT adoption, the **engagement** of multiple actors in the early stage of the technology diffusion is proclaimed to be decisive (Kshetri, 2018). The establishment of consortia (Wang, Han, et al., 2019)_and/or focused partnerships undoubtedly helps out in collaborating, coordinating and defining the network configuration (Svahn et al.,2017).

At the same way, SC readiness is even measured in terms of **interoperability of IT systems**. A diffused diversity in IT configurations displayed across the involved parties hinders the definition of standards and the adoption of common enabling infrastructures(Banerjee, 2018). Partners in BT adoption should provide systems that are complementary to each other (Wang, Han, et al., 2019). Extremely important to BT diffusion, logically, is that companies within the same SC are willing to co-invest and to cooperate to succeed in this. Lastly, considerations can be made on the attitude of the overall SC towards **innovation**. In some cases, industries show reluctancy in moving to newer technologies as the general pattern within the industry itself is stagnant (Woodside et al. 2017b)**.** This can be considered a more structural and field-specific factor, harder to change though.

All in all, the adoption of BT can deliver values proportionally to the articulation of the above-mentioned factors, drafting the degree of readiness shown by the single organization and the supply chain as a whole.

<u>Supply Chain Features</u>

Among all the various solutions blockchain stands at the hearth of, only few specific applications make this adoption particularly worthy. When brought into supply chains' dynamics, in fact, blockchain does its best (Kshetri, 2018). Modern industries are typically plagued by the following diffused troubles, owing to the increased competition, the ever-changing customers' requirements, globalization of the business processes and the fast-digital innovation.

Overall, this results in ecosystems where actors cannot integrate data at industry level, lacking visibility on the chain processes. Badly managed communication and not interoperable IT systems hinder the timely exchange of the required information, ending up with disputes, defaults and delays. Moreover, antiquate communication technologies like EDI clearly show their inadequacy in current industries, since information is required to flow seamlessly in various directions.

Additionally, the abundance and heterogeneity of the entities involved in the dense information transfers, add complexity to the system. This intricacy is reflected in the need for intermediaries and in the lack of accountability at systemic level. Consequently, high transaction and administrative costs are triggered, burdening supply chains with serious inefficiencies. Furthermore, firms taking part to the same systemic processes don't aggregate data at a common level, creating frictions and delays over those activities engaging various parties. Data integration at touchpoints is adequate, meaning that companies strive to pinpoint bottlenecks along the chain and cannot optimize their operations accordingly. Lastly, concurrent cause of the scarce data integration is the siloed IT architecture that is now responsible for a limited interoperability of diverse organizations' ERPs.

In these industries made of stand-alone parties, still most of the companies compete as realities on their own. This tendency inhibits the flow of precious information on downstream demand and forecasted sales. As a result, organizations struggle in effectively plan and execute their business, unable to predict demand variations and to flexibly adapt to supply volatility. At the same time, the demand side also contributes in adding complexity by asking for more customised and sustainable products and services. Consequently, firms need to find a way to proof products' provenance and compliance to standards as well as to deliver need-specific solutions, especially when it comes to IoT services. Eventually, lack of operational transparency is marked as a cause for counterfeit products or poisoned products, with potentially dramatic consequences if they reach the end of the chain. Case-study analysis, then, drew attention to the risk of KPIs manipulation, an illegal practice aimed at hiding inefficiencies and keeping customers' loyalty.

Furthermore, extended and geographically enlarged supply chains entail long movements, complex documentations and multiple touchpoints. Along these articulated journeys, the probability of fraudulent behaviours, contractual disputes and lost assets is worryingly high. The responsibility of goods tracking is typically assigned to the executing party, with limited or no visibility of the exact provenance. To tackle the lack of trust from customers and the above-reported problems, firms are asked to authenticate and validate received materials and handled data.

Any industry afflicted by these types of challenges is suggested to implement blockchain-based solutions. Lack of data **visibility**, systemic **process inefficiency**, difficult **demand management** and **trust** related issues can be all addressed by this new technology (Wang et al., 2019), (Insolar, 2019).

In addition, Abeyratne and Monfared (2016), link blockchain suitability to large networks made of miscellaneous parties, where it would result as a viable solution to tackle complexity. Any time industries take the shape of a huge fragmented bundle of firms disposed on an articulated multi-tier system, smart contracts are pointed as a valuable solution. **Complex and large supply chains** are typically crowded by many stakeholders, making it tough to trail the evolution of the agreed tasks and to manage financial flows accordingly. This status of articulation of a supply chain promotes the adoption of BT technology as a solution to align and coordinate firms and to streamline information and finance flows.

Technical implications

Despite being a powerful technology on its own, blockchain has more to offer when combined to other solutions, literature suggests (Samaniego and Deters, 2017). In particular, the integration with the realm of IoT is reported to significantly transform traditional business models, provided that basic requirements for the adoption of

IoT are achieved (Madakam et al. 2015). As described over the previous paragraphs, blockchain enables reliable and auditable transactions in a peer-to-peer systems where participants usually can't trust each other. Additionally, smart contracts have already been discussed as the digital coding of real agreed-upon contractual terms, ideally capable of automate them. The key role played by the IoT in this team game is given by the possibility of gathering information from the physical world, using smart sensors as sources. Exploiting such touchpoint between the digital and real worlds, such technology integration promises to automate multi-party processes, saving time and costs (Reyna et al. 2018).

Considering this potential, **interoperability with** smart sensors, and **IoT** in general, is observed by authors as a further mean to convince practitioners on BT. Especially when talking about sensors designed to measure and report data on temperature, humidity, light and location, the association with BT emerges to be useful. Smart sensors, in fact, would serve as oracles, making information flow into the digital network and possibly triggering smart contracts execution (Kshetri, 2017). In this self-reinforcing combination, data sources are always identifiable and accessible, while storing it immutably thanks to the cloud secure technology of BT. Applications frequently described as suitable to this scope are goods tracking along extended supply chains and automation of financial payments during goods transfer. Lastly, the creation of data marketplace for IoTs is also addressed as a serious field of adoption, where huge volumes of previously valueless data are transformed into new revenue sources (Wang et al. 2019).

Unifying blockchain and Internet of Things can be beneficial at the only condition that the requirements for IoT adoption are respected. This means that sensor data must be primarily secured and protected at best from any cyberattack or physical alteration at device level. In addition, the overall connected ecosystem must not be prohibitive in terms of maintenance costs and software updating. Further conditions are the existence of applications and software platforms to elaborate the data form the real world, with the consequent necessary of connecting IoT sensors with each other and Cloud systems (via API and IP).

Other technical implication BT adoption depends on, is the set of **drawbacks** it comes with. Out of the mostly agreed list of deficiencies (Sadhya and Sadhya, 2018), (Risius and Spohrer, 2017), (Dos Santos, Chaczko, 2019), (Casino et al. 2019), these gravitate around three major concerns: lack of trust, implementation issues and strategy-related considerations.

Regarding the mistrust around BT, three major concurrent causes exist. Firstly, the advantage of disintermediation provided by BT is counterbalanced by the need for "meta-trust". Technology adopters can see the transactions within their ecosystem freed by the costly intervention of third parties, but they must trust the platform itself even without a full understanding of the technical underpinnings. Another reason for concern is the platform security. Despite it is computationally hard to take control of the platform, a small possibility still exists and it threats users' privacy and data security. Sill about data, further burdens relate to the integration of BT software platform with physical oracles like IoT sensors. Chances are that physical devices get easily tampered or that they are not cryptographically protected. Besides this, at a technical viewpoint there are other items limiting BT diffusion. Many interviews suggested that technology is not ready yet to support large-scale and systemic applications, and few reported platform latency is a real obstacle to process thousands transactions. Scholars, on the other turn, reason that even if BT was ready for these ecosystems, the required energy consumption would be prohibitive. Lastly, although possibly the toughest challenge, so far, no common standards were set within or across industries to promote an organised and legally recognized usage of BT. Eventually, firms still wonder how to deal with the so-called "chicken and egg" paradox when talking about blockchain. The lack of real and successful large-scale case studies put decision makers in front of a bet, where they are asked to invest on a risky technology. The unclear Return Of Investment makes technology diffusion slow down, as companies still struggle to understand whether BT could add value for their specific business.

Both technologies evidently show limitations and future challenges, but their understanding is left to the dedicated paragraph in the literature review.

5.1.3 Analysis of the relationships among variables

The previously observed framework represents the starting point for this second phase. The interpretation of the variables aims at clarifying how they concur among each other and towards the decision of adopting BT. For sake of clarity, a conceptual model (Figure 3) based on mathematical functions is proposed to explain the framework logic.

The relationship existing between the three macro-variables and the dependent variable (Blockchain adoption) is a direct proportion, meaning that their positive impact ($A_i>0$) would make Blockchain adoption more meaningful (Y would increase). The mathematical function $Y=\sum i\ A_iX_i + B$ perfectly sums up the nature of this relationship.

On the other turn, a similar link occurs between each macro-variable and its micro-variables, and between each micro-variable and its parameters. Lastly, every single parameter will pay an impact on the micro-variable associated depending on the value of the whole set of sub-factors that parameter is function of.

The entire network of relationships between the diverse layers of the framework could be observed in the following chart.

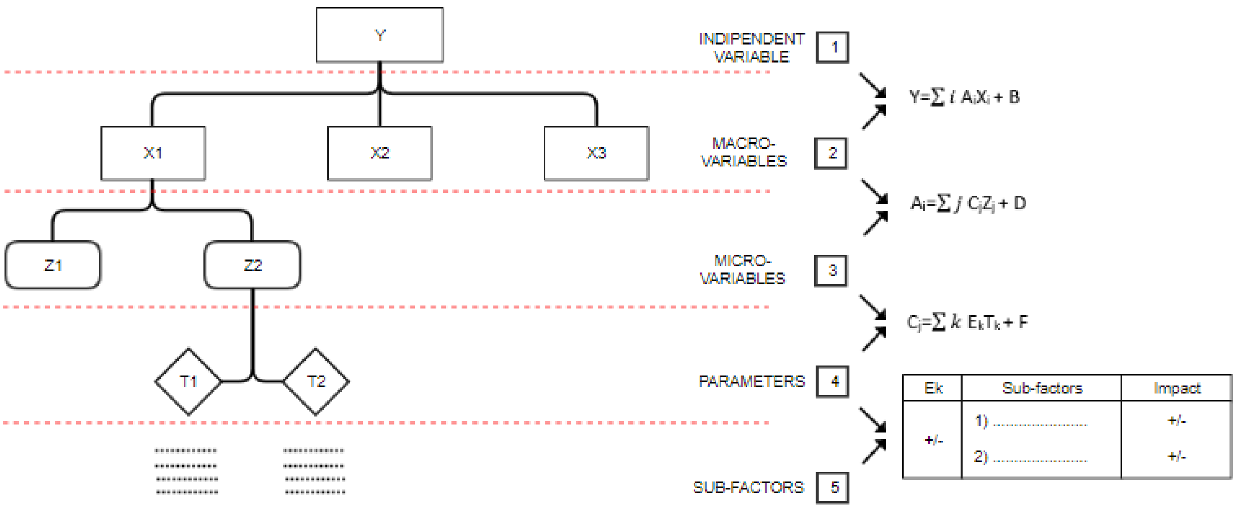


Figure 3: relationships among research variables

Apart from the mathematical relationships among variables, which do not fall into the research scope, figure 3 aims to explain that the convenience of the technology adoption relates to the contribution of any single sub-factors in the framework.

Made this premise, an application of the research framework is proposed below. Should a company evaluate BT as a future investment, the framework would allow the decision maker to use it as a checklist, by climbing it back from the bottom to the top. The tool drafted in Figure 24 below is the “variables tree”, which is set to help the user moving along the framework. In this way, organizations can evaluate whether the current status of all the sub-factors promotes or inhibits the technology adoption. By going back up the framework through the different layers of variables and considering the relationships between this layers, one can finally decide whether the as-is situation suits to blockchain introduction.

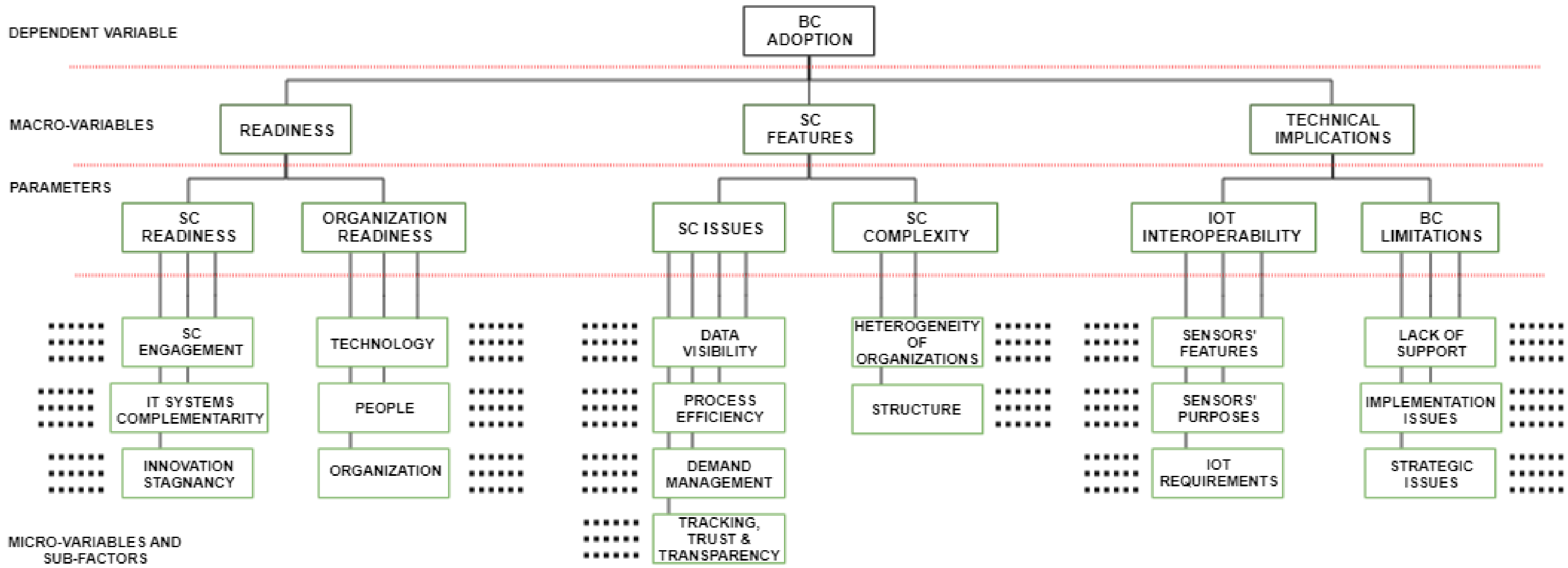


Figure 24: variables tree (author's elaboration)

5.2 RQ2*: Comparison between the content analysis and the multiple-case analysis*

The author decided to examine BT adoption with a diverse perspective by conducting a content analysis. Forty BT applications were selected, and the related grey literature was consulted to gather information on them. Afterwards, by comparing the outputs of the content analysis with those of interviews, the author intended to critically observe divergencies and similarities to make broader considerations on BT implementation in SC. The next pages will disclose the results of the content analysis and the final comparison.

5.2.1 Content analysis

As mentioned in the "Methodology" chapter, a content analysis was integrated to the multiple case-study analysis. After variables and their extensions (parameters and sub-factors) were identified via interviews, a content analysis was set up to make comparisons afterwards.

Once the BT applications were selected, the content analysis leveraged the corresponding grey literature, made of secondary sources, to evaluate the existing research framework from a different perspective. In detail, this consisted in the attribution of a specific level of evidence to each sub-factor in each BT application of the sample. To this purpose, a Likert scale was used as categorical indexing, as exhaustively explained in the methodology chapter. Eventually, the result of the content analysis was a list of average weights (levels of evidence), one per each sub-factor.

Table 2 showcases all these dimensions' weights, where a red colour is used to highlight the weights associated to the evident dimensions, with white cells identifying the not evident ones.

Willingness to cooperate	1,60	SUPPLY CHAIN ENGAGEMENT	0,95	SUPPLY CHAIN READINESS	0,53
Consortium support	0,30				
Interoperability of IT systems at partners' organization	0,30	COMPLEMENTARITY IT SYSTEMS AT PARTNERS' ORGANIZATIONS	0,30		
Innovation stagnancy	0,33	INNOVATION STAGNANCY	0,33		
Current IT architecture	0,25	TECHNOLOGY	0,25	ORGANIZATION READINESS	0,30
Level of knowledge and expertise on BC technology	0,35	PEOPLE	0,35		
Current Business Process Architecture	0,20	ORGANIZATION	0,30		
Organization's objectives	0,48				
Ability to invest	0,23				
Cost-effectiveness of the SC information exchange	0,95	DATA VISIBILITY	0,84	SUPPLY CHAIN ISSUES	0,82
Adequacy/effectiveness of existing communication technology	0,45				
End-2-end visibility along all SC operations	1,68				
Disputes and frauds creation and management	1,10				
Heterogeneity/diversity of IT systems	0,00				
Administrative costs	0,53	PROCESS EFFICIENCY	0,66		
Inter-company processes accountability / integration	1,00				
Visibility on bottleneck	0,30				
Interoperability of corporates' ERPs	0,05				
Data integration at SC process level	1,43				
Increased demand for quality, customized and sustainable products	1,05	DEMAND MANAGEMENT	0,64		
Level of responsiveness	0,33				
planning/scheduling effectiveness	0,45				
Operations transparency	0,75				
Effectiveness of assets traceability (assets lost, thefts and tampering)	1,50	TRACKING, TRANSPARENCY AND TRUST	1,14		
Trust level among organizations and customers	1,43				
Cost-effectiveness of validation process	0,50				
Heterogeneity of organizations	0,30	HETEROGENEITY OF ORGANIZATIONS	0,30	SUPPLY CHAIN COMLEXITY	0,46
Structure	0,63	STRUCTURE	0,63		
Dimensions measured	0,73	SENSORS' FEATURES	0,52	INTEROPERABILITY WITH IOT	0,49
Sensor typology	0,30				
Application level	0,53				
Tracking and trace	1,20	SENSORS' PURPOSES	0,67		
Predictive or preventive maintenance	0,15				
In-process visibility	1,15				
Real-time performance measurement and control	0,45				
Avoid not value-adding activities	0,38				
Data security and validation	0,10	IOT REQUIREMENTS	0,32		
Relatively low maintenance cost	0,03				
Need for real-time monitoring	0,58				
Availability of applications	0,60				
Efficient power consumption	0,00				
Interoperability with other IoT and Cloud software	0,60				
Black box (meta-trust required)	0,55	LACK OF SUPPORT/TRUST	0,44	BLOCKCHAIN LIMITATION	0,27
Platform security	0,20				
Zero-status issue	0,58				
Energy consumption	0,00	IMPLEMENTATION ISSUES	0,22		
Technology readiness	0,30				
Lack of standards	0,48				
Latency	0,10				
Monetization of the investment (no clear ROI)	0,18	STRATEGIC ISSUES	0,15		
Added value creation	0,13				

The major objective of the content analysis was to assess the framework outputs with data of the consulted grey literature regarding blockchain applications. Below, extensive considerations are reported on the data analysis, with the goal of pinpointing the most relevant sub-factors (according to the Likert scale) and explaining the reason of such results.

Summing up, here is an explanation of **WHICH** variables emerge as more relevant and of the reason **WHY** they are claimed so. Alongside with that, further reasonings describe **HOW** these dimensions are conceived, clarifying the possible meaning gaps among different sources.

Data analysis

As can be observed from Figure 25, only few of the sub-factors outlined in the framework were found to be evident (weight value not below 1) in the examples' documents. Possible reasons for this limited correspondence are reported in the paragraph called "Limitations of the content analysis".

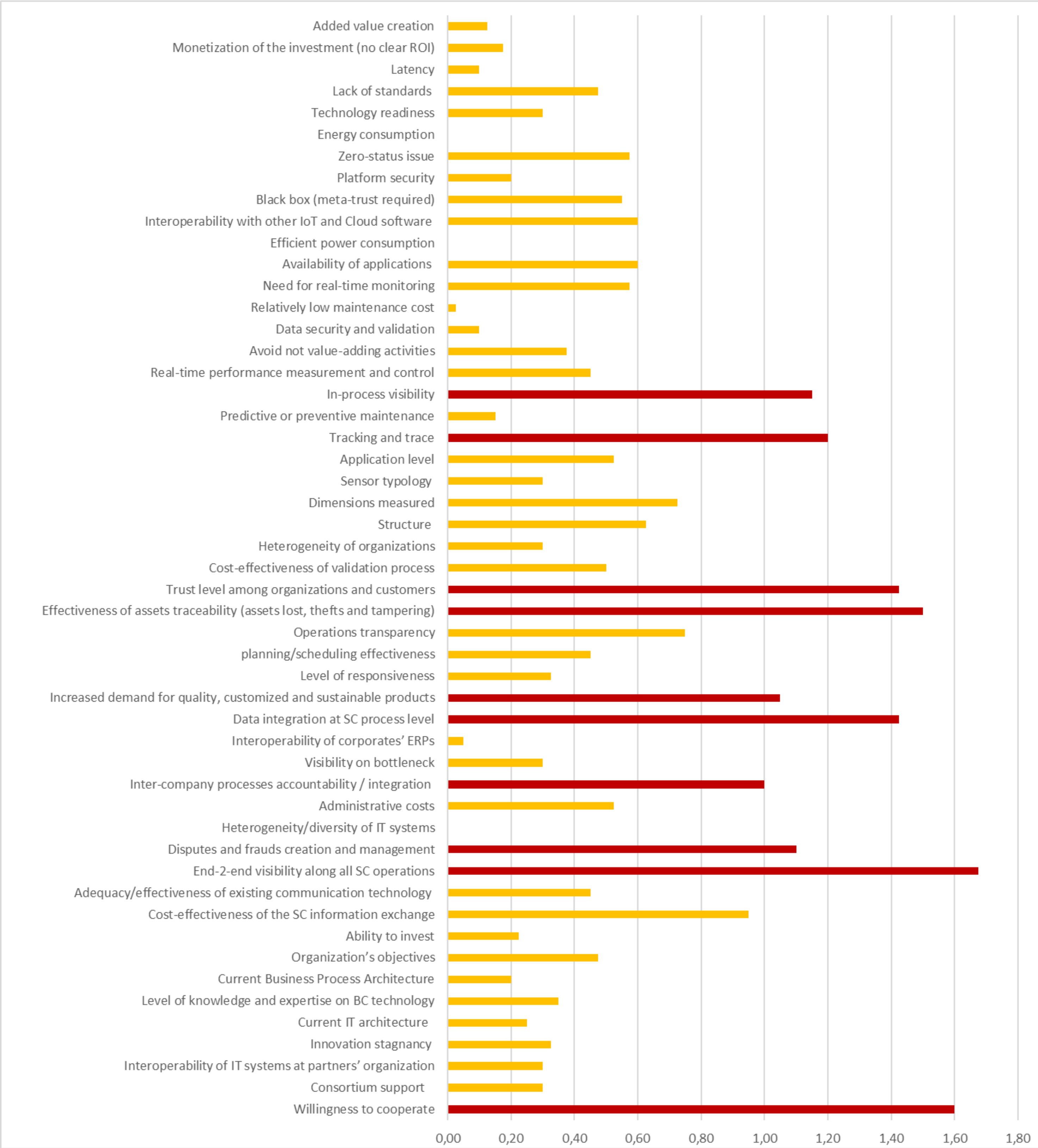


Figure 25: weights of the 51 sub-factors (red bars when the weight is above 1)

Out of the 51 sub-factors listed in the research framework, in fact, only 10 showcased an overall averaged weight above the discriminatory level 1. These 10 dimensions relate to 6 of the 19 framework parameters, namely "Supply Chain Engagement", "Data Visibility", "Process Efficiency", "Demand Management", "Tracking, Transparency and Trust" and "Sensors' Purposes". With reference to the upper layers of the framework, thus, evidences from the examples refer to the micro-variables "Supply Chain Readiness", "Supply Chain Issues" and "IoT Interoperability".

Focusing on the most evident dimensions, i.e. those with the highest overall average weights, it is clear that "**Willingness to cooperate**" and "**End-to-end visibility along all SC operations**" stand out. In 35 of the 40 examples, sources reported that BT applications resulted as a form of partnership and collaboration among different entities, reflecting the distributed nature of such technology. In 9 cases, these collaboration forms were even supported by officially recognized consortia and alliances, like the Blockchain in Transportation Alliance (BiTA), that gathers more than 500 members worldwide to set standards in favour of a widespread blockchain adoption. FedEx, UPS and Daimler are just three of the several players involved. The point is that, although Blockchain comes with some costs, it primarily requires different organizations to step into the same project, cooperating to test its functionalities; and the content analysis results strongly stressed it.

As repeated, the 40 examples database prompts that, when talking about BT suitability, a major concern at SC level is the lack of **end-to-end visibility** on the operations run along the chain. Further evidences of this dimension importance come from the set of interviews, which pointed it out 10 times out of 13 interviews. Typically, companies have a very limited perception of systemic processes, settling for a limited overview on what is going on at the first downstream and upstream layer.

There is plenty of cases where BT is used to bring transparency and overcome diffused communication issues, like testified by the considerably high weight of the sub-factor "Cost-effectiveness of the SC information exchange" (0.95). Most of the times this has to do with the lack of digitized documentation, which prevents information flows from running frictionless. Since many documents are still paper-based and manually compiled, a lot of time and money is absorbed to manage them. To this matter, an emblematic example is given by the BT project headed by Wave and Zim, which succeeded to make a first ever paperless Bill of Lading flow to the receiver within two hours from the vessel's departure, saving days of work. Quite a remarkable rate is associated to the "Adequacy of existing communication technologies", reported as an evident obstacle within supply chain 14 times. Here the problem is triggered by the contrast between the limited communication enabled by antiquate systems like EDI, and the faster and broader one required by modern supply chain. Indeed, technologies enabling bilateral information exchanges are nowadays of limited utility, as supply chain operations involve multiple parties and competition is set at systemic level. Therefore, a seamless, digitized, real-time and widespread communication is targeted.

Another dimension associated to data visibility is the **creation of disputes or frauds**, requiring complex processes afterwards to solve them out. The associated sub-factor, indeed, ended up with a 1.1 average weight throughout the BT applications. These complications, triggered by opportunistic behaviours, information asymmetries and moral hazard, harm both supply and demand side. Many times, especially in the food industry, inadequate goods are delivered to the final consumer, provoking outbreaks, dissatisfaction and fuss, besides forcing producers to recall entire lots. Contaminated or counterfeited products damage both the final consumers for health-related issues, and the supply side, which will have to spend time and resources trying to spot their origins. In China, for instance, numerous food safety scandals have made headlines, attributing to the Chinese food industry unhappy connotations. In 2008, a tainted milk scandal killed six children, besides making thousands ill. In that circumstance melanine, a widely used industrial compound, was added to milk to increase volumes and cheat regulatory tests. Still in China, another scandal followed in 2011, having pork as contaminated food. At the origins of this crisis was the usage of clenbuterol, a banned substance aimed at increasing muscle mass in livestock. Due to these multiple scandals, BT has been recently addressed as a mean to make food and other industries secure. Walmart

China, teaming up with VeChain, adopted the distributed ledger technology to make 23 product lines totally transparent, planning to expand it to 100 more.

Linked to data visibility is one of the sources of SC process inefficiency, which is summed up by the sub-factors “**Inter-company process accountability**” and “**Data integration at SC level**”. The key pain point is the lack in operations transparency, combined with ever existing opportunistic behaviours. In 38 BT applications, missing data integration at systemic level is said to prevent supply chain actors to run their operations transparently. BT might be a valid solution in both F&B and L&T industries. In the first case, it is hard to see a foolproof system capable of tracing back the product to its most upstream layers. In the second case, instead, players are still stuck to a simplistic configuration of standalone entity, perceiving data sharing and data integration with other members as a possible weakness. A project carried out by 300cubits with many large shipping liners has tried to prove BT potential within the transportation domain. Nevertheless, a lack of clarity in regulatory systems combined with a generally negative perception of the platform made this project come to an end on October the 1st 2019. With reference to the food industry, whereas, Apical has made an attempt to make the intrigued palm oil supply chain more transparent.

For instance, the BT application reported in the case 5 created a shared platform among all the stakeholders engaged in the FVL industry, bringing visibility on logistics status of the vehicles and enhancing OEM’s capacity management, S&OP processes with suppliers through real-time information sharing. In the example number 15, instead, joint forces from ABN AMBRO, Port of Rotterdam and Samsung SDS were oriented towards deliveries of first blockchain-sent containers. During the PoC, the project members benefitted from BT for the possibility of improving the demand forecasts and identifying the most suitable transportation mode for delivery.

Demand management also emerged as a crucial factor from the blockchain applications analysis. Specifically, a clear trend was easily mapped: an “**Increased demand for quality, customized and sustainable products**”. In details, although the desire for high-quality products with personalised features is evidently there, a major interest is displayed towards goods and services sustainability. Whatever the product typology, final customers claim for exhaustive information regarding the provenance, the production and distribution process conditions of products they want to buy. Nearly the 63% of the assessed BT applications unveiled that companies had to respond this emerging customers' need with a more sustainable and transparent supply chain. Such fashion, which is doomed to intensify considering the eco-friendlier attitude of Millenials, look at BT and IoT integration as a remedy. Companies in cases 28, 32, 36 and 40, for example, long for delivering food of which consumers can know anything of. By doing so, information regarding geographical provenance, upstream suppliers' processes, distribution and storage conditions can be rapidly checked via smartphones, by scanning a QR code or similar. Bext360, for instance, created a system that leverages AI, BT and IoT to provide customers with transparent and "green" coffee. By using a mobile app, demand side is able to dig into details about product origins and single suppliers' properties (quality of the coffee cherries, number of own trees, etc.). Simultaneously, the supply side manages to get rapid and fair compensations based on the supplied coffee quality level. Similar projects, despite less structured and organized, plan to do the same with whisky (32), tuna fish (36) and olive oil (40). As far as it concerns L&T industry, instead, only 5 BT applications out of 18 registered the same need for sustainable products, as it probably displays a weaker or indirect relationship with final consumers, that is where most of this tendency comes from.

Dwelling on "Demand Management", a conspicuous result was achieved by the sub-factor "Operations transparency". In the content analysis, the latter is connected to the open-minded approach of companies within the same SC to provide visibility on their own operations, enabling upstream and downstream partners to better deals with their own activities, objectives and operations planning. Results from the interviews had rather presented this sub-factor as the act of a company of transparently reporting its own operational results, with no advantageous alterations. In the end, no or poor reference was found of the bullwhip effect and the management of exception orders as enunciations of the demand management SC issues.

An additional SC issue that popped up from the database is the players' inability to know where their assets are along the supply chain. The corresponding sub-factor, namely "**Effectiveness of assets traceability**", was considered as "Not Evident" only in the 20% of the applications. Its relevance was recognized 9 times in the 18 L&T cases and 21 times in the 22 F&B cases. Throughout these applications, BT, frequently integrated with IoT, was set up to track and trace goods moving along the chain. At the roots of this need was the goal of improving assets management and boost the overall SC process efficiency. Case 29 suggested that BT can be used not only to spot assets' location over time, but even to measure transit times over the chain. This would give a powerful controlling tool for the implementation of dedicated interventions. By precisely identifying assets along the chain, any case of recall or similar assets withdrawal would allow the manufacturer to recollect only the specific faulty lots of units. In this way financial losses and faulty products diffusion would be minimized. In order to achieve an operating assets traceability system, assets are typically equipped with a locator or similar smart sensor, and eventually associated to a digital ID and tokens. Throughout the forty BT applications gathered in the database, common solutions in the Cold Chain (or other product types handling process) consisted in measuring few real-time dimensions at product, package or container level. With these system, goods localization was immediately available and key properties like temperature and humidity could be registered and shared on BT, pushing for end-to-end visibility. Moreover, the case 5 stressed the key role of assets traceability within the L&T realm to prevent assets losses or robbery. The problem of disappearing containers due to thefts is real, or sometimes hidden by organizations' top management to avoid paying high insurance premiums.

A loud statement coming from the content analysis is the worrying **mistrust** within the supply chain. Lack of reliance was appointed as a problem 31 times, outlining some interesting considerations. The first is that lack of trust is predominantly experienced among firms as a result of a scarce ineffective communication. As mentioned by Treiblmaier (2018), mistrust forces companies to sustain costs to monitor, supervise and control other entities. In the framework, such costs are associated to the sub-factors "Administrative costs" (under "Process efficiency") and

“Cost-effectiveness of the validation process”, respectively emerging with values of 0.53 and 0.5. Due to these costs, companies are not prone to collaborate, as it would imply a certain level of risk. BT promises to end this by providing a tool for transparent and timely information flow, bringing stakeholders on a unique platform where a single truth is shared and constantly updated. Content analysis also disclosed demand management challenges experienced by upstream and downstream players in trustless environments. When information on suppliers’ production capacities and customers’ demand are kept secret, planning and dimensioning of the company’s processes are deeply affected (“Planning and scheduling effectiveness” has weight of 0.45). On the other turn, though, the biggest evidence is that lack of trust is deeply weighing on relationships with final consumers. Where final customers realize to suffer from information asymmetry, they typically require more information or turn to more reliable competitors.

The relevance of mistrust issue within SC context has also been repeatedly confirmed by interviews, where companies mostly argued about unreliable partners. The belief is that delivering comprehensive information to the demand side about the provenance and the overall processes undertaken by the exchanged product will be of crucial importance.

The last two dimensions emerging as evident, besides testifying the resonance of information collection, confirm what has been said about BT and IoT integration. By merging the potentiality of sharing and managing data in a distributed system with the possibility of delivering huge amount of data to the database through smart sensors, a myriad of benefits can be unlocked. The complementarity of such technologies is indicated by the weights of several sub-factors linked to the interoperability with IoT. The highest values relate to the major purposes smart sensors are deployed for, when used with BT. “**Tracking and trace**” and “**In-process visibility**” are the most evident dimensions to these terms, and this is not a coincidence. The content analysis highlighted that sensors are typically adopted to enhance products traceability and to support process monitoring and control. By gathering specific information about key process dimensions through several sensors, BT upholds full visibility at systemic level. This is, for instance, how food provenance and history is tracked and reported to the customers. Smart tags, labels and various devices are generally set up at product, package or container level to record real-time product's properties and location, as well as transportation and storage conditions. When used at product level, a digital ID of the product is created on BT to ease full traceability. The adoption at container level grant that goods have been handled properly and no tampering has occurred.

At a broader span, the soundness of IoT and BT integration arise in the analysis through diverse sub-factors, despite their weights don't amount to 1, which is the minimum value to discriminate the evidence degree. For example, "Dimensions measured" certifies that the measurement of few dimensions better suit to BT bond. In particular, evidences from both content analysis and case studies are that sensors connected to BT generally assess temperature, humidity and location. Other monitored dimensions are application-dependent, like light or CO2 level. The sub-factor "Application level" discloses that sensors are deployed at different levels, varying with the objectives and products, as previously mentioned. Talking of which, there are few key purposes requiring sensors deployment. Beside those mentioned beforehand, content analysis prompts that companies opt for BT and IoT solutions for real-time performances control and minimization of not value-adding activities. Interesting considerations emerging from the database of BT applications is that companies go for smart sensors if they proof interoperability with other devices and Cloud systems, like BT, for an easier and effective data management. Smart sensors also need complementary applications to transform single pieces of data into something valuable. Software for data integration and analysis are necessary to grasp information from different sources, combine it to get patterns and other possible meanings. When these applications exist, if interoperability with other IT systems can be easily achieved and if there is a serious need for real-time information collection, the uptake of smart sensors with blockchain makes sense. No or limited proof, instead, has been collected on other requirements for the usage of IoT, like low maintenance cost, data security and efficient power consumption. This, which is partly due to the typology of data sources, might also suggest that most of the companies do not look at these conditions when implementing IoT.

Leaving IoT apart, content analysis was not able to proof evidence of any sub-factors linked to BT issues. This has not to be considered as a signal of limited relevance, though. Simply, the sources used to run the analysis are articles aimed at objectively describing the BT applications, while missing to critically assess their features. In fact, an overall result throughout the forty applications is that BT adoption still comes with some limitations. Most of them reflect a limited or insufficient trust towards this new technology, as can be observed by the weights of “Black box” and “Zero-status issue”, respectively 0,55 and 0,575. Still a certain feeling of reluctance is registered in both the industries, due to either a generally negative perception of BT, frequently associated to mysterious cryptocurrencies, or to security of IoT and BT integration. Owing to this uncertainty revolving around BT, interested companies still struggle to find partners willing to cooperate and share the associated risks and capital. As a consequence, BT skirmishes with many oppositions in its affirmation path as innovative technology. Testimony of such trust-related challenges, despite unbound to the content analysis, is the evolution of Facebook’s new BT-rooted payment system, called Libra. Mark Zuckerberg, CEO of Facebook, officially released the whitepaper of this ambitious project in June 2019, setting the goal of reaching out to the unbanked individuals. The plan, that would leverage the up-and-running social media user-base, could firstly praise the support of the 28 members of the Libra Association, including big players in like PayPal and Visa. In October 2019, though, even nudged by the American political pressure, the same biggest partners started announcing to decline to take part in Libra’s launch, planned in 2020. The first major name giving up was PayPal, followed by Mastercard, Stripe, Visa, eBay and Mercado Pago. Despite the reasons for such decision were not officially released, the feeling is that such big players do not trust BT technology enough to undergo Libra’s associated risk. Systemic lack of trust has to be partly ascribed to a wait-and-see strategy or weak participation of governmental institutions. Public administrations are still reluctant themselves towards blockchain and it does not encourage them to put efforts in regulating its adoption. The consequence, which is also confirmed by the correspondent sub-factor weight (0.475), is the absence or scarcity of standards. Missing both standards and large-scale working case studies, companies are brought to take BT with a grain of salt. When official guidelines and measures are not there, organizations grope in the dark, scared by the consistent risk that an investment in BT would imply.

No mention emerged of the implementation issue linked to the power consumption, that was rather discussed in literature with a certain concern. Scarce confirmations were pointed out with reference to the problems of "Latency", possibly due to the limited technicality of the data sources. A more consistent consideration was attributed to the "Technology readiness", appeared 10 times out of 40.

Finally, a scant acknowledgement of the so-called strategic issues was observed. While interviews with CEOs and other profiles suggest that "Monetization of the investment" is a real obstacle for BT, it came up just in the 13% of the assessed applications (5 times out of 40). The same reasoning relates to the concern of "Added value creation", ranking 0.125 in averaged weight.

Special considerations must be made on a couple of emerging yardsticks. The first could fit the concept of organization readiness, as the content analysis evidenced that values and mission of the companies somehow affect BT suitability. In details, where organizations express major concern towards supply chain sustainability and product traceability, BT seems to be a good solution. Therefore, when a company's mission is entangled with such notions, the meaningfulness of developing BT projects is higher. On the other turn, a further BT problem receiving remarkable attention was that of scalability. It resulted that, so far, the few working BT projects were on a limited scale, leaving doubts on the operations of the same system when expanded to bigger volumes and networks. Case 17, for instance, discusses the ambition of implementing blockchain traceability on a considerably high number of product lines (100) and large-scale applications. Moving from pilot projects and proves of concept to large-scale systems might hide multiple complications, both technical and strategic. Scalability problem, which could be somehow linked to the sub-factor “Technology readiness”, loudly turned out from the content analysis, completing the case-studies-based framework.

Lastly, other sub-factors did not appear to be evident or were not mentioned in this data analysis part. As for the micro-variable named “SC Readiness”, neither “Complementary IT systems at partners’ organizations” nor “Innovation stagnancy” found clear confirmations in the content analysis. Despite the weight of 0.325, the scarce systemic inclination towards innovation deserved a mention in the 30% of the applications, equally divided between L&T and F&B industries.

A very weak validation was noticed for the micro-variable “Organization Readiness”, where none of the sub-factors turned out to be evident and the average of the six sub-factors’ weights is equal to 0.30. This has to be analysed considering the difficulty in finding evidences of specific dimensions in a set of sources mostly reporting overviews and generic descriptions. In “Process Efficiency”, the “Interoperability of corporates’ ERPs” got a very feeble confirmation, ending with a weight of 0.05. “Administrative costs”, whereas, received a deeper consideration, as it deals with the need for disintermediation and bypassing unnecessary intermediaries, which has already been discussed as a relevant challenge.

Eventually, despite not definable as evident, the “Structure”, together with the “Heterogeneity of organizations”, advocated a certain relevance of the “SC complexity”. In 19 of the 40 applications, industries were told to be complex, opaque, disorganized or with a scattered structure. 12 of these 19 relate to the F&B realm, where a myriad of companies take part to long and fragmented supply chain. In a distributed world like these, BT is shown as a valuable solution to simplify, unite and streamline such industries, through a revolutionary data management.

Content analysis conclusions

In light of the methodology limitations and of the results discussed in the “Data analysis” paragraph, a final positive consideration can be expressed on the content analysis. Despite the limited levels of evidence, in fact, some interesting conclusions can be drawn:

1) Supply chain issues must be primarily assessed when talking about BT adoption, as it turned out that the existence of specific problematics make it more meaningful. Especially, the greatest evidences prompt that BT could deliver consistent value when industry's players suffer from two problem types: the ones linked to assets tracking and trust within the chain, and those related to data visibility. In particular, BT offers a powerful solution to keep track of the assets when they move along the chain and around the globe with a timely and secure system. Via tokenization or creation of assets' digital IDs, the platform prevents goods from getting lost or tampered with. Information about assets' conditions and supply chain processes is shared among the participating stakeholders, so that transparency and trust are set as roots of the relationships among them. Additionally, transparent supply chains manage to create a trusted bond also with customers, from whom an increasing demand for sustainable and secure products has been registered.

   Furthermore, the analysis pointed out BT as a remedy for data visibility issues. Inadequate or not available technologies facilitate information asymmetries and slow, ineffective data exchanges. This hinders the achievement of a full visibility along supply chain operations, leaving space to costly disputes and frauds. Distributed platforms like BT promise to stop this via a frictionless and secure environment, where many-to-many communications streamline SC processes.

2) The willingness to implement BT must be shared with other interested players in the industry, as the analysis showed that cooperation, partnerships and consortia participation are at the basis of successful cases. Joint forces are claimed to fill expertise gaps, share risks and capital outflows. In fact, being BT a network technology, it conceptually requires more players to get onboard in order to work.

   Weak evidences, instead, were identified in support of organizational dimensions as impactful factors on BT adoption.

3) The combination of BT and Internet of Things was frequently reported in the analysis as a viable solution for assets tracking and in-process real-time visibility. The integration of such technologies, used to combine the huge data volume of IoT and the powerful data management capabilities of BT, seems to work in both cases. Most common configurations adopt diverse smart sensors' typologies at product, package or truck/container level to upload on BT information about temperature, humidity and location mostly, with other dimensions that are case-specific.

4) Quite a considerable meaning is assumed by the SC configuration itself. Within intrigued, large and disorganized supply chains like both the L&T and F&B, the introduction of BT technology would be of great help. In fact, when industries develop in scattered and populated configurations, it is likely that communication and visibility problems pop up. As the number and diversity level of one industry's members increase, the content analysis reported that BT could help in bringing parties together, aligning them and streamlining SC processes.

5.2.2 Comparison between results of the content analysis and multiple-case analysis

A matrix (Appendix 4) was created as a starting point for this further analysis. In this matrix, the variables' levels of evidence are reported with reference to the interviews (X axis) and to the content analysis (Y axis). This allowed to highlight divergencies and concurrencies in the viewpoints of the interviewed profiles and grey literature. Below, the results of this comparison are structured in paragraphs, each introduced by a title.

"Consortia first"

Homogeneously across the collected data, it is evident that companies look at the presence of collaborating partners as primary condition. Nonetheless, significant differences can be identified. Most notably, the role of consortia receives much more attention when dealing with BT providers and adopters, since technology novelty and readiness requires them to join forces and knowledge so that standards and large-scale case studies can be developed. In this regard, the role of BiTA consortium is crucial as far as it concerns the transportation industry, with outstanding exponents like Daimler, FedEx and UPS. Similarly, the BT projections in the European market of FVL (Finished Vehicles Logistics) are considerable as supported by the novel Vinturas consortium. This is described as a set of various companies collaborating to adopt a unique BT platform for information sharing within the supply chain

On the other turn, IoT providers exhibit a lower interest towards consortia, as well as a peculiar concept of collaboration. Expressions like "strategic partnerships" and "eco-landscape", in fact, appear from IoT companies to synthetize what they mean for collaboration. In these cases, collaboration is presented as aimed to the search of companies providing complementary components (HW or SW), in order to deliver complete solutions to customers or to expand the business.

Considering this discrepancy, what can be concluded is that blockchain development requires a level of collaboration which is not limited to single partnerships. **Companies that are willing to implement this technology should firstly engage with a dedicated consortium, in order to get two type of benefits**. Firstly, **existing know-how** is typically shared within consortia, which would facilitate technology introduction. Most importantly, though, engaging with a consortium enables to **create the network** required by BT as a platform technology. All in all, potential BT adopters should primarily join blockchain consortia since they "need to create alliances to build their own digital network", as suggested by Vinturas' Lead blockchain architect.

"***Rush for digitalization***"

Regarding SC readiness, despite the examined industries have been historically reluctant to innovation, interviews spotted a diffused desire to lead the way or, at least, not to lag behind digital transformation. Clues from the case studies, in fact, were that "the F&B industry is stagnant" and that, in L&T, "the FVL market runs on low margins, reason why it is pretty conservative towards innovation". Nevertheless, both the analyses suggested that single companies care about keeping it up with innovations, since, as cited, they generally "want to step up in the digitalization of their business network" and "not to be cannibalized by competitors". Though, since digital technologies typically require changes in their business model, firms divide into two groups; those willing to adjust and those afraid of doing it. **Overall, the perception is that, despite industries might have traditionally behaved with a "wait-and-see" strategy in front of innovative technologies, BT adoption can be fostered by the increasing spread interest for digitalization displayed by individual companies.**

"The same for all"

At the organizational level, insights from both sources recognize a limited evidence of the associated sub-factors. What emerges from the big picture is that companies' features, being them BT or IOT providers, or adopters named in grey literature, are poorly considered. This might indicate that some single firms' features limitedly matter when implementing BT. Deeper clues from interviews suggested, for instance, that the individual company's IT architecture is less relevant than the compatibility among the whole network's IT systems. BT, in fact, does not require any additional HW component (as long as the IoT part, if needed, already exists), but rather it requires companies to abandon traditional siloed IT systems to switch to a standard interface; and this generates frictions. This adaptation requirement faces a reluctancy that becomes more intense as more heterogeneous the IT systems are across the industry. Simply, the more diversified the IT systems are at industry level, the harder it is to convince more companies to "switch" to BT.

In a nutshell, **companies** interested in implementing BT **should firstly abandon the monolithic nature of their IT systems and move to a more collaborative interpretation of these technologies**. Consortia might be helpful in that by setting guidelines for a "systemic adjustment" of the IT systems. Alternatively, **initiatives from big players might trigger market dynamics** with the result of convincing smaller entities to do the same. In this regard, Facebook's project called Libra is emblematic, since in the first months after its presentation it generated a huge appeal, with many companies ready to chase it.

"Do not underestimate processes and capital"

In addition, a point that was loudly raised by just one BT provider and scarcely confirmed in the content analysis is the need to redesign the Business Process Architecture (BPA) when blockchain is implemented. Despite the low evidence of other sources, this dimension was powerfully stressed by Insolar, which has, on its side, the most solid expertise among the selected BT providers. Therefore, it might be that grey literature and other providers underestimate what can be a tedious work. The same reasoning can be made on the sub-factor "ability to invest", that still sees a scant consideration from other sources.

"*Turn problems into opportunities*"

L&T and F&B industries appear to be plagued by a wide set of problems, which, considering the results of the content analysis, might stimulate companies to adopt it. In particular, both the analyses put the stress on the lack of **end-to-end visibility**, the rise and articulation of **customers' demand** and the ineffective **asset traceability** systems. All of them hark back to minor or related issues, mostly emphasised by the analyses. Here are some considerations about them.

Scarce visibility is framed in a larger plague that deals with data management and information sharing. Insights from interviews and content analysis suggest that firms are generally "blind out of their facilities" due to a set of concurrent causes. In fact, especially in L&T, they report that sometimes organizations have no clue on events depending on third parties, like deliveries or pickings. This relates to the faulty exchange of information and inadequate communication, exacerbated by communication technologies like EDI, that, despite still in use, are not suitable to multi-party ecosystems. Moreover, although grey literature does not mention it, the heterogeneity of IT systems across the industry is appointed by a few interviewees as hinder for information sharing. According to them, the adoption of common interfaces and portals would significantly change the situation. Overall, this results in a very scarce visibility at SC level which, in accordance to some interviewed profiles, could be fought with IoT and BT. In detail, despite they might be biased, BT providers identify in their technology an appealing solution, by bringing parties together on the same platform. On the other turn, a few IoT providers prompt that the adoption of smart sensors can overcome this problematic, provided that devices are interoperable with common shareable technologies like Cloud platforms. One further point linked to data flows along the chain regards the creation of disputes, claims and frauds. This dimension especially recurs in the examined BT applications, but more precise details are provided by interviews. The underlying problem is a combination of opportunistically handled information and fraudulent behaviours. These result in claims from customers, whose management comes with a cost, and stolen assets. Respectively, BT-related interviewees declare to target the former to reduce associated costs, while IoT-related respondents talk about the latter.

Last factors associated to data management and contributing to visibility issues are a few dimensions belonging to the sphere of process efficiency: data integration at SC level and inter-company processes integration. Both the sources stressed their relevance, as no effort is taken by companies to control and integrate processes at SC level. Reportedly to interviewed profiles, this has a lot to do with companies' attitude, as most of them still perceive themselves as "monolithic entities". Such approach, testified by the distribution of siloed IT systems, demonstrate that many firms prefer running solo rather than trying to achieve competitive advantage as entire supply chain.

Another broad SC problem regards demand management. In general, both sources assert that demand has increased in terms of volumes, specialized products and services and sustainable goods. Though, different analyses put the emphasis on different aspects. In facts, on one side interviews highlight the need for customization and the quantitative growth in products demand. Personalised products and services received much more evidence than the augmenting demand for information, emerged only in the case of 30 MHz, an IoT provider working in the agri-food field. On the other side, instead, a resounding factor was the request for sustainable products, appearing in the content analysis as an evident dimension. Across the examined BT applications, in fact, the attention was frequently focused on topics like food safety and provenance authentication. This result in an intense demand for transparent supply chains, traceability and, in general, sustainable goods. The discordance between the different spotlights in the two analyses can be traced back to the different viewpoints and types of information. In the interviews, indeed, factors like increased customization and volumes might be due to the more technical perspective of IoT and BT suppliers, as well as the focus on sustainability in the content analysis might be associated to a standpoint/information source closer to end users. At a broader perspective, this situation might indicate the potential role of BT in making supply chains sustainable, as testified by blockchain applications. At the same time, a possible link with IoT and BT providers' perspective might be that the demand for sustainable products pulled by end-users, arises upstream, at least in part, as the demand for specialized and customized products aimed to enable these sustainable technological solutions.

The rising demand for sustainable products is partially reflected by another research variable, which is the "trust level among organizations and customers". The expression "partially reflected" is ought to divergent opinions of the two analyses. In fact, while interviews stress the spread of trust issues among companies, linked to poor communication and interactions, grey literature moves the focus on the mistrust between companies and consumers. Specifically, the content analysis brought to light that, possibly due to past scandals, consumers do not trust F&B industry anymore. To compensate this suspicion, end-users now require firms to proof products authenticity and security, as well as to provide exhaustive compelling information about their production and distribution processes.

Still about demand management, interviews display a few information about challenges of planning and scheduling along the supply chain. Despite only 4 interviewees hit the topic, there is quite a strong evidence that the scant information sharing at a SC level also results in ineffectual production planning, capacity management and demand forecast. A major clue came from Insolar, that revealed how BT can practically help. The American BT described how companies can leverage BT-enabled data sharing to reduce working capital by reducing their inventories. The secret, according to the company, lies in using the platform to receive rolling updates on the suppliers and customers' inventory levels, so that the internal capacity can be better planned and, potentially, sold on marketplaces. Such perspective is somehow recognized in the content analysis, where a value of 0.45 is attributed to the sub-factor.

One last SC problem, also related to sustainability, concerns assets traceability along supply chains. Despite such dimension is univocally recognized as evident in both the sources, different hues exist of its meaning. In this case, the variety of insights is ascribable to the miscellaneous features of the assessed industries. In L&T, the problem of assets traceability shapes up in form of thefts and lost assets. The CEO of the BT-related company Aankhen even estimated that 10 to 15% of containers is lost during shipments, with other interviewees complaining about the same problem, which affects also IoT companies. VantiQ, for instance, develops IoT solutions to prevent disappearing containers and to tackle the grey market. Examples from the content analysis, then, talked about BT solutions expressly implemented for logistics purposes, like the tracking platform used by UPS.

Regarding the domain of F&B, whereas, the idea of traceability is oriented towards sustainability. Despite this does not emerge significantly from primary sources, possibly due to their greater propension for L&T solutions and technical topics, the content analysis frequently reports expressions like "from crop to fork" and "from bait to plate" in connection to this argument. In such sector, in fact, secondary sources mainly refer to transparent or sustainable supply chains, aimed at securing the provenance of goods like coffee beans, tuna fish and banana. Overall, the BT-IoT integration is addressed as a valid solution to win the lack of end-to-end asset traceability along supply chains.

Wrapping it up, this paragraph exhibits the major pain points of L&T and F&B industries, observing how BT introduction could contribute to solve them. Key issues are data management, affecting also process efficiency and demand management, traceability and the demand for sustainability. BT can support companies to tackle them in many ways. Data visibility along the chain is a primary goal achievable with blockchain, since companies can share info in a timely manner with a secure and shared platform. This would also result in increased collaboration, better demand planning and capacity management. Plus, lack of end-to-end traceability of assets along SC processes can be overcome by uploading information on assets' status on the platform, updating it with new transaction every time a new event occurs (for instance at every touchpoint). Lastly, this could also work to satisfy the growing end users' demand for products information, proving compliance with standards and authenticating their provenance.

All in all, lack of SC visibility, scarce SC collaboration, imprecise demand forecast, ineffective assets traceability and an increasing demand for sustainability are all existing challenges in L&T and F&B industries that might incentivize BT introduction. In this regard, though, a leader company should drag other adopters by demonstrating BT convenience in large-scale projects.

"*The more complex, the better*"

Evidences about supply chain complexity represent a double-edge sword for BT diffusion. The analyses observe that SCs are transforming into "very complex and big systems", with "more players per each layer". Insolar even estimated that nowadays companies deal with "twice as partners as two years ago". Industries are filled with a myriad of various entities, from banks to customs, buyers and 3PLs. These complexity and heterogeneity, though, might have two effects on BT. From one side, they could have a detrimental effect on existing levels of information sharing and visibility, as well as demand management practices, giving firms a reason to invest in BT. On the other turn, instead, heterogeneity of firms might obstruct its diffusion in the case also IT systems are too diversified, for the reason mentioned a few pages back. **What can be concluded is that, provided that the network's IT systems are not too diversified, BT implementation is incentivized by SC complexity due to its capacity of solving related issues.**

"IoT and BT together, but not always"

Overall evidences prompt that BT and IoT integration can be extremely useful in the context of achieving sustainability and traceability. The observation of data should make readers aware that such integration turns out to be meaningful only at specific conditions and for given purposes. Both sources highlight that track and trace is the main and most suitable purpose for IoT, especially in L&T. Smart sensors are used in the realm of assets management, primarily to observe their location. Keeping track of goods is the key prerogative, for which IoT providers offer solutions made of HW or SW or both. In these cases, requirement on sensors' features are very limited, as simple GPS locators are fine. Contrary, when sensors are asked to exchange real-time information, technical and costly solutions are necessary. These articulated solutions working with real-time data suit to specific customers' needs, like monitoring temperature and humidity to guarantee the respect of quality and security standards. Examples from primary sources are VantiQ, monitoring containers temperature to avoid deterioration of transported fish, or Aankhenn, deploying sensors to track minute by minute containers location. Simultaneously, though, these applications raise further concerns about the sensors' protocols and connectivity cost. As for the latter, some interviewed IoT providers offer low-power sensors, minimizing the cost of keeping a steady connection with other devices. Regarding sensors' protocols, IoT providers often clash with them since they prevent or make it difficult for different technologies to interact. Looking at the part of matrix concerning IoT requirements, in fact, it is possible to notice some interesting facts. What does not emerge from secondary sources is that adopting IoT technologies comes with some challenges. The key pain points, discussed during the interview, are data security and the ability of getting value out of data. While for the latter there is a valuable solution, the former remains an unsolved weakness of IoT. As agreed by some interviewees, data security is not granted with IoT devices because they can be easily hacked and there is no definitive remedy to that. What all the companies want, instead, is to create value from data, which can be achieved if it is properly elaborated and technologies are interoperable. Both these conditions have a common answer, identified by primary sources in software platforms and applications. By connecting all the devices to a unique software platform, data coming from all over the physical world can be conveyed and integrated. This procedure manages to overcome issues of missed interoperability due to protocols diversity. Similarly, software applications can be developed to elaborate data and properly visualize it, creating a friendly interface with users.

In this context, then, it is possible to understand the contribution of BT to the IoT. In terms of data management, in fact, conveying sensors' data on a BT platform represents a way to get access to a huge amount of data coming from distributed sources. Moreover, BT provides companies with the opportunity to have real-time visibility on assets moving along the chain. Simultaneously, this enables to handle data in a flexible and effective way, delivering a single truth through a shared platform. Plus, BT combined to smart sensors brings sustainability on another level. In fact, by keeping track of transactions history with an append-only secure mechanism, BT allows to check products' provenance and compliance to standards.

"In need for a leader"

Finally, discordances can be observed regarding BT limitations. As mentioned, it is reasonable that secondary sources display low evidences for these dimensions, as selected grey literature on BT applications mainly deals with the purposes and entities involved, with no or limited view on BT issues. Primary sources, instead, comprehensively discuss them, outlining three big challenges. At the viewpoint of IoT providers, the greatest obstacle is what was named by Gosling as the platform problem, associated to the variable of black-box. This consists in the fact that quite a vast scepticism exists towards BT technology across multiple industries, as a consequence of a limited technology understanding and of the absence of compelling business cases. In this context, the platform problem relates to the consequent low engagement of firms in BT initiatives. Hence the issue: a platform technology that cannot rely on the underlying network of companies.

Secondly, the vast majority of interviewed profiles appointed strategic factors as reasons why organizations do not invest in BT. Specifically, many IoT providers, when asked about possible future integration with BT, reported that, despite the interest in it might exist, what does not exist yet is the believe that BT could deliver more value than existing solutions. Their big fear is to spend money on a technology that, besides not adding value, does not even pay back the required investment. Another feeling stemming from interviews is that BT supporters are desperately looking for reasons that might, somehow, justify its adoption. Still, a concurrent cause is the lack of compelling BT applications demonstrating real benefits of such technology.

Lastly, also its fragmented development contributes to a tough diffusion of blockchain, as respondents state that too many standards exist to harmonize its diffusion and provide guidelines for effective implementations.

All in all, the analysis of BT obstacles evidenced a big problem that originates many others: **the lack of compelling use case**. Since companies can't really observe the realization of BT promises in a convincing application, most of them do not feel to take the risk. This generates and spreads mistrust across industries, triggering a low engagement in BT projects.

Such situation explains the "chicken and egg" problem that emerged a few times in the interviews: firms want to discover and experience BT advantages, but they do not make a step to realize it. In order to get over it, **big players**, supported by more consistent resources, **should lead the way in BT initiatives**, triggering market dynamics that would drag smaller entities to adopt the technology.

Conclusions

The comparison between content and multiple case analyses shed light on a few aspects of BT:

1. A pronounced interest exists, promoted by a generally diffused interest for digitalization trend. Independently from the specific industry's propension towards innovation, rising concerns for digital technologies create emphasis on blockchain technology.
2. L&T and F&B industries suffer from a set of problems that would benefit from BT introduction. In detail, these supply chains are affected by a deep lack of visibility at industry level, ineffective traceability and unmatched demand for sustainability. Its characteristics and advantages make BT a good solution, especially with regard to data management.

3. BT and IoT integration can be a powerful union, as they offer complementary features. From one side, BT platform needs data to manage and share across nodes, on the other side, smart sensors require a common environment where their data can flow into to be managed, elaborated and exploited to create value. In particular, these technologies propose to deliver most of their value in SC with regard to assets traceability and products sustainability, despite a few technical problems need to be addressed.
4. Three major aspects can complicate BT diffusion in these industries. The first is the low engagement shown by many companies, due to the diffused mistrust towards blockchain. The second is the compatibility of the whole industry's IT systems, which could discourage the network to adapt to a BT configuration. The last is represented by two requirements addressed to firms: financial capital and availability to redesign their process architecture.
5. One major guideline emerged for those companies interested in BT technology is to join dedicated consortia. Taking part to these groups of entities collaborating on BT results to be beneficial in three ways. Firstly, it supports the acquisition and development of know-how and skills, as they are typically shared in consortia. Secondly, they help companies in finding the network of players required by BT. Last, they could contribute to set guidelines for a systemic adaptation of IT systems, in case these represented a problem (as reported above).
6. At the moment, the biggest need of potential BT adopters is the initiative of a leader company in applying BT for the abovementioned SC problems. Facilitated by a broader set or resources, this company could trigger market dynamics demonstrating real BT benefits and dragging smaller players to follow their example. This would also contribute to mitigate trust issues associated to such technology.

Finally, this further analysis enabled the author to grasp a complete overview on the framework variables and their ideal configurations. Thus, a new tool was created to support the evaluation of BT. When the research framework is used from the top to the bottom, in fact, it could support the definition of the "ideal conditions" required to adopt blockchain. Here, the most suitable "values" of the macro-variables (Readiness, SC features and Technical Implications) are described in the table to permit potential investors to benchmark their starting situation with target conditions. This would help to identify gaps and to possibly support the definition of an action plan for the introduction of blockchain.

MACRO-VARIABLE	IDEAL CONDITIONS
Readiness	Suitability of blockchain adoption is a function of readiness at both supply chain and organization level. At systemic level, the ideal conditions envisage that companies within the industry show interest towards the project and get rapidly engaged with the related activities. This means that, from one side, companies participating to the same supply chain are willing to cooperate and to co-invest to promote blockchain introduction within their processes. From the other side, the same companies should create consortia, gathering diverse entities eager to adopt blockchain. This, besides creating synergies among them, would facilitate the information and expertise sharing, making it simpler to set standards and common directions. At a technological viewpoint, it results easier to introduce blockchain at the system level if the IT systems of the multiple companies staying at different levels of the chain are not too heterogeneous. These systems should demonstrate complementarity and interoperability, because the more diversified the set of IT systems adopted in the industry, the higher is the cost of moving to BT. Another parameter shaping the ideal premises for BT adoption is the systemic risk-taking tendency towards innovation. This is pretty much a structural property of the industry, as history proved how certain industries are more prone to innovation than others. At an organizational level, whereas, readiness assumes new implications. As far as it concerns technology, companies should be provided of an IT system that is as interoperable as possible with BT, or that could be easily used in a hybrid form with it. The underlying reason is that if a company is asked to carry out too many changes, this might lose its interest in the technology. Besides that, expertise on BT is a key requirement for companies. Skills and knowledge must be internally created or externally acquired through different human resource management procedures. If the employees are not familiar with BT, there is no way the company as a whole can. Furthermore, adaptations are required at a more general level within the company. First of all, the usage of BT needs to be associated to a specific business process configuration. This means that processes within functions are designed so that data automatically flow into the platform, and, vice-versa, the platform smart contracts could directly and autonomously trigger the execution of specific activities in the

	physical world (such as a payment to a supplier). If current business process architecture does not suit to this scheme, changes are necessary. Logically, the interested company should rely on a sufficient capital to allocate. In the event this is not available, the organization should think of alternative ways to get resources, like fundraising, crowdfunding or getting grants. Lastly, a company's manager willing to introduce BT within their business processes should be aware that this technology delivers great value especially for few applications. Therefore, if the organization's objectives coincide with these applications, further reasons to adopt blockchain exist. In details, examples of such applications are: reduction in Net Working Capital, assets tracking and traceability, IoT monetization, improvement of data collection and integration process and business model renovation.

MACRO-VARIABLE	IDEAL CONDITIONS
Supply Chain Features	There are some circumstances linked to the supply chain configuration making the interest in BT more justified. Being a digital network technology, BT suits by definitions to those contexts where a lot of actors take part. Besides numerous, if the supply chain structure is complex, BT potential can more easily emerge. In fact, complex industries are defined as made by many layers and many players for each layer. Within these scenarios, companies are likely to frequently need for intermediaries when dealing with other players of the same industry, as trust is missing. In order to compensate these mistrustful relationships, middlemen play their role in exchange for money and resources. The introduction of blockchain in situations like this is particularly meaningful, as it provides an advantageous alternative to centrally managed interactions and to the resource-absorbing relying on intermediaries. Consistent savings and streamlined SC interactions can be also delivered by BT which promotes a seamless and timely information sharing across the network nodes. Beyond the structural physiology of the industry, which is something single companies have no power on, there are specific issues, affecting the entire industry, calling for BT introduction. When BT adoption is intended to resolve at least one of them, further reasons to implement it exist. Firstly, BT powerfully responds to the need for improving data traceability along the supply chain. At the origin of this problem usually are inadequate and ineffective communication technology or not interoperable IT systems. EDI's performances, for instance, are acceptable in bilateral information exchanges between two companies, but they result pretty weak in network environments. Here information is required to flow real-time (timely) at a broad scale, reaching out all

	the stakeholders taking part to the same supply chain process. The lack of visibility on processes involving the whole industry creates disputes, whose management requires time and money. As information moves slowly, partially and sequentially along the chain, BT proposes itself as an appealing revolution. Leveraging cryptographic keys and distributed ledger, blockchain ensures secure information to be available throughout manufacturers, receivers, shippers, regulators and other entities involved. Digitization of documents would eliminate paper-based records, often at the roots of the mentioned problems. In addition, this ineffective data handling prevents SC processes from being cost-effective, since information coming from different actors is not integrated and stakeholders are not aligned or updated. This approach, usually called "one up one down", consisting in dealing only with the relationships and data flow of the first upstream and first downstream layer, hinders coordination and efficiency. Therefore, accountability at systemic level is currently a mirage and, logically, process inefficiencies increase given the inability to spot bottlenecks in inter-company processes. In these terms, BT intervenes by automating tasks, monitoring parameters and triggering specific actions or notifications. Another problem is represented by the diffused mistrust among the SC members. Intermediaries' intervention to get over this problem comes with tremendous administrative costs, since validation is required upon the information exchanged between companies. Assets tracking and operations transparency achievable via BT can help fight such ubiquitous inefficiency. Wrong or ineffective data management has even an influence on companies' ability do properly manage demand forecast and production planning. Uncertainty in the market makes it hard for the players to accurately picture the upcoming demand, thus forcing them to come up with new ways to be flexible. Still many companies believe to compete on their own, showing complete blindness towards the improvement of supply chain processes. When data on downstream demand and capacity production are exchanged rapidly on the whole industry, all the layers of the chain can benefit. BT could be of great help here, as information is shared across all the nodes: Increased responsiveness in planning and scheduling production and outsourcing, ability to foresee peaks and to handle exceptions can be achieved. Furthermore, end-users are requiring companies to keep a focus on products sustainability, quality and customization, pushing them to adjust their processes. As customers increasingly wish for goods that are 100% compliant to quality standards and environmental certifications, firms must be able to provide exhaustive information and create networks of adequate partners. To these terms, BT is extremely helpful as it keeps track of the product's history along the production and distribution process, so that entities at the end of the chain are able to verify what they care about.

MACRO-VARIABLE	IDEAL CONDITIONS
Technical implications	Opportunities offered by BT introduction can be furtherly exploited when combined with a proper IoT architecture. Smart sensors can be deployed as oracles, that are sources of information to feed the BT platform with up-to-date events. These devices are generally applied at truck, container or product level to measure real-time performances along the whole handling process, from suppliers to distributors. Using the huge amount of data coming from IoT, securing and recording it on BT makes it possible to keep track of the history of the product, to effectively plan maintenance activities or to thoroughly manage assets. Particularly, RFIDs, QR and NFC tags are extremely suitable to these applications. Besides them, sensors are typically aimed to measure dimensions like temperature, humidity, timing and locations. Despite that, IoT integration is beneficial only when starting conditions are favourable. Smart sensors usage is generally addressed to pursue needs of real-time monitoring, provided that applications exist to make data measurement, display and analysis user-friendly. Data moving from devices requires to easy integrate with the protocols of other Cloud software, like BT; otherwise it would lose any utility. At the same time, procedures, protocols and standards are required to secure this data and to validate it. Lastly, since IoT is generally adopted on large scale, maintenance cost of such hardware should not be prohibitive. Together with the pre-conditions to enable the interoperability with the IoT, practitioners and scholars primarily need to be aware of the whole set of limitations blockchain comes with. Since some of them are structural problems of the technology itself, actions can be taken to tackle issues like the lack of trust, lack of expertise and low engagement. In particular, two factors can help: dedicated consortia and the initiative of a leader company. Specifically, consortia could compensate to the lack of a network and expertise/skills, since companies within consortia typically share their knowledge and are eager to collaborate in BT projects. Possibly, then, consortia can also be useful in the definition of guidelines to approach BT and standards to harmonise its usage. The initiative of a big leader company in developing BT projects serves at overcoming the diffused rigidity towards and reluctancy towards such technology. Should this company manage to successfully implement BT, in fact, this would demonstrate smaller entities of BT benefits and convenience, dragging them into BT implementations. This would definitely help to win the mistrust and "chicken and egg" problem that limited blockchain so far.

Table 15: ideal conditions table, complete version (author's elaboration)

5.3 RQ3: *Identification and description of BT benefits*

Data triangulation brought to the identification of the multiple positive impacts that BT technology could bring when applied in SC. For this specific part of the research, data triangulation has been rooted on the following sources typologies:

- The research framework and the forty BT applications of the content analysis;
- Eight recognized papers on the consequences of BT in SC realm:
    1) (Kshetri, 2018)
    2) (Vyas et al., 2019)
    3) (Min, 2019)
    4) (Treiblmaier, 2018)
    5) (Babich & Hilary, 2018)
    6) (Wang, Han, et al., 2019)
    7) (Eljazzar, Amr, Kassem, & Ezzat, 2018)
    8) (Pai et al., 2018)

By considering, analysing and integrating their contents, a final dashboard was reaped to give a clear and comprehensive overview of the value unleashed. The dashboard is structured in two columns, where the first categorizes BT benefits in "SCM objectives" and the second articulates them into "Blockchain roles". In detail, the last column explains how the usage of such technology affects the corresponding SCM objective.

SCM OBJECTIVES	BLOCKCHAIN ROLES
COST	- Lowering administrative cost per transaction (1), (4), (6), (8) - Products recall (1), (2), (5), (8) - Paperwork elimination (1), (2), (6), (8) - Lowering regulatory compliance costs (1), (2), (4), (6) - Counterfeit and disputes prevention (1), (5), (6) - Waste and underused assets management through decentralized marketplaces (2), (7), (8)

SPEED	- Enabling fully automated processing of ownership transfer, payment of inventory managed by vendors (2), (5), (6), (8) - Business rules implementation through smart contracts (1), (2), (5), (6) - Securing and streamlining order fulfilment process (3), (6)
DEMAND AND PRODUCTION MANAGEMENT	- Secure decentralized P-2-P collaborative planning and forecasting platform (2), (7), (8) - Forecasts accuracy (7) - Increasing responsiveness to changes and exceptions (8) - Integrating data from 2^{nd} tier to n^{th} tier supply chain members (2), (5), - Providing single source of truth to build SC plans (2), (5), (8) - BT-transactions-based vendor selection according to registered (delivery performances) performances (5), (8)
RESILIENCE	- Mitigation of risks associated to middlemen and intermediaries (4), (6) - Data security /and transparency (4) → provide single consensus-based source of truth (1), (2), (5), (6), (7), (8) - Super-audit trail to tackle self-reported data (1), (2), (6), (8) - Visibility through exchange of reliable data (5), (6), (7) - Heightened connectivity fostering trust among partners (4), (6), (7), (8) - Only parties mutually accepted in the network can engage in transactions → secure partners and trading identification (2), (3) - Reward SC members for sharing reliable data (2), (6) - Providing real-time secure, validated data to monitor transport conditions (2), (5), (6) - Address holistic sources of risk (1), (5) - Providing data at the lowest possible level of granularity (2), (5) - Counterfeits, losses and damages prevention (3), (6) - Securing order fulfilment process (3) - Cybersecurity → fault tolerance (1), (5), (6)
ASSET MANAGEMENT EFFICIENCY	- Responding to the increasing demand for information from different stakeholders (1), (8) - Securing products' provenance (5), (6), (8) - Enabling sustainable Supply Chain (1), (6), (8) - Providing full products traceability (2), (6), (8) - Providing real-time secure, validated data to monitor transport conditions (6), (8) - Counterfeits, losses and damages prevention during assets management (2), (3), (5), (6), (8)

Table 4: BT benefits (author's elaboration)

Here follows a descriptive presentation of the table content, to better investigate the dynamics leading BT to generate value along the reported SCM dimensions.

Cost

As it will be discussed afterwards, Capgemini (2018) stressed in their report that cost saving is the major driver convincing companies to adopt BT. Despite it is hard to guess a ranking among the identified other benefits, cost saving was undoubtedly at the core of the topic. There are many ways for blockchain to cut costs: those related to regulations compliance, for instance. Being part of a globalized supply chain has now pros' and cons', as sticking to local regulations gets costly with the diversity of the regions hosting the operations. To add complexity and costs is the compliance with border crossing requirements, frequently slow and murky. BT is said to tear these costs down, by digitizing and standardizing shipping documents, while further contributing by making SC information flow seamlessly and transparently.

Another driver for cost saving is the ability to rapidly recognize the faulty items or lots of goods in case of contamination or fraud. Thanks to the timestamped information, in fact, contaminated products can be easily identified, thus supporting a dedicated and not invasive recall process. To these terms, cost reduction derives from the reduced research time for the identification phase and from the precision of recall, preventing regular goods from being wrongly sent back. In the same way, counterfeit and disputes can be stopped at their roots or even prevented, further contributing to recover money.

Moreover, with the digitalisation of shipping documents, like the Bill of Lading (look at the case 11 of the 40 BT applications, headed by Wave and Zim), costs related to manual paperwork can be omitted. Not only losses due to wrong manual reporting can be avoided, but even those associated to documents compliance, as already discussed.

Finally, BT has the potential to transform unused or underused assets and wastes into possible revenue sources. By tokenizing these assets, i.e. attributing them a digital ID, an online digital marketplace can be set up, running on blockchain. In this way, assets, being these tangible or intangible, can be securely exchanged and optimized. An example might be to exchange on the platform of empty spaces in the warehouse, as well as temporary unused trucks and transportation assets. Ultimately, an organization might think of sharing empty production lines according to weekly plans to a needing company. Regardless the asset type, overall this would bring to an improved net profit and resource utilization.

Speed

There are few BT properties capable of providing supply chains with increased process fluidity and enhanced speed. Most of the merits need to be recognized to the revolutionary automation degree introduced by smart contracts. When business rules and contractual terms are coded into a digital BT-supported environment, traditionally complex multi-stakeholder transactions can be accelerated or fully automated. For instance, when a shipment arrives at the buyer's warehouse, provided that contractual conditions have been correctly reported on BT, payment and possibly also the quality checks can be automatically executed. Besides reducing business process complexity through the elimination of some manual interventions, smart contracts have the ability to speed up SC processes by eliminating issues linked to payment withheld. Alongside with this, the elimination of contract registration and efforts spent for monitoring and updating, gains in process efficiency can be pursued.

As a smart contract can be invoked by oracles as well, the integration with IoT seems to get more sense. Lastly, when a set of smart contracts is set up to govern and streamline the processes within a complex and large environment, DAOs are claimed to deliver a huge value (Wang, Han, et al., 2019).

Besides that, the role of BT is quite flexible when it comes to process automation. Eljazzar, Amr, Kassem, & Ezzat (2018) have identified the contribution that could be given by blockchain to the order fulfilment process over its several steps. The following figure (Figure 26) should simplify the comprehension.

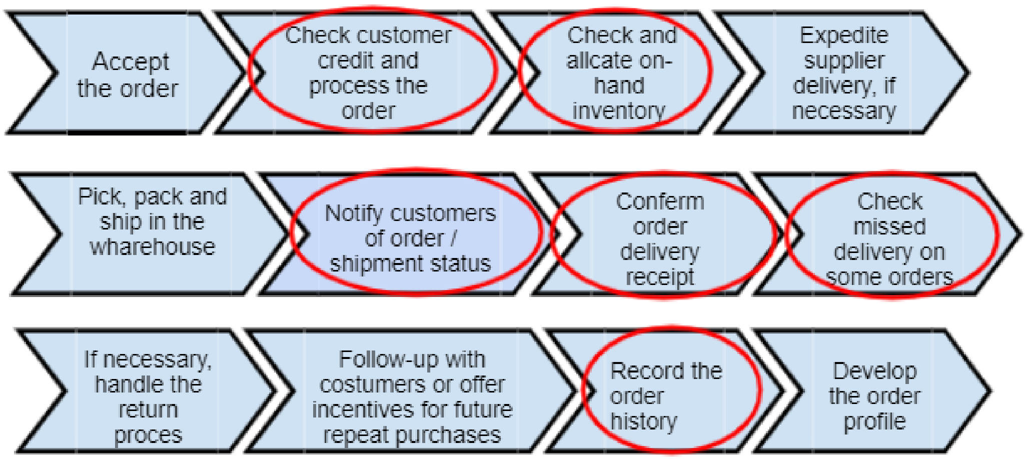


Figure 26: BT impact on the order fulfilment process (author's elaboration)

It is shown quite clearly that major benefits are triggered by the automation of time-consuming tasks like customer credit history confirmation, inventory status check-up, finances verification and order status notification. All along with speeding them up, a further advantage of supporting processes with BT is the full transparency, of which additional considerations will follow.

Demand and production management

The more companies know, the better they perform. It is about this simple relationship that BT steps into supply chain dynamics to bring new hopes. The rationale here is that, differently from what most of the organizations all over the world think, members of the same supply chain should work as a team. In a globalized word where uncertainties pop up at daily pace, collaborating with SC partners is the starting point to get over bloody competition. A big limit that has come up with the traditional concept of SC is the lack or scarcity of information sharing. Where technology was there, willingness to share it was not, and vice versa. But now times have changed: the technological advancements are brilliant and organizations start to get the need of competing in a team-alike configuration.

Made these premises, here is why and how BT can be valuable to SC entities. The distributed technology plays the crucial role of a unique platform for enhanced forms of collaboration. With the platform nodes occupied by the SC organizations, most of the benefits comes from the fast, transparent and secure information sharing. As the members start using BT as a point-to-point collaborative platform, enhanced performances in terms of planning and forecasting can be achieved. The acknowledgement of partners' production capacity and demand data brings considerable advantages in S&OP: more accurate forecasts, better exceptions management and increased responsiveness to changes. The point is that in the management of supplier-customer relationships, the core objective is to match customer's needs as fast, cheaply and better as possible. In this regard, entities belonging to the demand chain request full visibility on the customer side to optimize their decision and anticipate customers' notifications. Therefore, here is what BT does: granting all the members to have access, at any time, to the demand chain state so that they can adjust their plans and let the upstream players do the same.

The degree of such benefits predominantly varies with the technology diffusion: the more companies adhere, the more consistent is the data sharing and consequently the ability to correct forecasts and adjust operations. In general, the game-changing contribution of blockchain is the possibility to integrate data from tiers beyond the 2nd, in an extremely limited amount of time. This SC-long transparency releases value according to the starting elementary relationship: the more companies know, the better they perform. Such transparency allows different firms to have a unique reliable starting point, i.e. the same version of the truth, to create SC plans, fostering synergies and participation.

In the end, vendors management is the ultimate field where blockchain can say its piece. Once again, information visibility is what makes the game different. When BT platform hosts multiple companies and diverse potential suppliers of a company, the innovative technology can be used to sustain the vendors selection. In fact, by gathering the data available on the network, related to a group of potential suppliers' performances, the decision-maker can select the one/ones whose associated transactions on the database claim to be better.

Resilience

There is a key role that distributed ledger technologies play in diverse industries: that of making platform transactions secure and spreading trust among members. The near impossibility to tamper with the platform data paves the way for the resolution of what has been a major risk and cost source for SC: intermediation. Middlemen have always been necessary to fill trust gaps within a buyer-seller transaction, to deal with self-interest of the two parties. Nevertheless, BT shakes traditional business interactions by delivering end-to-end visibility and enhanced connectivity. The platform members deal with each other transparently, in a secure and protected environment characterized by an innovative data management system. The information flowing along the chain is reliable, preventing any type of transparency breach like the false self-reportedly data. As any transaction must be validated according to the in-force consensus mechanism before being added to the chain, all the platform members can operate with a diverse mindset and awareness. Moreover, a solid identification mechanism stands at the basis of a more secure system, where only those parties mutually accepted in the network can engage in transactions. This emerges as a risk mitigation achievement, direct consequence of the technology functionalities.

Further features contributing to shape resilient future supply chains are prevention of frauds and cybersecurity. As for the former, it has already been discussed how BT data integrity is relevant. Since data is added to the chain in a chronological sequence, frauds and disputes are not likely to happen, as data accessibility is immediate and possible frictions can be easily solved via fast checks. In the same way, cybercrimes are tackled hard to preclude dangerous data breaches, leading to possible market manipulations and financial thefts. High stakes and risks associated to data management are represented by the cyberattack withstood by Moller-Maersk in 2017, which condemned the largest container shipping line to a $300 million of lost revenue. The attack was facilitated by the centralization of the database system, showing one single risky point of failure. To this regard BT has been introduced as a possible remedy, since the points of failure are multiple and the cyberattack efforts need to be way more diffused and computationally expensive.

Overall, the fault tolerance, the immutability of data and the security of transactions and data management make BT a trusted environment for companies to exchange also sensitive information and to promote SC collaboration.

Asset management efficiency

The last category of benefits relates to the unmatchable capacity of tracking and tracing assets along the supply chain. It is frequently addressed as the biggest and most scalable potential of BT, since traditional supply chains relying on siloed centrally based databases do not permit to have full traceability on products moving along the chain.

With BT, data coming from all over the nodes is firstly validated and then added to the distributed ledger, so that any member could get visibility on the series of operations undergone by a product. The timestamping makes the information recorded on BT complete. If any member looked at the time-stamped sequence of a specific product, this should be able to observe its whole production and distribution advancements, as a result of data integration on the network. By collecting any transaction withstood by the product since its first presence on the chain, what is delivered to the final consumer is a set of information working as a certified provenance and history of the product itself. This platform property turns out to be extremely important considering the recent evolution in the needs of the demand side. Nowadays, consumers want to get full understanding of the origins of what they consume, demanding sustainability at systemic level. Furthermore, they insist that what is offered on the shelves has to be proved as a certified product, meaning that it has successfully undertaken all the quality and security controls all over the production and distribution phase.

This traceability can be furtherly taken to another level if integration with smart sensors is performed: by using these devices as oracle for the blockchain, information can even by collected about the temperature inside the truck during transportation or the humidity level in the warehouse during a certain time of the storage phase. In case of BT and IoT combination, traceability can occur in real-time.

Full traceability and enhanced visibility are also enablers, as mentioned multiple time so far, of an additional value: the avoidance of counterfeit, assets losses and damages. It frequently happens that assets are embedded with smart tags to verify their locations over time. Similarly, by officially reporting the entire history of a product, it is impossible for criminals to introduce fake goods into distribution systems.

"Who for – What for"

Further interesting findings come from Capgemini's Report (2018) (8), where BT benefits are pigeonholed and ranked according to the recipient. Three major recipient categories are used: consumer product organizations, retailers and manufacturers.

1) For **consumer product organizations**, the most of BT contribution can be found in tracking provenance of goods, especially food. Auditability, add-only data storage and data security are enablers for tracing the origin of goods, including any shift of ownership. Moreover, when combined with IoT, consumers can rely on a dependable system for tracking critical parameters. When fresh food or certain pharma products are moved along the chain, their sensitivity to key parameters like temperature and humidity need to be respected. Therefore, smart sensors are disposed as oracles to link the real world with the digital BT one.

Besides assets management and traceability, consumer product industry ambitiously looks at BT to get warranties that products shown on shelves have been handled in compliance with standards and regulations. This is also imputable to the recently frequent scandals having drugs counterfeit or food contamination as leading cause.
All in all, consumers want SC to evolve more sustainably, with major focuses on securing products' provenance. On the other turn, supply chains need to get used to deliver exhaustive information to consumers, keeping track of any product-related event and sticking to contractual conditions. Avoidance of contractual conditions breach can ultimately be achieved via smart sensors, by spotting any undesired parameter alteration (like temperature rise). By doing so, SC players are forced to become more accountable for their operations, leaving no space to false self-reported performances.

2) For **retailers**, two dominant benefits are delivered by BT platforms. Firstly, retailers working through their online marketplaces hope to move their systems on blockchain. When online marketplaces increase in size and volume, in fact, digital retailers face issues related to trust. Indeed, as most of them are rooted on a central authority managing and validating all the transactions itself, users may find it hard to trust the system, due to the easiness of tampering with. With BT, information flows and transaction validation change, with the first working faster and transparently and the second occurring at low costs, in real time via consensus mechanism and mining process. Ergo, trust in central authority, hardly achievable, is replaced by trust in the system and consensus rules, keeping verification costs restricted.
Through BT-enabled disintermediation and tokenization, online retailers can not only get over inevitable trust issues, but they can even think of new business models leveraging companies wastes and underused assets.

Moreover, retailers' stakes are high as far as it concerns counterfeit prevention. According to CNN Money (April 2016), the global counterfeit trade is worth $461 billion. The size and seriousness of the deal have made it necessary for entities involved in global trades necessary to find a remedy, and here is where BT can forcefully step in. Exploiting its distributed nature, BT platforms record timestamped events only after these have been previously validated by miners. When a unique tag is associated to the asset X, SC members operating on BT can be easily and instantly identified as they perform any transaction on the specific asset X. For instance, supposing that SC members on BT are the manufacturer, the logistic partner, the warehouse, the retailer and the customer; any transaction (ex. product scanning or handling) they perform on the asset X is timestamped on the platform, if validated. Logically, at the end of the supply chain, when customers scan the QR code on the asset X, its authenticity is immediate to check as a sequential story of events carried out on that asset by multiple actors. Being the platform tamper-proof, add-only and time-stamped, the output is the warranty that the examined product has not been counterfeited.

3) For **manufacturers**, BT adoption comes with conspicuous advantages. Primarily, the main support brought by this technology regards supplier management and process automation. Inefficiencies linked to supplier management are quite varied and economically consistent ($1.98 billion according to a study reported on Supplychaindive.com, in 2018). To blame are not only the phases of negotiation, authoring, execution, payment and renewal, still absorbing excessive money and time; but even the partners selection itself. Via BT, and specifically by encoding some easy-to-control business rules through smart contracts, processes can be automated and streamlined. BT allows to bypass useless intermediaries or to reduce approvals or waiting times, still granting operations to be run securely and in a trusted environment. Consequently, as information flows rapidly and operations are automated, execution speed increase and disputes are prevented. Thinking of a generic delivery case, automation via smart contracts might regard both the quality inspection successive to the proof of delivery and the payment execution afterwards. At the origins of suppliers' selection, BT seems to be of great help as well. Especially after a certain technology diffusion is achieved, suppliers' performances in terms of delivery times and other KPIs remain recorded on BT. Thus, companies can leverage

such data to screen partners according to their cost-effectiveness, preventing ex-ante to negotiate with underperforming actors.

Secondly, when blockchain is embraced by a sufficiently vast portion of the SC, it opens to fully integrated manufacturing processes and assets view. Such integration of asset-related data must be meant as extended along the whole product lifecycle, starting from design, but also including operations and maintenance. Besides delivering end-to-end product traceability, BT generally destroys mistrust barriers along the chain, favouring collaboration and facilitating exceptions handling.

6. CONCLUSIONS

This last chapter takes the stock of the research, making it clear how the document intends to support both practitioners and academics. The backbone of the chapter is represented by four major parts.

The first describes the leading contributions to the theoretical study of blockchain. The author explains which are the literature gaps at the roots of the investigation and how it is supposed to overcome them, possibly clarifying the new knowledge created.

The second block addresses the value of the inquiry at a managerial viewpoint. In particular, the author demonstrates how the various research tools should be used to support practitioners in the evaluation of BT. In a nutshell, this paragraph discloses the relevance of the investigation for organizations.

Successively, the reasons why the research findings are generalizable can be found in the third part. Methodology and practices made it possible not to bind these findings to one specific case.

Lastly, since the investigation is not flawless, in the fourth paragraph the author discusses the research limitations, providing suggestions to make future inquiries more accurate and BT topics better addressed.

6.1 Theoretical contributions

In terms of theoretical contributions, the research served to further investigate what emerges as one of the most promising technologies of the next 3-5 years: blockchain. The displayed findings represent a new frontier in the analysis of BT adoption in SC, considering the ***completeness, the structure and granularity*** of the research framework. The latter, in fact, stands as an attempt to approach the evaluation of BT adoption in a structured way, which was missing in the existing literature. The framework variables, indeed, are articulated into various levels of details, promoting an exhaustive analysis. In detail, the implementation of BT is investigated in relation with organization features, supply chain dimensions and IoT interoperability. The added value of the inquiry is finally represented by the field-based insights it is rooted on, making results reliable. Moreover, the comparative analysis brought to light further aspects that enriches the knowledge on blockchain in SC. Specifically, it merged primary and secondary sources to highlight the key drivers, complexities and risk factors. In detail, the analysis explained the key roles of consortia in the development and diffusion of BT, as well as the major need for major initiatives taken from big players to trigger BT-related market dynamics. Furthermore, it evidenced that IT heterogeneity, as well as organizations' reluctancy to adjust their processes architecture, might hinder technology diffusion. At the same time, a few SC problems emerge as potential drivers for the introduction of BT, as they plague multiple firms in both the examined industries. This investigation also contributes to the explanation of the value creation mechanism of BT in SC. The technology advantages, categorized in SCM dimensions, comprehensively report the ways blockchain deliver benefits, with a solid reference to both literature and BT applications. In particular, BT proved to deliver value to the dimensions of cost saving, speed, demand and production management, SC resilience and asset management efficiency.

6.2 Managerial contributions

At a managerial viewpoint, the tools and results of this research represent a solid support for companies that want to evaluate BT as future investment. Despite the key outputs has already been introduced, the author wants to provide readers with a final tool aimed at synthetizing the research content and its practical support. Therefore, the "Model for a comprehensive evaluation of BT" was created.

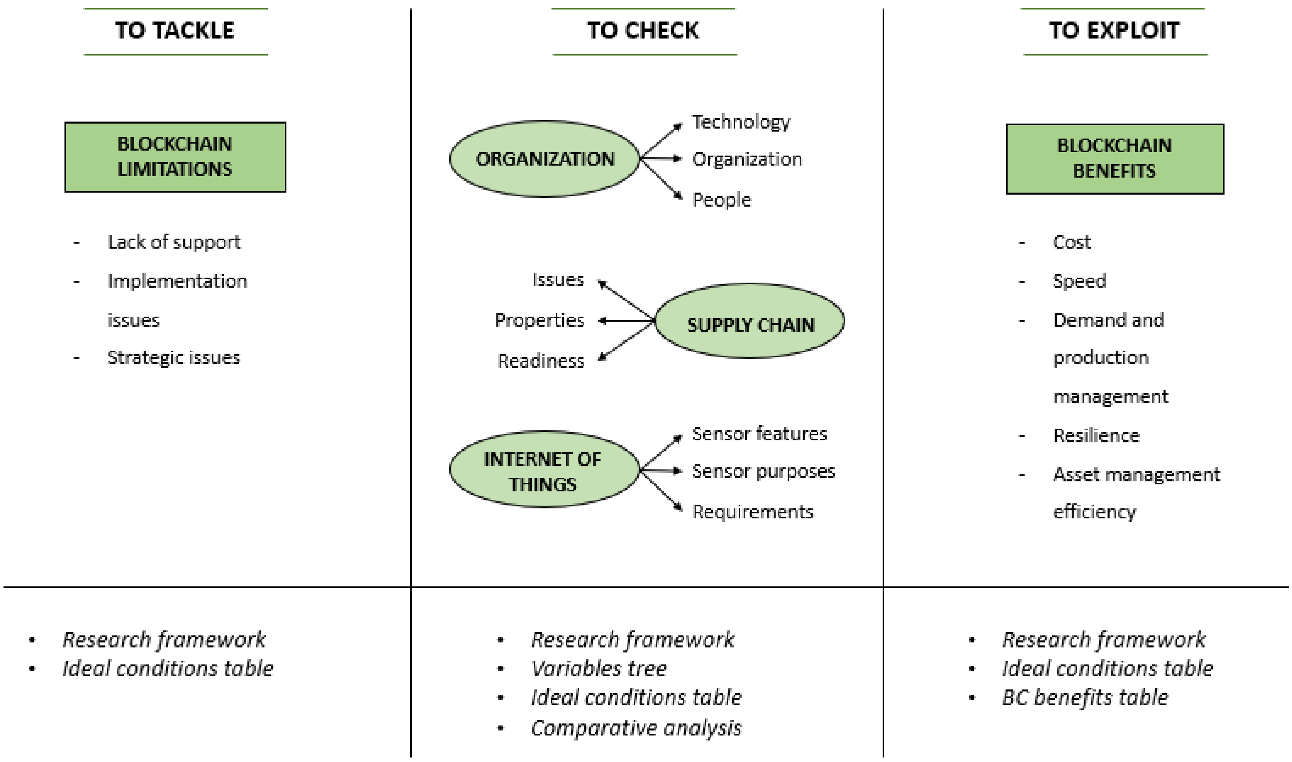


Figure 27: Model for a comprehensive evaluation of blockchain (author's elaboration)

The "Model for a comprehensive evaluation of blockchain" accompanies readers through the evaluative process in three steps.

1) Firstly, the decision maker is invited to check the as-is scenario of the case in examination with the support of both the *research framework* and the *variables tree*. In detail, this first evaluation must be performed along three major directions, that are the organization, the supply chain and the integration with IoT. The research dimensions corresponding to each direction can be found inside the framework, referring respectively to the micro-variables "Organizational Readiness" for the first, "Supply Chain Readiness", "Supply Chain Issues" and "Supply Chain Properties" for the second, and "Interoperability with IoT" for the third. At the beginning, model users should leverage the *ideal conditions table* to grasp information about the best configurations of the framework variables. Keeping them in mind, the *variables tree* must be then used as a checklist to compare the current statuses of the three areas

of analysis (organization, supply chain and internet of things) with the target ones. Consequently, this benchmark should also trigger actions aimed to fill the existing gaps between the as-is and the ideal conditions. Ultimately, the consideration of the comparative analysis results might be helpful too, as it supports companies in correctly approaching the technology.

2) In order to get a better view on the feasibility of BT implementation, the model user should move to the analysis of the BT benefits his case expects to achieve, depending on the company profile, the typology of implementation and the SCM dimension. In this phase, the benefits table should be the reference document.
3) Similarly, the last step, to be conducted in parallel with the second, consists in the assessment of those challenges associated to BT implementation. Combined with the result of step 2, this would assist the definition of pros and cons for the specific application purpose, with the goal of reaching a rational decision. In this regard, the framework micro-variable "Blockchain Limitations" should be the reference document.

6.3 Generalizability of the findings

Despite the research focus was kept on the two industries of L&T and F&B, the resulting findings are not case-specific and can be generalized by any practitioner or researcher involved in these domains. Reasons of this statement are explained below.

Given the topic novelty and the limited modern knowledge on BT implications in supply chain, the author needed an adequate supporting methodology. The multiple case assessment turned out to be a valuable approach to cope with the exploratory nature of the investigation. Such inquiry, indeed, had to sustain an inductive approach which was necessary to create new theories in such a messy realm.

A key feature of this methodology is, as the name suggests, the usage of multiple case-studies. It is possible associating to these cases the two reasons why the research findings are generalizable. The first works by definition and it is the fact of relying on various viewpoints (the case-studies) to formulate one common theory. To this purpose, the cross-case analysis is very emblematic as it perfectly sums up how the theory creation process works. The second was intentionally pursued, as it is linked to the selection criteria used for case studies. At the time of creating the sample, the author decided to make it considerably heterogeneous to get an even larger set of standpoints. The selected companies, in fact, compete as IoT and/or BT providers with different technical backgrounds. Moreover, they were chosen also considering the served markets, the dimensions and their geographical scope. In the end, in fact, the sample is made of companies and start-ups serving various types of L&T and/or F&B markets with a commonly global scope.

Ultimately, to add veracity and objectivity, the research framework was evaluated using insights of grey literature regarding real BT applications. Therefore, the adoption of both primary and secondary sources made the research even more complete, allowing the author to draw robust conclusions in the comparative analysis.

6.4 Research limits and future steps

This last chapter of the documents will disclose research limitations and possible future steps to continue the investigations on blockchain. Considering the increasing attention that the adoption of BT in SC is receiving, it is helpful to try providing some guidelines for a better future assessment.

Since research merits have been already discussed, it is important for a sake of clarity and transparency to report its existing limits. Some of them are linked to research choices or conditions while others merely depend on the available resources.

As far as it concerns the methodology, a few aspects may represent possible pain points. First of all, the time constraints did not permit the author to interview more than one profile per company in the multiple case analysis process. This results in two primary disadvantages: limited knowledge and single viewpoints. As for the former, asking questions only to one person put the researcher in front of the risk that the respondent was not knowledgeable about the topic. A few times, in fact, interviewees' level of preparation on certain topics was not high enough to get reliable information. Similarly, single-profile interviews face the risk of not totally reflecting the company's viewpoint and know-how, since they collect only one person's opinion. One last questionable point of the methodology, finally, is that a few times the research tutor was not available to take part to interviews. Despite the author has always behaved with the highest objectivity, this may damage the overall research reliability.

About the selection of the sample in the multiple case analysis, companies' availability forced the author to settle for a set of companies which results a bit unbalanced towards IoT providers. While, from one side, this helped in inspecting the smart sensors and IoT-related spheres, on the other turn it brought interviewer to deal with not-BT-friendly profiles. Those times, thus, answers on the BT part of the questionnaire were scarce. Lastly, one may also question the absence from the sample of BT adopters. This, though, is due to the simple starting decision not to target them, avoiding poor answers for confidentiality and the risk of reaching out only a very small number of firms.

Regarding the content analysis, it was already discussed that information availability was a big challenge. In fact, during the search for information material about the BT applications, a consistent companies' discretion as well as a general low availability made it hard to put the hands on sufficiently detailed data. This hindered the investigation since the level of granularity displayed by research variables was generally too low for the type of information available. In the end of the content analysis, this resulted in a low degree of evidence for most of the framework dimensions.

The last research mark can be argued to be its inductive and qualitative nature. Nevertheless, the almost unexplored research field as well as the technology novelty and complexity made such approach not only necessary but also the only feasible one. When dealing with such level of innovation, the only way to get results is to iteratively move from theory creation to theory testing. A further crucial clarification is that, being the research outputs qualitative, they need to be used as supporting tools. A comprehensive evaluation of BT can be achieved by combining these tools with more quantitative means, which are, though, missing nowadays.

Coherently with what stated so far, the author prompts that next research efforts should be oriented along the following directions.

Above all, what is truly necessary is to deepen the quantitative aspects linked to BT adoption in SC. This document provides a model to qualitatively evaluate the technology, but it lacks numbers supporting the rationale underneath. Future investigations, therefore, should collaborate with real-case applications and collect data about those business dimensions improved thanks to the introduction of BT. Sizing its benefits is the only way to understand if and when it makes sense to use blockchain.

Besides that, research results can be deepened and improved by enlarging the sample, possibly engaging with heterogeneous entities to cover all the nine quadrants of the classification matrix for case studies, as reported in figure X. At the moment, in fact, not all the combinations of IoT and BT providers with L&T and F&B industries are considered, which might limit the analysis results. Potentially, BT adopters might be more available in sharing their projects outputs, which might consistently help with the investigation, especially in delivering quantitative data currently missing.

Similarly, content analysis could be enhanced by expanding the sample of BT applications, making results even more valid. Lastly, grey literature can be complemented with sources possibly released directly from BT adopters examined in the sample.

APPENDIXES

Appendix 1 - Engagement email

Good afternoon!

I am Claudio Ratti, a master student currently collaborating with Windesheim University of Applied Sciences, in Zwolle. I am focusing on the link between Blockchain technology and IoT in supply chains, with specific reference to two industries: logistics and transportation, and agri-food. At Windesheim, we aim at evaluating costs and benefits of Blockchain adoption in conjunction with the use of sensors and other technologies to improve supply chain management.

While looking for relevant companies that could support me in this research, I came across your information and though that it would be interesting to hear your perspective on this topic. It would be great for me to discuss this with one of your experts in an interview of approximatively 30 minutes. I am more than happy to come and visit you, or alternatively we can setup a phone call.

I'm sure we will meet each other soon, in the meantime, I wish you a great day!

Sincerely,

Claudio

Appendix 2 - Interview Protocol

1. INTERVIEWEE'S NAME:
2. ROLE IN THE COMPANY:
3. COMPANY NAME:
4. SIZE OF THE COMPANY:
5. INDUSTRIES SERVED:
6. PRODUCTS / SERVICES OFFERED:
7. HOW DOES THEIR BUSINESS MODEL WORK?

- What is the **mission**?
- What is the value proposition? Which products and services are offered to the 2 target industries?
    - Sensor typology:
    - Performance measured:

    - Level of usage (product, pallet, container...):
- What are the purposes these sensors are used for? Who do they work for? Who are the customers?
- What are the customers' needs the products respond to? Which problems do they want to solve?
- Is the company part of a consortium of other IoT providers? Who are the suppliers of these sensors?

8. ABOUT THE SUPPLY CHAIN THE COMPANY'S CUSTOMERS ARE PART OF:
   - How complex and diversified is it?
   - How relevant are end-2-end traceability and authenticity? How are these achieved?
   - Are there many trusted third parties to validate transactions along the chain?
   - How do players communicate with each other?
   - Which is the IT architecture of these customers?

9. ABOUT SMART SENSORS DEPLOYMENT AND USAGE:
   - How are data coming from sensors managed? Are they stored in a centralized or decentralized way? Are these recorded with some paperwork? (data management)
   - Can sensors interact with each other or are they separated vertical silos? Is there a standard protocol to face different sensors? (data governance)
   - Are data coming from smart sensors totally reliable and immutable? (data trustworthiness)
   - Are maintenance costs for this type of sensors significant for IoT owners? (especially considering the high number of sensors)
   - Is it possible to track back each individual sensor? (identity)
   - Are these sensors secure? Can they be hacked and tampered with? If yes, how is this tackled? (data security)

10. RELATION WITH THE BLOCKCHAIN:
    - If they already use it:
        - How does the interaction between IoT and BT work? Do transactions take place on the BT platform or outside? And data storage?
        - How is the information coming from the smart sensors made reliable? "zero status issue".
        - How do they face the following issues? Scalability, sensitive data privacy, consensus mechanisms with IoT, legal issues.

    - If they don't already use it:
        - do you plan to integrate BT with IOT? Why? For which purposes?
        - What makes you reluctant from applying BT?
        - What is going to be the future of smart sensors in 5 years?

11. COULD YOU PROVIDE A PRACTICAL CASE OF IOT APPLICATION (AND BLOCKCHAIN INTEGRATION IF POSSIBLE)?

12. WHO ELSE SHOULD WE INTERVIEW TO MAKE OUR RESEARCH MORE COMPLETE? CAN YOU OPEN UP A CONTACT?

Appendix 3 – Blockchain applications selected for the content analysis

	COMPANIES	F&B	L&T	SHORT DESCRIPTION
1	**Provenance & FairFood**	X		Making coconut supply chain transparent
2	**Ambrosus**	X		Integrating IoT and Blockchain to protect high quality swiss cheese
3	**Provenance & Coop**	X		Digitally tracking fresh crops and their claims in real-time
4	**Provenance & Grassroots**	X		Making meat supply chain wholly transparent
5	**Vinturas**		X	A shared BC platform in the Finished Vehicles Logistics realm
6	**Carrefour**	X		BC used to make chicken, eggs and other products' supply chains transparent
7	**IBM, Nestlè, Tyson**	X		IBM, Nestlè, Tyson and others to tackle food safety worldwide
8	**Bait To Plate WWF**	X		Fish traceability for safe supply chain
9	**Oranco**	X		Authenticating imported wines' provenance in Chinese market
10	**Daimler & Filament**		X	P2P platform to improve the remanufactured components service
11	**Wave and Zim**		X	First pilot of paperless Bill of Lading based on BC
12	**Fedex**		X	Introducing mandated international standards in international shipping
13	**Heineken**	X		Tracking and storing provenance data of bottles for more sustainability
14	**Plus**	X		Using BC to track bananas along SC
15	**Port of Rotterdam, ABN AMRO, Samsung**		X	First BC-based container shipped to rotterdam
16	**UPS**		X	UPS using BC for tracking
17	**Walmart & Vechain**	X		Securing food provenance in China
18	**Vechain & DB schenker**		X	Using BC for monitoring suppliers' performances
19	**Fresh Turf & IBM**		X	Decentralised locker deliveries
20	**Albert Heijn**	X		Traceability in orange juice production
21	**Lane axis**		X	Cutting intermediaries in shipper-to-carrier solutions
22	**Maersk & IBM--> TradeLens**		X	Digitalize the shipping industry to promote secure info exchange and collaboration
23	**Solas VGM**		X	VGM portal boosting transparency on customer shipments (containers' weight)
24	**CargoLedger & PoRotterdam**		X	Innovate management of cargo and quality control
25	**Post NL**		X	Creation of a markeplace based on BC where manufacturers can sell groceries directly to consumers
26	**TallyStick**		X	Automate digital payments through BC
27	**300 CUBITS**		X	Trasforming the shipping industry by tokenizing containers
28	**Bext360**	X		Provides comprehensive traceability on coffee supply chain
29	**Kouvola Innovation**		X	Introducing smart devices in containers to make shipping industry more traceable
30	**OriginTrail**	X		Traceability initiatives for different products
31	**Viant // Treum**	X		Delivering transparency and traceability in Food industry
32	**AdelphiDistillery**	X		Securing the provenance and authenticity of wisky
33	**Arcnet**	X		Securing provenance of Meat and beverages
34	**ArcNet**	X		Securing provenance and traceability of beer
35	**TimeSeries & Van Dorp**		X	Combining BC and IoT to improve automated planning
36	**Bumble Bee Food**	X		Using BC and IoT to track provenance of tuna foods
37	**Apical**	X		Track the provenance of palm oil to make that industry sustainable
38	**Helium and Nestlé**	X	X	Exploit the new Hotspot network to refil the offices water cooler
39	**Waltonchain**	X		Big data and BC, with IoT, applied to agriculture for food safety
40	**Ambrosus**	X		Integrate IoT and BC to verify quality and provenance of olive oil

Appendix 4 – Matrix interviews vs content analysis

		30 MHZ	AANKHEN	AURELIUS ENTERPRISE	CISCO JASPER	INSOLAR	MODUM	OMNI-ID
Willingness to cooperate	1,60	HIGH: ONLINE COLLABORATION THROUGH PLATFORM, EX. GROWERS USING CONSULTANCY COMPANIES' DATA FOR PEST MANAGEMENT AND PREVENTION. A LOT OF PARTNERSHIPS	HIGH: DEDICATED PARTNERSHIPS	HIGH: "COMPANIES WANT TO COLLABORATE FOR INNOVATION, TO CREATE ECO-LANDSCAPES"	HIGH: THEY OPERATE IN A "PARTNERS ECOSYSTEM"	HIGH: THEY HAVE A LOT OF ALLIANCES GOING ON	LOW: THEY JUST CARE ABOUT HAVING CUSTOMERS REQUIRING THE TECHNOLOGY (BC)	HIGH: THEY THINK IT IS RELEVANT TO COLLABORATE AT SC LEVEL AS UPSTREAM SUPPLIER, ESPECIALLY WITH DISTRIBUTORS
Consortium support	0,30	LOW, N.M.	HIGH: THEY ARE PART OF BITA	LOW, N.M.	LOW, N.M.	HIGH: THEY ARE PART OF BITA	LOW, N.M.	LOW: NOT PART OF CONSORTIA
Interoperability of IT systems at partners' organization	0,30	LOW, N.M.	LOW	LOW: COMPANIES NEED TO SHARE SYSTEMS TO COLLABORATE ON A SC LEVEL	LOW	HIGH: COMPANIES' VARIOUS IT SYSTEMS ARE AN OBSTACLE TO IMPLEMENT BC . "TECHNICAL COMPATIBILITY WITH EXISTING IT SYSTEMS"	LOW	LOW, N.M.
Innovation stagnancy	0,33	LOW, N.M.	LOW, N.M.	HIGH: COMPANIES WANT TO INNOVATE THEIR BUSINESS MODEL	HIGH: "NOWADAYS COMPANIES WANT EITHER TO BE THE FORERUNNERS OF DIGITIZATION OR NOT TO BE CANNIBALIZED BY COMPETITORS"	HIGH: COMPANIES WANT TO "STEP UP IN THE DIGITALIZATION OF THEIR BUSINESS NETWORK"	LOW	LOW, N.M.
Current IT architecture	0,25	LOW, N.M.	HIGH: NO SOFTWARE HAS TO BE IMPLEMENTED, VALUE CAN BE CREATED FROM DAY 1	LOW	LOW, N.M.	LOW: IT IS A PROBLEM WHEN VARIOUS IT SYSTEMS EXIST AT SC LEVEL	LOW, N.M.	LOW, N.M.
Level of knowledge and expertise on BC technology	0,35	LOW, N.M.	HIGH: THEY HAVE BEEN WORKING WITH IOT AND BC FOR A WHILE	LOW	LOW, N.M.	LOW, N.M.	HIGH: GENERAL KNOW-HOW IS QUITE LIMITED ON BC AND THIS IS RECOGNISED AS A PROBLEM	LOW, N.M.
Current Business Process Architecture	0,20	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW, N.M.	HIGH: "BC REQUIRES CHANGES IN BUSINESS PROCESSES ", WHICH MAY BE A BLOCKER. SOMETIMES A REDESIGN IS REQUIRED	LOW, N.M.	LOW, N.M.
Organization's objectives	0,48	HIGH: REAL-TIME MONITORING AND CONTROL OF CROP PERFORMANCES, INVENTORY MANAGEMENT, RESURCE OPTIMIZATION	LOW, N.M.	HIGH: THEY WANT TO MAKE VALUE OUT OF THEIR DATA AND OPTIMIZE PROCESS, LIKE THE TIME TO MARKET	HIGH: FLEET MANAGEMENT, ASSET TRACEABILITY ARE SUITABLE TO BC ADOPTION	HIGH: COMPANIES WANT TO DECREASE WC,	LOW: THEY JUST OFFER SOLUTIONS TO INCREASE CUSTOMER SERVICE, WHICH IS TOO GENERAL	HIGH: THEY HAVE HIGH INTERESTS IN ASSET MANAGEMENT
Ability to invest	0,23	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW, N.M.	HIGH: "INABILITY TO ALLOCATE ADDITIONAL RESOURCES TO IT SYSTEMS"	LOW, N.M.	LOW

		30 MHZ	AANKHEN	AURELIUS ENTERPRISE	CISCO JASPER	INSOLAR	MODUM	OMNI-ID
Cost-effectiveness of the SC information exchange	0,95	LOW, N.M.	HIGH: INFORMATION IS OPPORTUNISTICALLY HANDLED TO HIDE INEFFICIENCIES	LOW, N.M.	LOW, THE PROBLEM IS ASSOCIATED TO THE DISCONNECTION BETWEEN PARTIES OF THE SC	LOW, N.M.	HIGH: "THERE IS A LACK OF INFO SHARING"	LOW, N.M.
Adequacy/effectiveness of existing communication technology	0,45	LOW, N.M.	LOW	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW, N.M.
End-2-end visibility along all SC operations	1,68	LOW, N.M.	HIGH: IT'S A MAJOR PROBLEM OF SC , BUT THE IOT CAN BE A SOLUTION TO PROVIDE REAL-TIME VISIBILITY. FOR EXAMPLE ONE OF THEIR CUSTOMER COMPANIES ADMITTED THEY HAVE NO IDEA WHEN DELIVERIES ARE PERFORMED	HIGH: "COMPANIES WANT TO ACHIEVE COMPETITIVE ADVANTAGE THROUGH THEIR SC" BUT CURRENTLY THEY HAVE NO VISIBILITY ON THE VARIOUS SC STAGES	HIGH: "THERE IS NO VISIBILITY ALONG THE SC,ESPECIALLY ALONG THE COLD CHAIN"	HIGH: "BC SERVES AT EXPANDING VISIBILITY ON SC PROCESSES"	HIGH	LOW, N.M.
Disputes and frauds creation and management	1,10	LOW, N.M.	HIGH: A LOT OF ASSETS ARE LOST DUE TO FRAUDS	LOW	LOW, N.M.	HIGH: COMPANIES WANT TO REDUCE CLAIMS RESOLVANT TIMES AND COSTS	HIGH: ESPECIALLY IN THE COLD CHAIN, THERE IS A STRICT REGULATION TO STICK TO	LOW, N.M.
Heterogeneity/diversity of IT systems	0,00	LOW, N.M.	LOW	HIGH: COMMUNICATION SHOULD BE FACILITATED BY THE ADOPTION OF SIMILAR SYSTEMS	LOW, N.M.	HIGH	LOW, N.M.	LOW, N.M.
Administrative costs	0,53	LOW, N.M.	LOW	LOW, N.M.	LOW	LOW, N.M.	LOW, N.M.	LOW, N.M.
Inter-company processes accountability / integration	1,00	LOW, N.M.	HIGH: COMPANIES ARE NOT ACCOUNTABLE FOR THE INEFFICIENCIES THEY CREATE	HIGH, LACK OF SENSORS AND PLATFORMS INTEGRATION AT SC LEVEL	HIGH: THERE IS A DISCONNECTION AMONG INFRASTRUCTURE, APPLICATION AND SENSOR LEVELS	LOW, N.M.	HIGH: COMPANIES HAVE A VERY LOW OVERVIEW OF THE SC	LOW, N.M.
Visibility on bottleneck	0,30	HIGH: PERFORMANCE PREDICATBILITY, ERRORS PREVENTION	LOW	LOW	LOW,N.M	HIGH: "THE WHOLE NETWORK SUFFERS FROM A LIMITED VISIBILITY, AT ANY LAYER", ALSO BECAUSE THE SYSTEMS ARE NOT INTERCONNECTED	LOW, N.M.	LOW, N.M.
Interoperability of corporates' ERPs	0,05	LOW, N.M.	LOW	LOW, N.M.	LOW,N.M	HIGH: EVERYONE HAS HIS OWN ERP SYSTEM AND CUSTOMER MANAGEMENT SOFTWARE.	LOW, N.M.	LOW, N.M.
Data integration at SC process level	1,43	HIGH: FOSTER ONLINE COLLABORATION AND DATA SHARING AMONG MULTIPLE PARTIES (EX. GROWERS AND CONSULTANCY FIRMS)	HIGH: NO SC KPIS FOR SYSTEMIC CONTROL	HIGH: COMPANIES NEED TO SHARE DATA AT SC LEVEL	HIGH: DEVICES ARE NOT INTERCONNECTED AT SC LEVEL SO THAT DATA INTEGRATION AT SC LEVEL IS NOT ACHIEVABLE	LOW	HIGH: LACK OF INFORMATION SHARING CAUSES A LOW INTEGRATION OF DATA AT SC	HIGH: COMPANIES WORK AS MONOLITHIC ENTITIES AND DO NOT INTAGRATE DATA AT SC LEVEL
Increased demand for quality, customized and sustainable products	1,05	HIGH: INCREASE DEMAND FOR PRODUCTS AND INFORMATION ON PROVENANCE (FROM CROP TO FORK)	LOW	HIGH: CUSOTMERS' DEMAND IS INCREASING ALL OVER THE WORLD	LOW, N.M.	LOW, N.M.	HIGH: INRCEASING DEMAND FOR PRODUCT CUSTOMIZATION AND HIGH QUALITY GOODS. "MUCH MORE SPECIFIC AND SPECIALIZED SUPPLY CHAINS", "IT'S GETTING MUCH MORE PERSONALIZED"	LOW, N.M.
Level of responsiveness	0,33	LOW, N.M.	LOW	HIGH: COMPANIES ARE WORKING TOGETHER TO DECREAESE TIME TO MARKET AND TO BE MORE RESPONSIVE, IN TERMS OF EXCEPTIONS AND PEAKS	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW, N.M.
planning/scheduling effectiveness	0,45	LOW, N.M.	LOW	HIGH: COMPANIES WANT TO COLLECT DATA ACROSS THE SC TO SUPPORT PLANNING AND SCHEDULING	LOW, N.M.	HIGH: DATA SHARING AMONG COMPANIES CAN BE USED TO REDUCE WC AND INVENTORY LEVEL BY GETTING INVENTORY INFORMATION FROM SUPPLIERS AND CUSTOMERS TO REDUCE THEIR EXTRA CAPACITY OR TO SELL IT ON NEW PEER TO PEER MARKETS .	LOW, N.M.	LOW, N.M.
Operations transparency	0,75	LOW, N.M.	HIGH: MANY COMPANIES MANIPULATE THEIR KPIS TO HIDE THEIR PROBLEMS	LOW, N.M.	LOW, THERE IS A LACK OF TRANSAPRENCY, BUT IT IS LINKED TO THE SCARCE INTEGRATION OF DEVICES AT SC LEVEL	LOW, N.M.	LOW, N.M.	LOW, N.M.
Effectiveness of assets traceability (assets lost, thefts and tampering)	1,50	HIGH: LACK OF END-2-END TRACEABILITY FROM CROP TO FORK	HIGH: MANY ASSETS ARE LOST DUE TO SCARCE TRACEABILITY	LOW, N.M.	HIGH: NEED FOR AUTOMATIC CONNECTIVITY FOR ASSET TRACKING AND REMOTE DIAGNOSTIC.	LOW, N.M.	HIGH: LACK OF END-2-END TRACEABILITY IS A MAJOR PROBLEM	HIGH: IT IS CRUCIAL TO KNOW"WHERE IS THE PRODUCT", ALSO TO PREVENT ASSETS LOST
Trust level among organizations and customers	1,43	HIGH: CUSTOMERS REQUIRE TRACEABLE PRODUCTS TO BE SURE OF THEIR PROVENANCE	HIGH: TRUST IS LOW ESPECIALLY BECAUSE THE ENTIRE FINANCIAL SYSTEM IS BROKEN (NOBODY PAYS ON DELIVERY, FINANCIAL AND PHYSICAL FLOWS ARE FRAGMENTED)	LOW, N.M.	HIGH: MISTRUST ONLY AMONG COMPANIES, DUE TO THE SCARCE INTEGRATION OF LEVELS	HIGH: "THEIR CONTROL TOWER SOLVES TRUST ISSUES AMONG COMPANIES "	HIGH: "THERE ARE A LOT OF COMPANIES IN THE CHAIN THAT DO NOT KNOW NEITHER TRUST EACH OTHER"	LOW, N.M.
Cost-effectiveness of validation process	0,50	LOW, N.M.	LOW: JUST A CONSEQUENCE OF POOR TRUST AMONG COMANIES, WHICH REQUIRES INTERMEDIARIES TO INTERVENE	LOW, N.M.	LOW	HIGH: DATA AUTHENTICITY IS A PROBLEM ESPECIALLY WITH SUB-CONTRACTORS AND THIRD PARTIES	HIGH: IT IS IMPORTANT FOR COMPANIES TO AUTHENTICATE DATA ABOUT TEMPERATURE AND DELIVERIES CONDITIONS	LOW

		30 MHZ	AANKHEN	AURELIUS ENTERPRISE	CISCO JASPER	INSOLAR	MODUM	OMNI-ID
Heterogeneity of organizations	0,30	LOW, N.M.	LOW	LOW	LOW, N.M.	HIGH: THERE ARE A MYRIAD OF VARIOUS PLAYERS INVOLVED, FROM BANKS, TO 3PLS, CUSTOMS, BUYERS	HIGH: "VERY ZOOMED-IN VIEW OF THE SC, WITH MORE PLAYERS PER EACH LAYER"	HIGH: COMPANIES COMPOSING SUPPLY CHAINS ARE VERY DIVERSIFIED
Structure and complexity	0,63	LOW, N.M.	LOW	LOW	LOW, N.M.	HIGH: THERE ARE A LOT OF SUBCONTRACTORS, LAYERS. "TWICE AS PARTNERS AS 2 YEARS AGO"	HIGH: "VERY COMPLEX AND BIG SYSTEMS"	LOW
Dimensions measured	0,73	HIGH: WIND SPEED, TEMPERATURE, HUMIDITY, OBJECT COUNTING , CO2	HIGH: HUMIDITY, TEMPERATURE, LOCATION, LIGHT	LOW	HIGH: TEMPERATURE, HUMIDITY, LOCATION, LIGHT	HIGH: TEMPERATURE, LOCATION AND HUMIDITY	HIGH: SPECIFIC ON TEMPERATURE MONITORING FOR PHARMA AND F&B. NEXT WILL BE LIGHT, HUMIDITY AND SHOCK	HIGH: ONLY AM-I-THERE SENSORS, LOCATION
Sensor typology	0,30	HIGH: WIRELESS SENSORS, GATEWAYS, REPEATERS	HIGH: TRACK DEVICES, GE DEVICES AND ALL TRANSPORTATION IOT SENSORS	LOW	HIGH: FIXED LINE AND CONNECTED SENSOR-NET	HIGH: RFIDs, TRACKERS AND ACTUATORS	LOW: EMBEDDED DEVICES AND SENSORS REMOTELY CONFIGURABLE	HIGH: RFID
Application level	0,53	LOW: CROP, PLENT, FRUIT LEVEL	LOW: CONTAINER AND TRUCK LEVEL ARE VERY SUITABLE TO BC	LOW	LOW: TRUCK OR CONTAINER	LOW: TRUCK LEVEL	LOW: TRUCK LEVEL	HIGH: ONLY TRUCK LEVEL
Tracking and trace	1,20	LOW, N.M.	HIGH: MAJOR GOAL OF IOT	LOW, THEY USE SENSORS MORE AT MACHINE LEVEL TO MONITOR PERFORMANCES	HIGH: MAJOR GOAL OF IOT, N.M.	HIGH	LOW: THEIR FOCUS IS ON TEMPERATURE SINCE LOCATION MEASURING REQUIRES COMPLETELY OTHER FEATURES	HIGH: CONTAINERS TRACKING WITH TAMPER-PROOF SYSTEM
Predictive or preventive maintenance	0,15	LOW, N.M.	LOW	HIGH	LOW, N.M.	HIGH: PROACTIVE RESPONSE WHEN DATA IS NOT IN LINE WITH STANDARDS	LOW, N.M.	LOW
In-process visibility	1,15	HIGH	HIGH: TO PROVIDE VISIBILITY AT SC LEVEL	HIGH: COMPANIES HAVE NO CLUE ON THER PROCESSES" AND SENSORS HELP COMPANIES IN KNOWING WHAT THEIR MACHINES ARE DOING --> PROBLEMS OF MAINTENANCE COST AND SENSORS' VISIBILITY CAN BE SOLVED WITH SW PLATFORMS, BUT NOT DATA SECURITY	LOW	LOW	LOW, N.M.	HIGH
Real-time performance measurement and control	0,45	HIGH	HIGH: SENSORS ARE USED TO KNOW THE EXACT LOCATION OF ASSETS AT ANY TIME	HIGH, IT IS IMPORTAT TO MEASURE AND MONITOR R-T PERFORMANCES OF MACHINES	HIGH	HIGH	HIGH: SENSORS ARE USED TO MONITOR REAL-TIME TEMPERATURE DURING TRANSPORTATIONS	HIGH
Avoid not value-adding activities	0,38	HIGH: RESOURCE OPTIMIZATION (EX. DEDICATED PLANTS WATERING PROGRAMS)	HIGH: BY MONITORING PERFORMANCES WITH IOT, THEY DENOTED THAT ALMNOST 50% OF A COMPANY'S EMPLOYEES DO NOT VALUE-ADDING ACTIVITIES	LOW	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW
Data security and validation	0,10	LOW, N.M.	HIGH: THEY MAKE DATA SECURITY START BY DESIGN, THAT THEY HAVE FULL CONTROL ON THE WHOLE PROCESS OF TECHNOLOGY MANUFACTURING AND PROCUREMENT, ELIMINATING ANY TOUCHPOINT, PREVENTING ANYONE FROM INSTALLING, CHANGING AND OPERATING UNPROPERLY.	HIGH: IT IS A SERIOUS PROBLEM THAT CANNOT BE SOLVED WITH SW PLATFORMS	HIGH: DATA SECURITY IS A MAJOR CONCERN ESPECIALLY AT DEVICE SITE	LOW, N.M.	LOW, N.M.	LOW: IT IS NOT THEIR PURVIEW TO SECURE SENSOR DATA
Relatively low maintenance cost	0,03	LOW, N.M.	LOW, N.M.	LOW, THIS PROBLEM CAN BE SOLVED THORUGH SOFTWARE PLATFORM	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW
Need for real-time monitoring	0,58	HIGH: THIS IS THE MAJOR PURPOSE OF IOT APPLICATION IN THIS CASE	LOW, N.M.	LOW	HIGH	LOW, N.M.	HIGH	HIGH
Availability of applications	0,60	HIGH: A PLATFORM IS USED TO STREAMLINE, DEPLOY AND VISUALIZE DATA	HIGH, THEY PROVIDE SW TO ELABORATE AND EXPLOIT DATA COMING FROM THE HW	HIGH: APPLICATIONS HELP FIRMS	LOW: IT IS IMPORTANT TO NORMALIZE DATA THORUGH HW AND SW TOOLSETS	LOW, N.M.	HIGH: CLOUD APPLICATIONS ARE USED TO VISUALIZE DATA .	LOW,N.M.

		30 MHZ	AANKHEN	AURELIUS ENTERPRISE	CISCO JASPER	INSOLAR	MODUM	OMNI-ID
Availability of applications	0,60	HIGH: A PLATFORM IS USED TO STREAMLINE, DEPLOY AND VISUALIZE DATA	HIGH, THEY PROVIDE SW TO ELABORATE AND EXPLOIT DATA COMING FROM THE HW	HIGH: APPLICATIONS HELP FIRMS	LOW: IT IS IMPORTANT TO NORMALIZE DATA THORUGH HW AND SW TOOLSETS	LOW, N.M.	HIGH: CLOUD APPLICATIONS ARE USED TO VISUALIZE DATA .	LOW,N.M.
Efficient power consumption	0,00	LOW, N.M.	LOW	LOW, N.M.	LOW, N.M.	LOW, N.M.	HIGH: STEADY INTERACTIONS AMONG DEVICES ARE ENERGY DEMANDING	LOW
Interoperability with other IoT and Cloud software	0,60	HIGH: SENSORS CAN COMMUNICATE WITH OTHER DEVICES AND WITH THE PLATFORM	HIGH: THEIR IOT SYSTEM IS INTEROPERABLE WITH BC AND OTHER CLOUD PLATFORMS	HIGH: DATA NEED TO BE HANLDED ON DEDICATED PLATFORMS	HIGH: IT IS IMPORTANT FOR SENORS AND PLATFORMS TO COMMUNICATE WITH EACH OTHER AND TO USE THE SAME PROTOCOLS	LOW, N.M.	HIGH: CLOUD SOLUTION INTEROPERABLE. THE BIG CHALLENGE IS TO USE COMMON STANDARDS TO MAKE SENSORS COMMUNICATE EACH OTHER	LOW: THEIR ONLY CONCERN IS THAT THEIR DEVICES COULD COMMUNICATE WITH READERS
Black box (meta-trust required)	0,55	HIGH: HYPED AND OVERRATED TECHNOLOGY	LOW	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW	LOW, N.M.
Platform security	0,20	HIGH	LOW	LOW, N.M.	HIGH	LOW, N.M.	LOW	LOW, N.M.
Zero-status issue	0,58	HIGH: GULLIBLE COMBINATION OF PHYSICAL AND DIGITLAL DOMAINS	LOW	LOW, N.M.	LOW, N.M.	HIGH: LOW EVIDENCE BUT JUST BECAUSE IT IS NOT ABOUT BC, IT IS LINKED TO IOT. THE POINT IS THAT BC HAS JUST A ROLE OF TIME-STAMPING INFORMATION, NOT OF VERIFY ITS VERIFIABILITY OUTSIDE THE PLATFORM. SOME SYSTEMS CAN BE IMPLEMENTED ON TOP OF BC TO OVERCOME THIS PROBLEM.	HIGH: TRANSACTIONS ARE SIGNED ON THE LOGGERS THEMSELVES. IT MAKES SURE THAT DATA REMAINS THE SAME AS ENTERING THE CLOUD.	LOW, N.M.
Energy consumption	0,00	LOW, N.M.	LOW	LOW, N.M.	LOW, N.M.	HIGH: IT IS IMPORTANT WHEN YOU CONSIDER THE TOTAL COST OF OWNERSHIP. THE TRANSACTION VALIDATION AND STORAGE PROCESSES ARE VERY DEMANDING IN TERMS OF ENERGY.	LOW	LOW, N.M.
Technology readiness	0,30	LOW, N.M.	HIGH: TECHNOLOGY IS NOT EXISTING AT THE LEVEL OF PRODUCTION READNIESS. NO LARGE SCALE CASES	LOW, N.M.	LOW, N.M.	HIGH: SCALABILITY IS A PROBLEM ARISING AFTER TRANSACTION COSTS AND IT ADJUSTMENT COSTS. "THE THROUGHPUT OF THE SYSTEM SHOULD GROW IN RELATION WITH THE NETWORK SIZE" AND THIS IS A PROBLEM FOR BC. SCALABILITY ISSUE EMERGES WHEN COMPANIES THINK OF BC FOR THE PRODUCTION SCALE	HIGH: IT IS STILL LOOKING FOR PRACTICAL USE CASES	LOW, N.M.
Lack of standards	0,48	LOW, N.M.	HIGH: NO STANDARDS DEFINED. FOR INSTANCE, DIFFERENT BC-BASED TRACKING SYSTEMS EXIST	LOW, N.M.	HIGH: STANDARDS DIVERSITY IS A MAJOR REASON WHY POTENTIAL USERS DO NOT TRUST BC APPLICATIONS	LOW, N.M.	LOW	LOW, N.M.
Latency	0,10	LOW, N.M.	LOW	LOW, N.M.	LOW,N.M.	LOW, N.M.	LOW	LOW, N.M.
Monetization of the investment (no clear ROI)	0,18	LOW, N.M.	LOW	LOW, N.M.	HIGH: MANY FIRMS DON'T KNOWW HOW TO MONETIZE THE INVESTMENT	LOW, N.M.	HIGH: COMPANIES STRUGGLE TO FIND CUSTOMERS WILLING TO PAY FOR IT	LOW, N.M.
Added value creation	0,13	HIGH: NO ADDITIONAL ADVANTAGE IS PERCEIVED COMPARED TO SENSORS AND PLATFORM INTEGRATION	HIGH: SOME FEATURES OF BC ARE NOT VALUE ADDING. THE INTERVIEW SUGGESTED THAT BC SUPPORTERS FALL INTO THE "LAW OF THE INSTRUMENT"	HIGH: BC MUST HAVE A SPECIFIC PURPOSE	LOW, N.M.	LOW, N.M.	HIGH: IT IS DIFFICULT TO DEMONSTRATE BC BENEFITS TO POTENTIAL ADOPTERS	HIGH: THERE IS NO PERCEIVED BENEFIT

		QUADMINDS	SIGFOX	SIGNALZ	THE IOT COMPANY	VANTIQ	VINTURAS
Willingness to cooperate	1,60	HIGH: THEY NEED CUSTOMERS AND PARTNERS WILLING TO INVEST IN BC TO START THE PILOT	LOW: THEY COLLABORATE WITH MANY PARTNERS BUT WITH OUT THE INTENTION OF SPREADING TECHNOLOGIES	HIGH: IT IS VERY IMPORTANT FOR THEM TO COLLABORATE WITH COMPANIES PROVIDING THE HW PART . LOOKING FOR STRATEGIC PARTNERSHIPS	HIGH: "WE HAVE PARTNERS SUPPORTING US WITH HW AND SW"	HIGH: THEY GENERALLY WORK THROUGH PARTNERS , RELYING ON THEM TO GET SPECIFIC KNOWLEDGE ABOUT PARTICULAR SENSORS' FEATURES ACROSS INDUSTRIES . DATA IS USEFUL ONLY IF VARIOUS PARTIES ARE CONNECTED	HIGH: "TRENDS FORCE COMPANIES TO COLLABORATE" "YOU NEED TO CREATE ALLIANCES TO BUILD YOUR OWN DIGITAL NETWORK". THE LOW ENGAGEMENT IN BC IS PROVOKED BY LOW TRUST AND TRADITIONAL ATTITUDE TOWARDS STAND-ALONE COMPETITION RATHER THAN INDUSTRY COMPETITION
Consortium support	0,30	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW, N.M.	HIGH: THEY BELIEVE STAYING IN CONSORTIA IS USEFUL AND THEY ARE INTERESTED IN GETTING INVOLVED	HIGH: THEY BUILT VINTURAS AS A CONSORTIUM TO FOSTER BC ADOPTION
Interoperability of IT systems at partners' organization	0,30	LOW	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW, N.M.	HIGH: SILOED SYSTEMS ARE A MAJOR PROBLEM, AS A STANDARD INTERFACE IS MISSING TO CONNECT ALL THE PLAYERS. VINTURAS IS CONVINCED BC IS WORTH IT ESPECIALLY TO PROVIDE VISIBILITY TO SC COMPANIES, BECAUSE THEY WOULD NOT HAVE TO FACE SWITCHING COSTS TO "PLUG" THEIR SOLUTIONS TO THE BC
Innovation stagnancy	0,33	HIGH: F&B INDUSTRY IS STAGNANT	HIGH: MANY COMPANIES ARE FRIGHTENED BY THE NEED TO CHANGE THEIR BUSINESS MODEL TO DIGITAL TECHNOLOGIES, AT LEAST THIS IS A MAJOR OBSTACLE FOR BC	LOW, N.M.	LOW	HIGH: MANY COMPANIES ASK FOR BC JUST TO LEAD THE WAY TO DIGITIZATION.	HIGH: THE FVL INDUSTRY HAS VERY LOW MARGINS, REASON WHY IT IS PRETTY CONSERVATIVE TOWARDS INNOVATION. MANY COMAPNIES, ESPECIALLY IN GERMANY, ARE PLAYING A WAIT-AND-SEE STRATEGY, WHILE OTHER FEW COMPANIES IN SPAIN AND SWEDEN ARE MORE WILLING TO TAKE THE RISK
Current IT architecture	0,25	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW, N.M.
Level of knowledge and expertise on BC technology	0,35	LOW, N.M.	LOW, N.M.	HIGH: THEIR KNOWLEDGE OF BC IS VERY LIMITED	HIGH: THEY PROVIDE END-TO-END SUPPORT IN IOT PROJECTS DEVELOPMENT, BUT NOT BC	LOW, N.M.	LOW, N.M.
Current Business Process Architecture	0,20	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW, N.M.
Organization's objectives	0,48	HIGH: ASSET TRACEABILITY, WASTE MANAGEMENT, REDUCE LOGISTICS COST, INCREASE CUSTOMERS' SATISFACTION	LOW, N.M.	HIGH: PREDICTIVE INTERVENTIONS, PROCESS OPTIMIZATION	HIGH: MOST COMMON OBJECTIVES ARE TO OPTIMIZE PROCESSES AND TO GET VALUE OUT OF DATA	HIGH: ASSET TRACEABILITY AS MAJOR CONCERN , PROVIDING BETTER CUSTOMER SERVICE IN TERMS OF PRECISE TRACEABILITY	HIGH: MAJOR FOCUS ON ASSETS TRACEABILITY
Ability to invest	0,23	LOW	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW,N.M.

		QUADMINDS	SIGFOX	SIGNALZ	THE IOT COMPANY	VANTIQ	VINTURAS
Cost-effectiveness of the SC information exchange	0,95	HIGH: PROBLEM OF COMMUNICATION BETWEEN DRIVERS IN THE TRUCK AND THE FINAL CUSTOMERS	LOW, N.M.	LOW, N.M.	LOW	LOW	LOW,N.M.
Adequacy/effectiveness of existing communication technology	0,45	LOW	LOW, N.M.	LOW, N.M.	LOW	LOW, N.M.	HIGH: EDI , MAILING ARE NOT ADEQUATE "EDI CANNOT SUPPORT SYSTEMIC COLLABORATION"
End-2-end visibility along all SC operations	1,68	HIGH: SCARCE VISIBILITY ON SC PROCESSES, "COMPANIES ARE BLIND AS FAR AS IT CONCERNS PROCESSES OUT OF THEIR FACILITIES"	HIGH: DATA-CROSSING FROM DIFFERENT DEVICES IS USED TO SOLVE LACK OF VISIBILITY ALONG THE INDUSTRY	LOW, N.M.	HIGH: END-2-END VISIBILITY REMARKED AS A BIG TROUBLE FOR SC	HIGH: "END-TO-END VISIBILITY IS THE REAL PLAGUE OF SC"	HIGH: NO SC VISIBILITY OVERALL, "THEY HAVE A LACK OF VISIBILITY, SHIPPERS HAVE NO CLUE WHEN GOODS ARE PICKED UP UNTILL THE CAR ARRIVAL, THEY ARE LAGGING BEHIND A DAY" "WE ARE CLOSING THE GAP BETWEEN PARTIES"
Disputes and frauds creation and management	1,10	LOW, N.M.	LOW, N.M.	LOW	LOW	HIGH: MANY CASES OF TRAILERS THEFTS	HIGH: : 70 % REDUCTION IN DAMAGE AND CLAIMS HANDLING COSTS EXPECTED
Heterogeneity/diversity of IT systems	0,00	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW	LOW, N.M.	HIGH:"DEALERS GROUPS WITH VARIOUS BRANDS HAVE DIFFERENT PORTALS AND INTERFACES"
Administrative costs	0,53	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW	LOW, N.M.	HIGH: "IT IS ABOUT SIMPLIFYNG THE ADMIN PROCESS THROUGHOUT THE SC", "BC SAVES INTEGRATION COST"
Inter-company processes accountability / integration	1,00	LOW	LOW, N.M.	LOW, N.M.	LOW	LOW	LOW, N.M.
Visibility on bottleneck	0,30	LOW	LOW, N.M.	LOW, N.M.	LOW	LOW	HGH: EVERYONE HAS THE SAME VIEW ON PROBLEMS AND DAMAGES
Interoperability of corporates' ERPs	0,05	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW	LOW, N.M.	LOW, N.M.
Data integration at SC process level	1,43	LOW	LOW, N.M.	LOW, N.M.	HIGH: SILOED SOLUTIONS PREVENT COMPANIES FROM INTEGRATING DATA AT THE SYSTEM LEVEL	LOW	HIGH: NO COMMON OVERVIEW OF SC, BECAUSE WE ARE STILL STUCK AT AN API-ECONOMY WHERE EVERYONE ONLY SEES HIS PART OF THE CHAIN
Increased demand for quality, customized and sustainable products	1,05	HIGH: COMPANIES ARE REQUIRING NEW CUSTOMIZED SERVICES, LIKE THE REVERSE LOGISTICS	LOW, N.M.	HIGH: THERE IS A VERY INRCEASING DEMAND FOR CUSTOMISED PRODUCTS.	LOW: THE BIG DESIRE FROM THEIR CUSTOMERS IS TO GET MORE DATA ABOUT ANYTHING	LOW, N.M.	HIGH: "DEMAND OF VEHICLES SERVICE WILL UBERIZE THE MARKET" SINCE THERE ARE MANY LOGISTICS PARTIES THAT CAN TAKE OVER THE OTHER VERTICAL ACTIVITIES
Level of responsiveness	0,33	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW	LOW	LOW. N.M.
planning/scheduling effectiveness	0,45	HIGH: THEY NEED TO DECREASE INVENTORY AND IMPROVE PLANNING .THEY USE INVENTORY ALERTS	LOW, N.M.	LOW, N.M.	LOW	HIGH: SCARCE DATA EXCHANGE PREVENTS COMPANIES TO PROPERLY SERVE CUSTOMERS AND TO SUCCESSFULLY FORECAST DEMAND	LOW. N.M.
Operations transparency	0,75	LOW, N.M.	LOW, N.M.	LOW	LOW	LOW	LOW. N.M.
Effectiveness of assets traceability (assets lost, thefts and tampering)	1,50	HIGH:THEY NEED TO EXACTLY KNOW WHEN DELIVERIES WILL BE PERFORMED AS WELL AS CUSTOMERS WANT TO KNOW WHEN PACKAGES WILL ARRIVE	HIGH: ASSET MANAGEMENT IN L&T IS A PRIORITY	LOW, N.M.	HIGH: "WE WORK WITH TRAILIERS COMPANIES (LEASING TRAILERS) SUFFERING FROM TRAILERS THEFTS, WHICH HAPPENS QUITE SOMETIMES"	HIGH: THEY TACKLE CONTAINERS THEFTS AND THE GREY MARKET AS A WHOLE	HIGH: SHIPPER HAVE NO CLUE WHEN EXACTLY DELIVERIES OR PICK-UPS WILL BE PERFORMED
Trust level among organizations and customers	1,43	LOW	LOW, N.M.	LOW, N.M.	LOW	LOW	HIGH: BC PROVIDES TRUST AMONG COMPANIES BY PUTTING THEM ON A COMMON LEDGER
Cost-effectiveness of validation process	0,50	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW	LOW	LOW, N.M.

		QUADMINDS	SIGFOX	SIGNALZ	THE IOT COMPANY	VANTIQ	VINTURAS
Heterogeneity of organizations	0,30	LOW	HIGH: "ONE OF THE BIGGEST CHALLENGES IS REPRESENTED BY SC PLAYERS' DIVESRITY AND SC COMPLEXITY"	LOW, N.M.	LOW	HIGH: L&T INDUSTRY IS VERY COMPLEX AND DIVERSIFIED, WHICH INFLUENCES BC DIFFUSION	HIGH: THERE IS A MIRYAD OF VARIOUS ACTORS INVOLVED, FROM OEMS TO 3PLS AND BANKS
Structure and complexity	0,63	HIGH: SERVED INDUSTRIES ARE RECOGNIZED AS COMPLEX, ESPECIALLY WITH REFERENCE TO THE REQUIRED SERVICES	HIGH: "ONE OF THE BIGGEST CHALLENGES IS REPRESENTED BY SC PLAYERS' DIVERSITY AND SC COMPLEXITY"	LOW, N.M.	LOW	HIGH: L&T INDUSTRY IS VERY COMPLEX AND DIVERSIFIED, WHICH INFLUENCES BC DIFFUSION	HIGH: INCREASING COMPLEXITY DUE TO THIRD PARTIES ENTERING THE MARKET WITH THE RISK TO CANNIBALIZE OTHER PLAYERS BY INTEGRATING VERTICALLY
Dimensions measured	0,73	HIGH: TEMPERATURE, LOCATION, SPEED	HIGH: TEMPERATURE, LOCATION, PRESSURE, SHOCK	HIGH: WATER QUALITY PARAMETERS	HIGH: GPS LOCATION, TEMPERATUREE, HUMIDITY, CO2 LEVEL, PRESSURE	HIGH: LOCATION, TEMPERATURE AND SHOCK (FOR POTENTIALLY FRAGILE GOODS)	LOW: GPS LOCATION, TIMES OF OPENING
Sensor typology	0,30	HIGH: GPS, GPRS, RFID AND CUSTOMIZED SOLUTIONS	HIGH:LOW-COST OR ULTRA-LOW-COST SENSORS	LOW: THEY CARE ABOUT SOFTWARE PART	LOW: THEY DO NOT PRODUCE HW BUT THEY USE TRACKERS AND LPAN SENSORS	HIGH: SIGFOX FOR THEIR QUITE LOW FREQUENCY (NOT METER BY METER)	LOW: COMPUTER DEVICES ON TRUCKS, NOT SMART SENSORS
Application level	0,53	HIGH: TRUCK LEVEL	HIGH: PACKAGE LEVEL, DUE TO THE TRADE-OFF BETWEEN MAINTENANCE COST AND PERFORMANCE LEVEL	LOW: BOTH MACHINES AND FIELD LEVEL	HIGH: TRUCK LEVEL, TANK LEVEL	HIGH: PALLET AND CONTAINER	HIGH: TRUCK LEVEL
Tracking and trace	1,20	HIGH: INFORMATION FOR CUSTOMERS' LOGISTICS, THEY TRACK SMALL CONTAINERS	HIGH: ONE OF THEIR MAIN APPLICATIONS, ESPECIALLY IN L&T	LOW	HIGH: "WHAT WE DO IN LOGISTICS IS MOSTLY TRACK AND TRACE, TO WHOM WE OFFER WHOLE SOLUTIONS(HW AND SW)" --> LONG SHOT IS UBERIZATION OF CONTAINER MARKET	HIGH: THEY KEEP TRACK OF THEIR ASSETS	HIGH: MAJOR FOCUS, BUT NOT IN REAL-TIME
Predictive or preventive maintenance	0,15	LOW, N.M.	LOW, N.M.	HIGH: ALGORITHMS CAN BE ADDED TO THE PLATFORM TO PERFORM PREDICTIVE MAINTENANCE	LOW, N.M.	LOW	LOW, N.M.
In-process visibility	1,15	LOW	LOW	HIGH: MACHINES ARE CONNECTED TO EACH OTHER TO MONITOR THEIR PERFORMANCES. EX. MONITORING OF VESSELS' ENGINES PERFORMANCES	LOW, N.M.	LOW	LOW, N.M.
Real-time performance measurement and control	0,45	HIGH	HIGH: TO KNOW WHAT IS WHERE AND AT WHAT TIME	LOW	HIGH: THEY NEED TO KNOW WHERE CONTAINERS ARE IN A SPECIFIC TIME WINDOW TO SUPPORT UBER-LINE SYSTEMS	HIGH: THEY AIM AT CATCH AND RESPOND TO IOT DATA SOON, IN REAL-TIME. "THEY WANT TO MONITOR TEMPERATURE OF CONTAINERS TO SECURE FISH QUALITY"	LOW, N.M.
Avoid not value-adding activities	0,38	LOW, N.M.	LOW, N.M.	LOW	LOW, N.M.	LOW	LOW, N.M.
Data security and validation	0,10	LOW: THEY DO NOT HAVE A STRUCTURED METHOD TO VALIDATE OR SECURE DATA, BUT THEY ARE AWARE THIS IS SOMETHING TO OVERCOME.	LOW, N.M.	HIGH: "DATA SECURITY VARIES WITH PROTOCOLS AND THIS DEVSERVES MORE ATTENTION"	LOW, N.M.	HIGH: DATA SECURITY IS A MAJOR CONCERN AS IOT DEVICES COULD BE HACKED VERY EASILY	LOW, N.M.
Relatively low maintenance cost	0,03	LOW	HIGH: "THIS IS TYPICALLY NEGLECTED BUT ACTUALLY VERY HIGH"	HIGH: MANUALLY UPDATES OF SENSORS IS VERY COSTLY	HIGH: LOW-POWER CONSUMPTION ALLOWS FOR LOW COST SOLUTIONS, WHICH IS A REQUIREMENT OF CUSTOMERS	HIGH: THE COST OF RFID TAGS IS GETTING SO LOW THAT EVERYTHING IN A FEW YEARS WILL BE SENSORISED.	LOW, N.M.
Need for real-time monitoring	0,58	HIGH: THEY NEED TO REAL-TIME MONITOR TRUCKS TO PROVIDE DATA FOR LOGISTICS PURPOSES	HIGH: REAL-TIME ASSET TRACEABILITY REQUIRES IOT	LOW	HIGH	LOW	LOW, N.M.

		QUADMINDS	SIGFOX	SIGNALZ	THE IOT COMPANY	VANTIQ	VINTURAS
Availability of applications	0,60	HIGH: API ARE USED FOR BETTER COMMUNICATION AMONG SENSORS	HIGH: APPLICATIONS AS A KEY ENABLER FOR CUSTOMERS TO GET AND INTEGRATE DATA FROM VARIOUS SOURCES	HIGH: SIGNLAZ REPRESENTS A SOFTWARE APPLICATION CAPABLE OF CONVEYING ELABORATED SENSORS DATA INTO EXCEL SHEETS	HIGH: THEY OFFER THEIR SOFTWARE PLATFORM TO GET VALUE OUT OF DATA	HIGH: "APPLICATIONS FOR MANAGING BUSINES EVENTS TO ANALYZE THEM AND REACT TO PATTERN" "LOOKING AT IT NOW AND RESPONDING TO IT NOW"	LOW, N.M.
Efficient power consumption	0,00	LOW	HIGH: THEY OFFER THE LEAST ENERGY CONSUMING DEVICE-TO-CLOUD CONNECTIION	LOW, N.M.	HIGH: THEIR LOW.POWER SENSORS ARE USED TO PROVIDE CONNECTIVITY AT LOW COST.THEIR COMPANIES SAVE UP TO 70.000 EURO PER YEAR THANKS TO LOW-POWER CONNECTIVITY	LOW	LOW, N.M.
Interoperability with other IoT and Cloud software	0,60	HIGH: INTEGRATION WITH SW TO MAKE DATA VALUABLE	HIGH: THEIR SENSORS ARE COMPATIBLE WITH OTHER SYSTEMS AND TECHNOLOGIES LIKE WIFI, BLEUTOOTH AND GPS TO FOSTER CONNECTIVITY	HIGH:"DIFFERENT BRANDS OF SENSORS USUALLY REQUIRES DIFFERENT SYSTEMS TO MANAGE DATA" THIS IS WHY A SW PLATFORM LIKE SIGNALZ IS HELPFUL, IT ELIMINATES PROBLEMS LINKED TO DIFFERENT PROTOCOLS	HIGH: "WE DEVELOPPED OUR OWN SW PLETFORM TO GET RID OF DIVERSE SENSORS PROTOCOLS"	HIGH: "OUR SOLUTION , MADE OF SOFTWARE PLATFORMS, CONNECTS TO OTHER SYSTEMS". THEY BELIEVE INTEGRATION OF IOT WITH OTHER TECHNOLOGIES WILL BE THE BASIS FOR THE FUTURE	LOW, N.M.
Black box (meta-trust required)	0,55	HIGH: THE LOW LEVEL OF ENGAGEMENT FROM OTHER PLAYERS MAKES IT HARD TO CONDUCT POC.	HIGH: NOW THERE IS A LOT OF SCEPTICISM	LOW, N.M.	LOW, N.M.	HIGH: TRUST ISSUES KEEP AWAY COMPANIES, BUT BC MAKES SENSE ONLY IF MANY PARTIES PARTICIPATE . BC IS NOT PRESENTED IN A MARKETABLE WAY, VENDORS CAN'T TELL WHY BC IS ADOPTED	HIGH: LOW TRUST TOWARDS BC CREATES THE PLATFORM PROBLEM. PEOPLE ARE USED TO COMPETITION AS STAND-ALONE COMPANIES, NOT AS AN INDUSTRY AS A WHOLE. THIS IS THE REASON WHY THE ENGAGEMENT IS LOW
Platform security	0,20	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW	HIGH: DATA PRIVACY IS AN EXISTING PROBLEM .NONETHELESS, THEY USE PUBLIC AND PRIVATE CRYPTOKEYS TO MAKE DATA SECURE.
Zero-status issue	0,58	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW	LOW
Energy consumption	0,00	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW, N.M.	LOW	LOWM N.M.
Technology readiness	0,30	LOW, N.M.	HIGH: THE HIGH EXPECTATIONS ON BC ARE NOT PROVED BY REAL-CASE APPLICATIONS	LOW, N.M.	LOW, N.M.	HIGH: "THERE IS NO COMPELLING USE-CASE CONVINCING US TO ADOPT BC" --> IT'S A CHICKEN AND EGG PROBLEM	LOWM N.M.
Lack of standards	0,48	LOW, N.M.	LOW,N.M.	LOW, N.M.	LOW, N.M.	HIGH: "THE PROBLEM WE SEE IS THAT BC IS VERY FRAGMENTED "	HIGH: THE ABSENCE OF UNIQUE BC STANDARDS PREVENTS FROM SOLVING IT DIVERSITY
Latency	0,10	LOW, N.M.	LOW,N.M.	LOW, N.M.	LOW, N.M.	LOW	HIGH: LATENCY IN GETTING THE TRUTH TO AND OUT THE NODES (1.5 SEC)
Monetization of the investment (no clear ROI)	0,18	HIGH: THERE IS NO PROOF IT JUSTIFIES THE INVESTMENT	HIGH: THE PROBLEM IS "THE INABILITY OF POC TO MIRROR THE FINANCIAL LONG-TERM IMPLICATIONS OF SUCH TECHNOLOGY"	LOW, N.M.	LOW, N.M.	LOW	LOW
Added value creation	0,13	HIGH: MOST OF THE COMPANIES DO NOT PERCEIVE ANY ADDED VALUE. VERIFY IF THE BC SCENARIO THEY PROPOSED TO CUSTOMERS FITS THEIR STRATEGY	LOW, N.M.	HIGH: THEY DON'T SEE IT AS A TOP PRIORITY, THEY DONT' SEE THAT BIG CHANCE	LOW, N.M.	HIGH: THEY DON'T SEE HOW IT MAY HELP WITH REFRENCE TO THEIR CUSTOMERS' NEEDS. THERE IS NO REAL MARKET-PULL, SOME COMPANIES ARE ASKING FOR BC BUT THEY CAN'T TELL WHY. THEY JUST SEE IT AS A WAY TO LEAD THE DIGITIZATION	HIGH: FEAR OF INVESTING IN A TECHNOLOGY THAT STILL HAS TO DEMONSTRATE TO BE WORTH IT

Appendix 5 – Within-case analysis

30MHZ

	“We're building the data platform for agriculture”
Name	30MHz
HQ location (city, country)	Amsterdam, the Netherlands
Industries served	Agri-food
Company role	IoT provider
Geographical scope	Global
Role of the interviewed profile	CEO

General overview

30MHz is a company offering innovative solutions in the agricultural sector. It operates in the belief that any company can gain efficiency, sustainability and cost-effectiveness through the proper use of technology and data. This business reality, held up by 30 employees, wants to become the mean to digitize the business. They offer both hardware and software components in a comprehensive value proposition that aims to gather, monitor, streamline and visualize data effectively.

They offer their products and services to small farmers as well as large seed breeders like Monsanto, counting more than 250 customers all over the world. What they offer is a unique combination of smart sensors and software platform. The formers are arranged at crop or plant level to grasp real-time data. The latter, on its turn, funnels the data, elaborates and visualises it so that users can get value out of that.

The CEO reported to partner with various companies all over the world, not taking part to consortia though.

Supply chain characteristics

Despite being slightly closer to the agri-food domain rather than the examined F&B one, the interview with 30MHz provided some insights. What clearly emerged from Paganelli's words is the serious problem of missing end-to-end traceability "from crop to fork". With this expression practitioners mean the difficulty in tracing assets and products along the chain, since their "production" in crops to their consumption at the final clients' tables. Overall, this results in a systemic inefficiency regarding operations at any level of the chain. According to the interviewee, achieving a full-scale visibility along the supply chain would result in higher products quality and enhanced customer services. Nowadays, indeed, customers pay more attention to the product information, using provenance and compliance to quality standards as decision criteria.

Relationship with IoT and BT

An evident linkage with the world of IoT emerged, as both hardware and software elements are offered. On the hardware side, 30MHz owns wireless sensors, repeaters and various gateways, which are used to detect information about temperature, humidity, wind speed, CO_2 and number of assets. The major need requiring this technology adoption is to take performance measurement and control to the next level. Users require indoor applications for real-time control of crops performances and for inventory management, advancing for a better resources' utilization.

On the other turn, though, 30MHz's CEO Flavia Paganelli firmly opposed to the integration of BT with their IoT-based value proposition, addressing it as a hyped and overrated technology. Her concerns on BT were mostly associated to the platform security, the difficulty of securely updating software and the gullible integration of physical and digital worlds. All in all, she reported not to see any additional benefit in adopting BT, while foreseeing a brighter future for IoT and AI union.

AANKHEN

	"Delivering value at the first use"
Name	Aankhen Inc.
HQ location (city, country)	San Jose, California, US
Industries served	Food chain, eCommerce, T&L
Company role	IoT and BT provider
Geographical scope	Global
Role of the interviewed profile	CEO

General overview

Aankhen is a $ 10 million yearly revenues technology company that plans to provide industries with visibility and security through the IoT application. They have already worked for various big companies like Dell, for whom they deployed a new global embedded cost optimization, and Nestlé, where they have merits for the design of a new data warehousing system and the introduction of better KPIs in the industry. They are active in both L&T and F&B, with various types of interventions. As for the former, Aankhen deals with e-commerce (total cost reduction, fulfilment visibility and security), port security (thefts reduction during import/export), revenue authorities (revenue leakage reduction by improving visibility) and 3PL (proactive JIT and management of on-time deliveries). As for the food chain, whereas, they enable cold chain monitoring and agri-logistics life-cycle visibility and security.

Their value proposition is rooted on the concept of "delivering value at the first use". By combining IoT with Cloud computing and some BT's features like immutability, transparency and records transactions, they intend to provide visibility to the SC. By looking at the SC holistically, from both the physical and the financial side, they leverage a different procurement process with a different track of records system. Starting from scratch, now they are seeing the advantages of past choices like that of preferring Auto-IDs to RFids to support an open SC adoption. Now they work for big companies linked to the Defense to track containers worldwide.

Lastly, they recently took part to the BiTA to provide standardization of BT applications in the L&T domain.

Supply chain characteristics

The CEO seemed to have a very peculiar but precise idea on modern SCs. On the light of his 30-year experience in the field, he claimed that the entire financial system is broken, because, so far, there has not been the adequate technology to record and secure transactions. This condemned the whole credit-and-debt system to get broken. The inability to have a general perception of the entire SC performances pushes many players to hide their problems and inefficiencies. In this mechanism, he stated that manipulations are frequent, and data are typically adjusted to show performance levels higher than the real ones. For instance, he appraised that 10 to 15% of containers get lost during shipments and that big companies in the F&B realm have no precise delivery schedules, but data is manipulated by top managers (like CFOs) to hide it. This permits companies to pretend offering a great customer value, keeping their brand attractiveness stable.

Overall, he condemned modern industries for the arduous lack of visibility that impedes to make the widespread inefficiencies come up, suggesting IoT and BT integration for a possible remedy.

Relationship with IoT and BT

As already mentioned, Aankhen makes an intense usage of IoT, integrating it with Cloud systems and some BT features. Data coming from smart sensors and Auto-IDs all over the world are funnelled and elaborated to provide full-scale visibility. Data is collected at container or truck level concerning location, light, temperature, humidity and gases concentration. Embedding all types of transportation modes with track devices, GE devices and others, asset traceability is ensured. With regard to data security, they praise a security starting “by design”, as they are involved in the whole process of technology manufacturing and procurement. By stepping into every potential touchpoint, they prevent anyone from installing, changing and operating where it’s not proper.

As for BT, despite they use some of its functionalities, the CEO recognized some limitations. First of all, the technology is not existing at the level of production readiness, as it will take some time to reach its dominant design and cost-effective configuration. Secondly, he insisted that standards are necessary to be defined, as BT-based tracking systems are different from each other. With this regard, though, BiTA is organizing multi-side efforts to get over it. Lastly, he repeated that BT adoption should be market-pulled rather than technology-pushed, as its introduction makes sense only it is meant to answer to specific needs.

AURELIUS ENTERPRISE

AURELIUS ENTERPRISE	“Continuous delivery of insight and intelligence to make smarter, better and faster decisions that can be controlled and managed during the full lifecycle”
Name	Aurelius Enterprise
HQ location (city, country)	Amsterdam, the Netherlands
Industries served	Aerospace, automotive, consumer goods, L&T, mining
Company role	IoT provider
Geographical scope	Global
Role of the interviewed profile	Project Manager

General overview

Aurelius Enterprise is a company supporting other business entities in their path towards the digital transformation. With the combination of Artificial Intelligence, Machine Learning and data analytics, they promise to make traditional companies into Industry 4.0 enterprises. Despite not directly dealing with the hardware side of IoT, they are experts in delivering consultancy and hardware solutions for Industrial IoT and digital transformation. Basically, they offer software to make value out of sensors and data, by designing, implementing and monitoring IoT processes. Their market mostly consists in manufacturing companies like Philipps and Mercedes.

Lastly, they have active partnerships with companies like IoT One, but with no commitment to any consortium linked to IoT.

Supply chain characteristics

When asked about the L&T and F&B, Mr. Hiralal cited the lack of supply chain visibility as the biggest problem. This challenge hinders a homogeneous process quality at any stage of the chain and puts actors in front of troubles with the increasing customer service required. Beyond this, a large portion of the organizations working with Internet of Things does not manage to capitalise the investment and to make profit out of it. The reason is linked to the technology complexity and to the usually long distance between the IoT adoption level and the final users. The answer, yet, is to deploy IoT to collect data all over the SC to optimize machines, to support planning and scheduling activities and to become more responsive to demand changes. Lastly, he reported that many companies in these domains experience the digital transformation moving around and want to evolve to new business models.

Relationship with IoT and BT

Despite the link with BT is not there, the company’s confidence with the IoT realm was precious for the interview. When discussing on smart sensors, the interviewee claimed that some problems need to be taken into account: lack of visibility, high maintenance costs, data management and data security. According to him, while the first two can be solved out by simply integrating devices with a common software, the last two are more intrigued. In fact, hardware and software union allows for a transparent identification and traceability of each object, but it still does not cover the issues of data security and management. Together with this, scalability was also cited as a major problem, since it is hard to replicate the good results of a limited IoT-based PoC (Proof of Concept) when the scope is enlarged to bigger realities.

CISCO JASPER

cisco Jasper	"Manage connectivity of all your IoT devices"
Name	Cisco Jasper
HQ location (city, country)	Santa Clara, California, US
Industries served	Agriculture, Healthcare, Retail, T&L, Smart cities
Company role	IoT provider
Geographical scope	Global
Role of the interviewed profile	Sales Leader

General overview

Cisco acquired Jasper in 2016 for $1.4 billion, getting access to its up-and-running customer base and product range in various industries like F&B and industrial sectors. Now it is one of Cisco's branch, where 296 employees work to provide a software platform for those entities offering their own cloud services. The value proposition of Cisco Jasper, which saves up money from investing in own AI systems, is a mix of hardware and software components. The major value, though, is contained in the software platform, through which customers can access expert staff and dedicated infrastructures. The core idea is to create an edge model where data, after being normalized, can be propagated to any other application in need. By working more at the IP level rather than the purely HW one, the value proposition aims to create a common environment for machines, assets and processes.

Lastly, since they lack some confidence with the sensor/hardware side, a lot of partnerships have been kicked off, bringing Cisco Jasper to work with a partner ecosystem approach.

Supply chain characteristics

The experience of Cisco Jasper in both the analysed industries loudly emerged during the interview. In both the domains, but especially in the F&B one, a big challenge is the lack of visibility along the supply chain, impeding involved actors to know what is going on at upper and lower layers. Together with that, they typically do not manage to bring the value out of their business outcomes. Another leading problem, somehow linked to the lack of visibility, is the inadequate performance measurement system, making process efficiency level drop. A further issue contributing to the absent visibility is the disconnection between the infrastructure, application and sensor layers, which hinders data integration at SC level.

Last but not the least, companies often want to be on the edge of innovation either to be the forerunners or to avoid being cannibalized by competitors.

Relationship with IoT and BT

The link with the IoT is intuitive, as Cisco Jasper has a value proposition centred on connectivity. A lot of discussed applications have brought customers to increase profitability, gaining customer loyalty and reducing operational costs. For instance, IoT is deployed in the Cold Chain all the way from factories to stores to proof standards compliance during production and distribution. Real-case applications worked on sets of fixed lines and connected devices for fleet management, asset traceability and conditions monitoring. Here, sensors grasped information concerning temperature, location, humidity and light. Despite of the various successful stories, Mr. Baldwin cannot avoid talking about few IoT limitations. In detail, he identified the protocols diversity as a major obstacle for data normalization. Along the three steps of IoT, connecting, analysing and operating, a key challenge is to make devices communicate with each other and with the platform. Lastly, another hindrance is represented by data security, which is quite problematic in hyper-connected environments like these.

About blockchain, Cisco Jasper's position is neutral due to some concerns. Firstly, it is difficult to monetize BT investments, even considering the efforts of filling knowledge and skill gaps. After that, other fears come from the lack of standards and data security, preventing possible users from trusting the platform.

INSOLAR

INSOLAR	"Enabling companies' transformation by building the best open-source blockchain platform, applications and tools"
Name	Insolar
HQ location (city, country)	Zug, Switzerland
Industries served	L&T, energy and utilities, retail and consumer goods, automotive
Company role	BT provider
Geographical scope	Global
Role of the interviewed profile	Head of innovation

General overview

Insolar is an interesting and active name in the BT domain. It can be defined as a technology company running on global scale. At Insolar, almost 80 employees are committed to the creation of a new innovative permissionless blockchain platform, the Insolar Blockchain Platform. This is a blockchain solution thought for businesses in any type of industry. They promised to deliver an open-source solution capable of overcoming traditional issues of scalability, privacy and interoperability. Their value proposition, fully BT-centred, is set to answer specific customers' needs: working capital (WC) optimization, demand planning improvement and enhanced SC visibility.

Like many other entities in the spheres of transportation, logistics and blockchain, Insolar is part of the BiTA, the organization aimed to drive BT standards and adoption.

Supply chain characteristics

Their advanced knowledge on L&T made the interview quite helpful. Reportedly to what released by the expert Mr. Krillov, this industry is deeply affected by the lack of visibility at systemic level, not only with sub-contractors and expanded over the first tier. This makes the environment dramatically unreliable, frequently weighted by opportunistic behaviours. A further evidence from this discussion was that the supply chain is becoming ever more complex and diversified. This is testified by the analysis on the interactions among companies, which grow in number ad size, as an average company is said to have today twice as partners as before. Moreover, complications with regard to this type of digital business come from the lack of interoperability among corporates' ERP systems, which burdens synergies between firms' operations. Similarly, many companies' existing IT systems are not suitable to BT applications, requiring them to properly adjust.

Sometimes, though, BT and IoT are used simultaneously for track and trace solutions and predictive maintenance. Smart sensors, provided by third parties, are used as oracles to convey data on the BT platform, where location, temperature and humidity information is registered.

Ultimately, some companies within this domain showed a pronounced innovation boost, which might even drive competitors to move accordingly.

Relationship with IoT and BT

Various solutions are put in place through the BT platform: beside track & trace and predictive maintenance, also proactive responses and peer-to-peer marketplaces are valuable alternatives. The integration between IoT and BT is case-dependent: BT is typically addressed for its capability to authenticate data, but data storage can be done on other systems as well. When questioned about the possible problems of BT, the interviewee had quite a lot to say. He named the starting IT configuration of companies as one of the major obstacles to BT diffusion, as changes would be required at both process and IT level. Together with this, also companies' limited flexibility in allocating resources to the IT is problematic. Nevertheless, he stressed that with Ethereum and Hyperledger there are no scalability costs, as the throughput capacity increases with the network size. Lastly, though, he cannot hide his concerns about the enormous energy consumption in terms of both mining computing power and of overall system consumption.

No mention was made on the zero-status issue, but he recognized that their business exclusively consists in ensuring that data entering the platform is authentic.

MODUM

modum	"Delivering trusted insights through our products and services that improve our customers value chain automation"
Name	Modum
HQ location (city, country)	Zurich, Switzerland
Industries served	F&B, cold chain, healthcare
Company role	IoT and BT provider
Geographical scope	Global

Role of the interviewed profile	Product manager

General overview

Modum is young technology start-up, founded in 2016, that offers cutting-edge solutions to digitize supply chains. Its offer, leveraging BT and IoT sensing, is directed towards various industries, including F&B and L&T. Their vision is to achieve reliability, quality, customer success and trusted relationships by making scattered data into inputs for optimization and automation. The 35 employees collaborate to deliver a unique value proposition made of IoT hardware, cloud solutions and blockchain functionalities. One of their main products, besides being a testimony of the business type, is the MODsense, which is the top-of-class system for temperature monitoring. It is designed for large-volume, last-stage shipments, as it unlocks value for various stakeholders involved. After the logger is associated to the shipment at container or product level, temperature data is real-time registered and sent to the logistics team via BLE or NFC. By scanning the shipment ID, it is made secure and data is uploaded to the BT platform, where it can be verified by the permissioned stakeholders. All in all, data authenticity and process automation result as major benefits.

Their most relevant works address last mile logistics parties, big pharmaceutical manufacturers and Swisspost. They have active partnerships with major technology players like SAP and AWS, but no consortia participation.

Supply chain characteristics

Once again, primary considerations were made on the lack of end-to-end visibility within the supply chain. The emerging situation displays actors 100% focused on playing their own role, with no interest or means to integrate data and streamline processes at system level. Additionally, the interview exhibited the way customer demand is changing, rising needs for customised, specialised and more sustainable products. Alongside, F&B industry made register high stakes for improving SC processes to prevent low-quality products or goods not compliant with regulations from being distributed. Similarly, technology is required to help out with counterfeits prevention.

Relationship with IoT and BT

Modum offers extremely advanced and marketable BT-IoT solutions. In the pharma industry, for instance, big companies use Modum's solutions within their shipments to monitor in real-time and with an easily accessible database the product conditions in terms of temperature. This IoT solutions are remotely configurable and work with scans or Bluetooth, so that it is not necessary to plug them out and in other devices to access and download data. Discussing about challenges, the interviewee admitted that a major concern for the IoT is represented by the interoperability of devices, which is put at test by a great heterogeneity of sensors. In fact, when many different technologies are asked to communicate with each other, all the issues of limited standardization pop up.

As for BT, its adoption is aimed at making transactions secure and tamper-proof, but it still stands as a good fit with IOT. Talking about problems, the lack of business cases in the market and the difficulty in monetizing investments were firstly mentioned. Further limitations to BT adoptions were said to be the generally limited knowledge of BT, the industry's stagnancy in terms of innovation and the poor know-how and expertise all over the companies.

OMNI-ID

Omni-ID	"Experienced. Effective. Trusted."
Name	Omni-ID
HQ location (city, country)	New York, US
Industries served	L&T, Retail, Oil & Gas, Returnable Transport Items

Company role	IoT provider
Geographical scope	Global
Role of the interviewed profile	Key Account Manager

General overview

Started as an R&D team in the 1990s, Omni-ID is now a stand-alone leader company in the auto-identification industry. Nowadays, Omni-ID is the number 1 manufacturer and supplier of industrial RFIDs globally. After many years of studies on the promising technology of RFids, consistent improvements led to cross-sector applications and a new perception of the tags. Company's value proposition is made of both hardware and software, with a major presence of the former. By working for various companies all over the industries, Omni-ID, which now counts 75 employees, is taking RFids usage to new standards. Deepening the technology's functionalities, the organization developed various solutions, especially for asset tracking, smart containers, material flow management and replenishment. These are delivered to a heterogeneous set of customers, from governmental institutions to mining facilities. All in all, main objectives are in-process visibility and real-time control.

Their value proposition is principally made of hardware, in particular RFid tags, with no SH nor readers. Being at the very upstream edge of the SC, they traditionally have a collaborative approach with the whole SC, but they don't adhere to any consortium.

Supply chain characteristics

Leveraging on its expertise in logistics, Omni-ID reported that the only question worrying the players in this sector is "Where are the products?". Asset tracking is a crucial need they have since a lot of money and value fades away due to container or product losses. In addition, they recognized that SC is moving towards an accentuated complexity and a broad heterogeneity. SC tiers are enlarging and increasing in number, reason why technology innovation needs to keep up with it.

Relationship with IoT and BT

A lot of IoT can be found in Omni-ID's solutions, as RFids represent one of the first components to be ever associated to the Internet of Things. The company offers both active and passive tags, besides ProVIEW, which is an innovative Material Flow Management solution providing tracking, visual instructions and dynamic control for complex manufacturing. One application example is the deployment of a seal on the back of containers for improving asset tracking. When the window is opened, the seal changes a flag in the associated RFid, keeping a proof that the container was opened, and possibly tampered with. Overall, asset tracking and inventory management are the key purposes of their solutions.

Despite their familiarity with IoT, the stated that pursuing data security is not their purview. On the other turn, the reasons why BT has not entered yet their value proposition are mainly linked to the market features. In fact, they claimed that most of their customer companies are monolithic, eager to only track internal data with no need to certify it. Although not used yet, the company believes in a future where IoT and BT will be jointly adopted as IoT will become the underlying tool, not the technology itself.

QUADMINDS

	"IoT innovation that allows us to understand market needs, translate them into real quality solutions, generating smarter companies and cities"
Name	QuadMinds
HQ location (city, country)	Buenos Aires, Argentina
Industries served	L&T, Aeronautics, Oil & Gas, Waste Management
Company role	IoT provider

Geographical scope	Global
Role of the interviewed profile	Product Manager

General overview

Quadminds is a technology company offering IoT-centred solutions all over the world. They operate for various industries: besides logistics and F&B, also the oil and gas sector, aeronautics and waste management. To these domains they offer a set of sensors to be used for greater a greater operational control and to be integrated with an online platform. Here data coming from the real world is combined to let the user cross checking various business performances. Furthermore, should a company already have its own hardware part, Quadminds can also provide the single online platform to integrate with the existing hardware through APIs.

Their offer is generally required by distributors in the F&B domain, line InBev, oil and gas companies and others interested in their logistics solutions. Besides that, as mentioned, they recently stepped into the market of waste management after integrating vertically.

They are not part of consortia.

Supply chain characteristics

Great hints could be grasped by the interview with Mr. Alejandro Rapoport. The engagement of Omni-ID with both the examined industries made the meeting extremely useful. About the Logistics and Transportation domain, he denounced a deep lack of visibility, both along the supplier-manufacturer-distributor chain but also between final customers and the rest of the chain. In particular, the latter cannot say what time goods will be delivered, as a consequence of the ineffective traceability and delivery planning systems. Furthermore, he put the stress on the increasing SC complexity, meant as a multi-dimensional problem. First of all, companies start requiring new services, like reverse logistics for empty cranes in the

F&B industry. Additionally, actors become more diverse and inter-company communication is scarce.

The F&B domain, besides exhibiting visibility troubles as well, is weighted by what was called as innovation stagnancy. Players in this sector don't want to risk innovating with n warranties of clear return.

In both the cases, firms showcase an increased interest for track and trace solutions for improving customer services and decreasing logistics costs through performance monitoring.

Relationship with IoT and BT

Data validation and security were appointed as key challenges for the IoT world, since no process is put in place to proof data validity in their applications. At the same time, data hacking is frequently not considered as a problem in the logistics domain, despite they are aware hack attacks are very possible. Nevertheless, they believe IoT will take the lead over the next years due to the application diffusion and the decreasing price.

About blockchain, there has not been yet the intention to invest in BT potential. Reasons are that no additional value is perceived neither from customers nor at the company level. They think BT is a real buzzword, since there are no proves in the market that it brings enough benefits to justify the investment. Alongside with that, overall SC engagement in BT is very limited, making PoC hard to perform and driving required capital high.

SIGFOX

	"Building a deep communication service for the earth. A safety net for all"
Name	Sigfox
HQ location (city, country)	Labége, France
Industries served	L&T, Manufacturing, Smart Cities, Agriculture, Smart Buildings, Retail, Insurance
Company role	IoT provider
Geographical scope	Global
Role of the interviewed profile	Technical Director

General overview

SigFox is a huge reality in the IoT domain, with 442 employees and a coverage of 65 countries all over the globe. Framed in the digitization process, their solutions are set to enable a smart, simple, low-cost and low-power connectivity. Their multi-oriented value proposition is embraced by several industries, from L&T to Retail and from smart building to agriculture. They deliver both HW and SW infrastructure to let customers develop their own applications. One of the major benefits of their solutions is the low power consumption required by device-to-cloud connections. Their top-of-class product is the SigFox Bubble, a low-power beaconing proximity detector.

Working in a cross-sectoral environment, they often deal with large distributors, partnering with multiple entities.

Supply chain characteristics

Talking about L&T and F&B industries, the interviewee described SC complexity and increasing diversity as major pain points, together with the remarkable maintenance cost. In fact, sustaining an ever-connected Internet-spread environment where devices are continuously working next to software infrastructure is very expensive in terms of maintenance. SigFox, therefore, is putting efforts in taking these costs down by creating a connection which is very limited in power consumption, extending batteries lifecycles.

Relationship with IoT and BT

Despite the extremely advanced solutions running on IoT, the interview highlighted some concerns coming from SigFox. Mr. Fourtet warned that the deployment of Internet of Things must be evaluated considering the trade-off between energy consumption and performance level, denouncing that sometimes the game does not worth the candle. Simultaneously, the maintenance costs cannot be neglected as they are actually high. Eventually, a great threat of moving to the IoT is given by the changes required at the business model level.

In relation to blockchain, a technology SigFox has not considered yet, the interviewee affirmed that two key problems exist. The first is the overall hype phenomenon that has been creating too much noise and very high expectation on BT. The second is then represented by the inability of PoCs to mirror the actual financial long-term implications of such technology.

SIGNALZ

	“SignalZ. The IoT analytics platform”
Name	SignalZ
HQ location (city, country)	Veenendaal, the Netherlands
Industries served	Smart Shipping, Smart Industry
Company role	IoT provider
Geographical scope	Global
Role of the interviewed profile	CEO

General overview

SignalZ is quite an emerging start-up in the field of IoT. In its dawning, what this company offers to the market is an IoT platform capable of transforming sensor data into crucial inputs for process optimization and preventive actions. The main characteristics of this platform are the automatic detection of data from the field and its openness, making it easy to exchange data with other data handling programs (Excel and Power BI) and to add smart algorithms via R or Python. Beyond this, the platform is entirely cloud-based, running on any digital user-interface. The concept of SignalZ is to exploit AI, Business Intelligence, Digital Twin and the IoT to enable data monitoring and ad-hoc data management systems.

Their value proposition, centred on the software platform, has been so far addressed by agricultural and industrial companies. Ultimately, also public administration results as one of their customers.

Owing to their young stage, SignalZ is constantly looking for strategic partnerships, since like many other early-stage IoT companies they need to complete their offer with the HW part, currently missing.

Supply chain characteristics

Unfortunately, the respondent was not knowledgeable on the properties of the served SCs. The point he raised about it was a constantly increasing demand for customised products and services. Together with this, he claimed that the overall customer service required is rising as well.

Relationship with IoT and BT

The strong connection with the IoT is embodied by the leading example. One application of SignalZ platform regarded a food producer consuming a lot of water during the production process. Problems in this case arose from the regulation on levels of pollution of these water wastes. The contribution of this start-up was crucial for the provision of a monitoring system capable of improving the decision-making process on waste optimization.

The main reason to appreciate the platform is the fact of overcoming the problem of sensors interoperability. As mentioned, sensors heterogeneity hinders IoT adoption due to the diversity in communication and connectivity protocols. SignalZ platform eliminates this limitation by making devices and platform speak the same language. Nevertheless, Mr. Van Oost admitted that data security and maintenance costs are the most worrying factors to be tackled.

About BT, they do not plan to implement it yet. His position on the topic of IoT-BT integration was quite firm, as he believes no further value could be created. Although, the interviewee's knowledge of BT was quite limited according to what he himself confessed. His opinion was that the future of IoT is more likely in conjunction with machine learning and 5G.

THE IOT COMPANY

	“Connecting everything everywhere”
Name	The IoT Company
HQ location (city, country)	Rotterdam, the Netherlands
Industries served	Agriculture, Environment, Healthcare, Infrastructure, T&L, Energy, Industry, Smart Cities
Company role	IoT provider
Geographical scope	Europe
Role of the interviewed profile	CEO

General overview

The IoT company is quite a fresh reality (born in 2017) having IoT projects as main dish on their menu. With a turnover of 700.000 € in 2018, they are committed to various industries, ranging from logistics to agriculture and energy. What they basically do is to own and manage projects having the Internet of Things at the core. In the industries of interest, they are active only on the logistics side, where many on-going projects see big trailer companies and truck owners as customers (no names were disclosed due to data confidentiality).

Their value proposition is based on an intense collaboration with partners providing HW and SH, filling it up with experienced know-how in the project evolution.

Supply chain characteristics

The company’s CEO reported the lack of end-to-end traceability as the major obstacle for the examined SCs. He deepened the topic by adding that the involved actors are typically unable to get, use and elaborate data properly, making it meaningful in a cheap way. And that's where The IoT company steps in.

According to Mr. Kooyman, then, the main reasons pushing companies to address his services are process optimization and traceability. His customers want to save money by getting the tools to analyse their processes, improving them afterwards.

Lastly, he claimed that some big players in logistics might even have ambitious long-term goals for which IoT can be a powerful enabler. One of this, for instance, can be the development of a Uber-like system for the container market, enabling various interested stakeholders to check out containers' location and availability. Once again, then, it is a matter of innovation propensity.

Relationship with IoT and BT

Once again, maintenance cost was named as the biggest challenge concerning IoT. Nevertheless, he is convinced that since the adoption of smart sensors is skyrocketing, costs will drop down. He proved a strong confidence in IoT as he stressed that smart sensors are not a buzzword anymore, as it was few years ago, but they are becoming a standard for various industries.

Instead, unfortunately he was not familiar enough with BT to critically comment it.

VANTIQ

VANTIQ	"Accelerating enterprise Digital Transformation with innovative technologies to digitize while maximizing the effectiveness of humans"
Name	VANTIQ
HQ location (city, country)	Walnut Creek, California (US)
Industries served	L&T, Smart Manufacturing and Smart cities
Company role	IoT provider

Geographical scope	Global
Role of the interviewed profile	Director International Pre-Sales

General overview

Active in the domain of Digital Transformation, VANTIQ is a technology company aimed at driving changes in this information-driven world. With a vast range of customers, the company is globally spread, running across industries from Oil and Gas to Retail. A special focus is kept for the domain of L&T, where the application of VANTIQ's platform is particularly powerful. Speaking of which, the software platform is all readers need to know about the value proposition. Starting from the idea that database-centric applications are now replaced by event-driven systems, VANTIQ's platform is meant to manage these events. By sensing, analysing events and acting accordingly, this solution supports the creation of event-driven applications in a way that is rapid to develop, suiting the transactional nature of events. Additionally, the integration with other technologies such as AI, BT and IoT can easily occur.

The interviewee reported not to be involved in consortia, but to be extremely interested in taking part to a potential Living Lab.

Supply chain characteristics

The interviewer took advantage from the company's expertise in various industries, grasping insights and getting confirmations for the framework. First of all, VANTIQ recognized how complex and diversified the L&T world is, making it hard for blockchain to install. Various actors from various SC tiers might have quite different goals and investment capability. Besides that, assets traceability is a tedious work which is getting major interest to increase customer service.

Lastly, the real plague of most of the industries is, as repeated many times, the lack of visibility. This has important backflashes as it prevents companies to properly serve customers, in terms of deliveries and products' requirements. Alongside with that, the inability to observe other tiers' operations and statistics (like production and demand) impedes an accurate demand forecast at any level.

In consideration of such challenges, practitioners look at VANTIQ's value proposition in search for manageable and flexible solutions which can be easily scaled up.

Relationship with IoT and BT

The adoption of IoT sensors, despite not directly managed by VANTIQ, adds a lot of values to the company's software platform. In L&T, they adopt smart sensors, GPS positioning and more to notify the events to the platform and unlock several possibilities. For example, it enables the integration among systems, documents and people. Furthermore, events analysis serves to identify SC threats and bottlenecks, observing upstream production's impact of downstream delivery performance. Not much was discussed about the sensors' technicalities though, since they primarily deal with the platform. For instance, it emerged that Sigfox sensors are used (for their feature of data frequency) at pallet or container level, to analyse location, temperature and shocks.

About BT, the company is not there yet despite they received some proposals. The reason is that they believe a lot of challenges need firstly to be solved. First of all, they do not really see an added value with reference to customers' needs, whose concurrent cause is that BT is a black box, showing no evident quantitative proof of its convenience. Plus, it is a very fragmented technology, with multiple applications for various sectors, which brings to a very low understanding of its benefits. The interviewee talked about the "chicken and egg problem", since SC actors wonder what should come first, whether the investment on BT or the proof that is works. At the same time, SC fragmentation prevents small players to see enough benefits in BT to get onboard.

VINTURAS

VINTURAS sharing progress	"A standardised data-set creates opportunities to steer the supply chain, use AI and develop new business models"
Name	Vinturas
HQ location (city, country)	Leek, the Netherlands
Industries served	Logistics, Finished Vehicles Logistics
Company role	BT consortium
Geographical scope	Europe
Role of the interviewed profile	Lead Blockchain Architect

General overview

Vinturas is a blockchain consortium, a legal entity created by a number of Logistic Service Providers (LSPs) in the Finished Vehicles Logistics (FVL). The goal is to gather together different interested stakeholders of a complex industry on the same BT platform. Dealers, OEMs, National Sales Organizations, fleet owners, consumers, authorities, EU and national governments are all involved. Ideally, thee parties would be all registered on the same platform where data can be shared in a safe and immutable way. Data from trucks and facilities are uploaded to the platform to provide full visibility, proving the key role of BT in facilitating collaboration. The idea of creating a consortium, initially proposed by AutoLink (Baltics), Axess Logistics (Nordics), Groupe CAT (France), Koopman Logistics Group (Netherlands) and NVD (Ireland), has also the long-term goal to promote new business models.

12 million vehicles are expected to be connected to the platform, with a full-scale operational visibility in the European Market, from Scandinavia to Spain. A key partner of such group is IBM.

Supply chain characteristics

As it may seem logic, Vinturas was mainly created to address the serious pain point of visibility lack in the FVL industry. The diverse parties taking part to the SC are ”operationally blind”, meaning that they have limited clue on assets’ location and flow in a certain moment, bound to lag behind a 1.5 day time delay. Besides that, the rise of multi-brand dealer groups put them in front of the necessity to interact with different IT systems of different suppliers, making it difficult, time-consuming and costly. Heterogeneity of IT systems was appointed as a major obstacle for SC visibility, as many actors still communicate via EDI, which is unsustainable in a multi-party complex system like this. All in all, the participant members are said to benefit from a 17% reduction in damaging and claims handling costs, as a consequence of optimized processes.

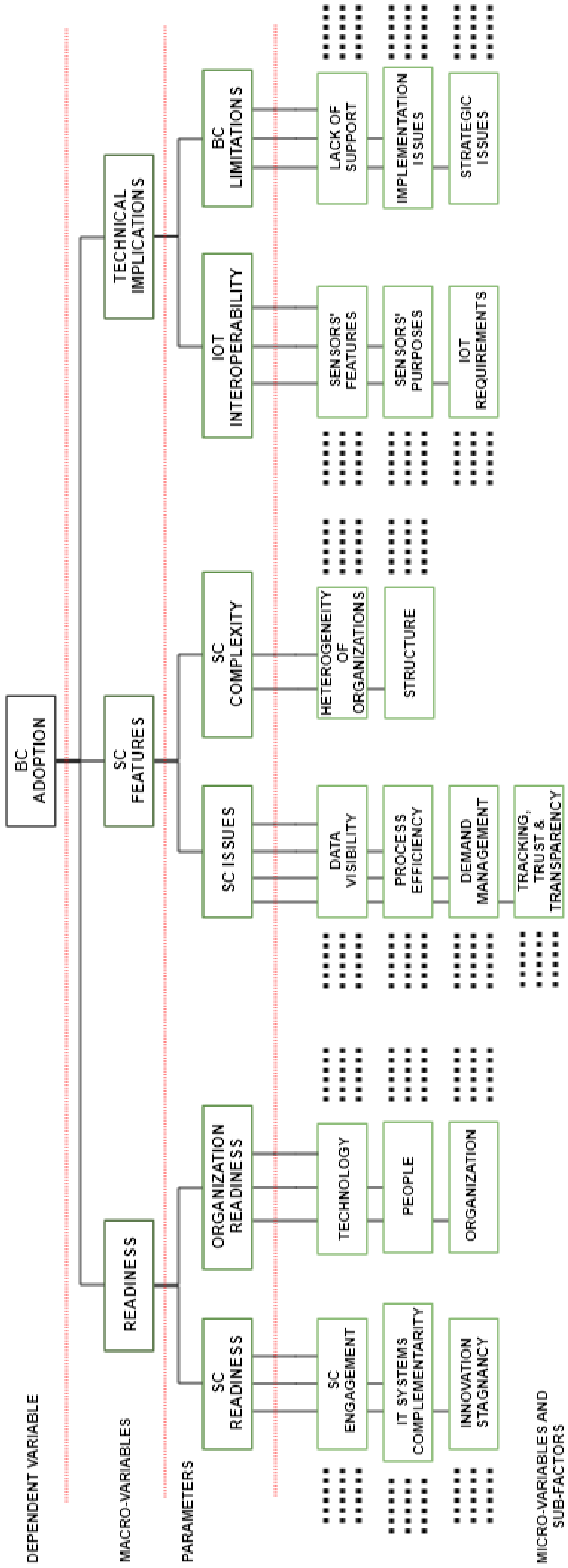
Moreover, the FVL domain showcases two emerging trends. The first is the tendency of consolidating multi-brand dealers with mid-size companies to create a virtual network of delivery and diversify services. The second is a trend of uberization: if LSPs will not be able to match high customer expectations in terms of delivery time, other players from other markets (ex. Uber) might step in to try replacing them.

Relationship with IoT and BT

Extremely relevant were the insights collected by the interviewee, who, despite being the lead BT architect of one of the biggest BT consortia in the world, recognized that there are some “technical nuts to crack”. First of all, he talked about the system latency, as the BT system requires 1.5 seconds to get the truth in and out of the nodes. Simultaneously, IT systems heterogeneity, due to the absence of well-defined standards, is another hinder to BT introduction as it requires companies to face additional investments. Less technical but still problematic is the difficulty in bringing partners onboard, which is a platform problem. The latter is linked to the multi-oriented mindsets of companies, which are not aligned towards customers, as it emerges from the poor collaboration along the supply chain. Overall, then, a very limited trust in BT is evident, especially in this specific conservative market where firms compete on low margins.

Lastly, again, the "chicken and egg" issue was named, meaning that companies still struggle to understand whether to take the risk or to adopt a "wait and see" strategy.

Appendix 6 – Variables tree


DEPENDENT VARIABLE
BC ADOPTION
MACRO-VARIABLES
READINESS
SC FEATURES
TECHNICAL IMPLICATIONS
PARAMETERS
SC READINESS
ORGANIZATION READINESS
SC ISSUES
SC COMPLEXITY
IOT INTEROPERABILITY
BC LIMITATIONS
MICRO-VARIABLES AND SUB-FACTORS
SC ENGAGEMENT
IT SYSTEMS COMPLEMENTARITY
INNOVATION STAGNANCY
TECHNOLOGY
PEOPLE
ORGANIZATION
DATA VISIBILITY
PROCESS EFFICIENCY
DEMAND MANAGEMENT
TRACKING, TRUST & TRANSPARENCY
HETEROGENEITY OF ORGANIZATIONS
STRUCTURE
SENSORS' FEATURES
SENSORS' PURPOSES
IOT REQUIREMENTS
LACK OF SUPPORT
IMPLEMENTATION ISSUES
STRATEGIC ISSUES

Bibliography

Abeyratne, S., & Monfared, R. (2016). *Blockchain ready manufacturing supply chain using distributed ledger*. (October).

Acar, Y., & Atadeniz, S. N. (2015). Comparison of integrated and local planning approaches for the supply network of a globally-dispersed enterprise. *International Journal of Production Economics*. https://doi.org/10.1016/j.ijpe.2015.05.028

Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications. *IEEE Communications Surveys and Tutorials*. https://doi.org/10.1109/COMST.2015.2444095

Alicke, K., Rachor, J., & Seyfert, A. (2016). Supply Chain 4.0 – the next-generation digital supply chain. *McKinsey & Company Supply Chain Management*, (June), 1–16.

Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of Things : A survey. *Computer Networks*, *54*(15), 2787–2805. https://doi.org/10.1016/j.comnet.2010.05.010

Auramo, J., Kauremaa, J., & Tanskanen, K. (2006). *Benefits of IT in supply chain management: an explorative study of progressive companies*.

Babich, V., & Hilary, G. (2018). What Operations Management Researchers Should Know About Blockchain Technology. In *SSRN*. https://doi.org/10.2139/ssrn.3131250

Banerjee, A. (2018). Blockchain Technology: Supply Chain Insights from ERP. In *Advances in Computers* (Vol. 111, pp. 69–98). https://doi.org/10.1016/bs.adcom.2018.03.007

Barlow, D. H., Blanchard, E. B., Hayes, S. C., & Epstein, L. H. (1977). Single-case designs and clinical biofeedback experimentation. *Biofeedback and Self-Regulation*. https://doi.org/10.1007/BF00998648

Barratt, M., Choi, T. Y., & Li, M. (2011). Qualitative case studies in operations management: Trends, research outcomes, and future research implications. *Journal of Operations Management*. https://doi.org/10.1016/j.jom.2010.06.002

Bitfuri. (2016). *Digital Assets on Public Blockchains*. *2016*, 1–37.

Botta, A., De Donato, W., Persico, V., & Pescapé, A. (2016). Integration of Cloud computing and Internet of Things: A survey. *Future Generation Computer Systems*. https://doi.org/10.1016/j.future.2015.09.021

Boucher, P., Nascimento, S., & Kritikos, M. (2017). How Blockchain Technology Could Change Our Lives. *European Parliament*.

Bowersox, D. J., Closs, D. J., & Stank, T. P. (2000). Ten mega-trends that will revolutionize supply chain logistics. *Journal of Business Logistics*.

Brink, T., Philipp Sprenger, D.-I., Schulte Fraunhofer IML, A. T., Tanja Brink, B., & Schulte, A. T. (2018). *Blockchain-enabled Supply Chain Finance solutions for Logistics Service Providers The Supply Chain Finance Essential Knowledge Series Blockchain-enabled Supply Chain Finance solutions for Logistics Service Providers Blockchain-enabled Supply Chain Finance*. Retrieved from www.scfcommunity.org

Buterin, V. (2014). A next-generation smart contract and decentralized application platform. *Etherum*, (January), 1–36. Retrieved from http://buyxpr.com/build/pdfs/EthereumWhitePaper.pdf

Büyüközkan, G., & Göçer, F. (2018). Digital Supply Chain: Literature review and a proposed framework for future research. *Computers in Industry*, *97*, 157–177. https://doi.org/10.1016/j.compind.2018.02.010

Caceres, R., & Friday, A. (2012). Ubicomp systems at 20: Progress, opportunities, and challenges. *IEEE Pervasive Computing*. https://doi.org/10.1109/MPRV.2011.85

Cao, M., & Zhang, Q. (2011). Supply chain collaboration: Impact on collaborative advantage and firm performance. *Journal of Operations Management*, *29*(3), 163–180. https://doi.org/10.1016/j.jom.2010.12.008

Casino, F., Dasaklis, T. K., & Patsakis, C. (2019). A systematic literature review of blockchain-based applications: Current status, classification and open issues. *Telematics and Informatics*, *36*(November 2018), 55–81. https://doi.org/10.1016/j.tele.2018.11.006

Chen, S., Xu, H., Liu, D., Hu, B., & Wang, H. (2014). A vision of IoT: Applications, challenges, and opportunities with China Perspective. *IEEE Internet of Things Journal*. https://doi.org/10.1109/JIOT.2014.2337336

Christidis, K., & Devetsikiotis, M. (2016). Blockchains and Smart Contracts for the Internet of Things. *IEEE Access*. https://doi.org/10.1109/ACCESS.2016.2566339

Christopher, M. (1992). *Logistics and supply chain management: creating value-adding networks*.

Christopher, Martin, & Peck, H. (2004). Building the Resilient Supply Chain. *The International Journal of Logistics Management*. https://doi.org/10.1108/09574090410700275

Cooper, M. C., Lambert, D. M., & Pagh, J. D. (1997). Supply Chain Management: More Than a New Name for Logistics. *The International Journal of Logistics Management*, *8*(1), 1–14. https://doi.org/10.1108/09574099710805556

Coyle, J. J., Langley, C. J. J., Novack, R. A., & Gibson, B. J. (2013). Managing Supply Chains: A Logistics Approach. In *South-Western, Cengage Learning*.

Dos Santos, A. P., & Chaczko, Z. (2019). Blockchain: Status-quo, enablers and inhibitors. *26th International Conference on Systems Engineering, ICSEng 2018 - Proceedings*. https://doi.org/10.1109/ICSENG.2018.8638187

Drucker, P. F. (2018). Management's New Paradigms. In *The Essential Drucker*. https://doi.org/10.4324/9780080939322-6

Ebers, M. (2017). Organisationsmodelle für Innovation. *Schmalenbachs Zeitschrift Für Betriebswirtschaftliche Forschung*. https://doi.org/10.1007/s41471-016-0021-x

Eisenhardt, K. M. (1989). Building Theories from Case Study Research. *Academy of Management Review*. https://doi.org/10.5465/amr.1989.4308385

Eljazzar, M. M., Amr, M. A., Kassem, S. S., & Ezzat, M. (2018). *MERGING SUPPLY CHAIN AND BLOCKCHAIN TECHNOLOGIES*. 1–6.

Eschenauer, L., & Gligor, V. D. (2002). A key-management scheme for distributed sensor networks. *Proceedings of the ACM Conference on Computer and Communications Security*. https://doi.org/10.1145/586115.586117

Evans, D. (2011). *The Internet of Things How the Next Evolution of the Internet The Internet of Things How the Next Evolution of the Internet Is Changing Everything*. (April).

Ganesan, S. (1994). Determinants of Long-Term Orientation in Buyer-Seller Relationships. *Journal of Marketing*. https://doi.org/10.2307/1252265

Gatteschi, V., Lamberti, F., Demartini, C., Pranteda, C., & Santamaria, V. (2018). To Blockchain or Not to Blockchain: That Is the Question. *IT Professional*. https://doi.org/10.1109/MITP.2018.021921652

Gatteschi, V., Lamberti, F., Demartini, C., Pranteda, C., & Santamaría, V. (2018). Blockchain and smart contracts for insurance: Is the technology mature enough? *Future Internet*, *10*(2), 8–13. https://doi.org/10.3390/fi10020020

Golosova, J., & Romanovs, A. (2018). The advantages and disadvantages of the blockchain technology. *2018 IEEE 6th Workshop on Advances in Information, Electronic and Electrical Engineering, AIEEE 2018 - Proceedings*. https://doi.org/10.1109/AIEEE.2018.8592253

GSM Association. (2019). *The Mobile Economy 2019*. 56. Retrieved from www.gsmaintelligence.com

Gubbi, J., Buyya, R., & Marusic, S. (2013). *Internet of Things (IoT): A Vision , Architectural Elements , and Future Directions*. (1), 1–19.

Hackius, N., & Petersen, M. (2017). Blockchain in Logistics and Supply Chain: Trick or Treat? *Proceedings of the Hamburg International Conference of Logistics (HICL), 9783745043*, 23. Retrieved from https://tore.tuhh.de/bitstream/11420/1447/1/petersen_hackius_blockchain_in_scm_and_logistics_hicl_2017.pdf

Handfield, R. B., & Bechtel, C. (2002). The role of trust and relationship structure in improving supply chain responsiveness. *Industrial Marketing Management*. https://doi.org/10.1016/S0019-8501(01)00169-9

Holotiuk, F., & Moormann, J. (2018). Organizational adoption of digital innovation: The case of blockchain technology. *26th European Conference on Information Systems: Beyond Digitization - Facets of Socio-Technical Change, ECIS 2018*.

Huang, G. Q., Lau, J. S. K., & Mak, K. L. (2003). The impacts of sharing production information on supply chain dynamics: A review of the literature. *International Journal of Production Research*. https://doi.org/10.1080/0020754031000069625

Iansiti, M., & Lakhani, K. R. (2017). The truth about blockchain. *Harvard Business Review*.

Insolar. (2019). *Blockchain inspired distributed business networks*.

Johnson, J. L., & Sohi, R. S. (2003). The development of interfirm partnering competence: Platforms for learning, learning activities, and consequences of learning. *Journal of Business Research*. https://doi.org/10.1016/S0148-2963(01)00260-0

Khan, R., Khan, S. U., Zaheer, R., & Khan, S. (2012). Future internet: The internet of things architecture, possible applications and key challenges. *Proceedings - 10th International Conference on Frontiers of Information Technology, FIT 2012*. https://doi.org/10.1109/FIT.2012.53

Koçoğlu, I., Imamoğlu, S. Z., Ince, H., & Keskin, H. (2011). The effect of supply chain integration on information sharing: Enhancing the supply chain performance. *Procedia - Social and Behavioral Sciences*. https://doi.org/10.1016/j.sbspro.2011.09.016

Korpela, K., Hallikas, J., & Dahlberg, T. (2017). Digital Supply Chain Transformation toward Blockchain Integration. *Proceedings of the 50th Hawaii International Conference on System Sciences (2017)*. https://doi.org/10.24251/hicss.2017.506

Kshetri, N. (2018). 1 Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management*. https://doi.org/10.1016/j.ijinfomgt.2017.12.005

Kuntze, C., Martin, A., Regnier, C., & Silva, I. (2018). Deliver on time or pay the fine : Speed and precision as the new. *McKinsey & Company*, (September).

Kwon, I. W. G., & Suh, T. (2005). Trust, commitment and relationships in supply chain management: A path analysis. *Supply Chain Management*. https://doi.org/10.1108/13598540510578351

La Londe, B. J., & Masters, J. M. (1994). *EMERGING LOGISTICS STRATEGIES: BLUEPRINTS FOR THE NEXT CENTURY*.

Lambert, D M, Stock, J. R., & Ellram, L. M. (1998). Fundamentals of Logistics Management. *New York Irwin*.

Lambert, Douglas M., & Cooper, M. C. (2000). Issues in supply chain management. *Industrial Marketing Management*. https://doi.org/10.1016/S0019-8501(99)00113-3

Lee, S. Do, Shin, M. K., & Kim, H. J. (2007). EPC vs. IPv6 mapping mechanism. *International Conference on Advanced Communication Technology, ICACT*. https://doi.org/10.1109/ICACT.2007.358583

Lee, I., & Lee, K. (2015). The Internet of Things (IoT): Applications, investments, and challenges for enterprises. *Business Horizons*. https://doi.org/10.1016/j.bushor.2015.03.008

Lele, A. (2019). Blockchain. In *Smart Innovation, Systems and Technologies*. https://doi.org/10.1007/978-981-13-3384-2_12

Li, F., Hou, J. Q., & Xu, D. M. (2010). Managing disruption risks in supply chain. *Proceedings - 2010 IEEE International Conference on Emergency Management and Management Sciences, ICEMMS 2010*, 434–438. https://doi.org/10.1109/ICEMMS.2010.5563408

Lo, S. K., Xu, X., Chiam, Y. K., & Lu, Q. (2018). Evaluating Suitability of Applying Blockchain. *Proceedings of the IEEE International Conference on Engineering of Complex Computer Systems, ICECCS*, *2017-Novem*(November), 158–161. https://doi.org/10.1109/ICECCS.2017.26

Madakam, S., Ramaswamy, R., & Tripathi, S. (2015). Internet of Things (IoT): A

Literature Review. *Journal of Computer and Communications*, *03*(05), 164–173. https://doi.org/10.4236/jcc.2015.35021

McKinsey & Company. (2017). Blockchain Technology in the Insurance Sector. *Quarterly Meeting of the Federal Advisory Committee on Insurance (FACI)*, 1–16. Retrieved from https://www.treasury.gov/initiatives/fio/Documents/McKinsey_FACI_Blockchain_in_Insurance.pdf

Mentzer, J. T., DeWitt, W., Keebler, J. S., Min, S., Nix, N. W., Smith, C. D., & Zacharia, Z. G. (2001). DEFINING SUPPLY CHAIN MANAGEMENT. *Journal of Business Logistics*. https://doi.org/10.1002/j.2158-1592.2001.tb00001.x

Mentzer, J. T., Keebler, J. S., Nix, N. W., Smith, C. D., & Zacharia, Z. G. (2001). JOURNAL OF BUSINESS LOGISTICS, Vol.22, No. 2, 2001 1. *Journal of Business*, *22*(2), 1–25. Retrieved from http://www.nihul.biu.ac.il/_Uploads/dbsAttachedFiles/Image20100516092131-m1.pdf

Meredith, J. (1998). Building operations management theory through case and field research. *Journal of Operations Management*. https://doi.org/10.1016/s0272-6963(98)00023-0

Mettler, M. (2016). Blockchain technology in healthcare: The revolution starts here. *2016 IEEE 18th International Conference on E-Health Networking, Applications and Services, Healthcom 2016*. https://doi.org/10.1109/HealthCom.2016.7749510

Min, H. (2019). Blockchain technology for enhancing supply chain resilience. *Business Horizons*, *62*(1), 35–45. https://doi.org/10.1016/j.bushor.2018.08.012

Morgan, R. M., & Hunt, S. D. (1994). The Commitment-Trust Theory of Relationship Marketing. *Journal of Marketing*. https://doi.org/10.2307/1252308

Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash SyNakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. Consulted, 1–9. doi:10.1007/s10838-008-9062-0stem. *Consulted*. https://doi.org/10.1007/s10838-008-9062-0

Nakasumi, M. (2017). Information sharing for supply chain management based on block chain technology. *Proceedings - 2017 IEEE 19th Conference on Business Informatics, CBI 2017*. https://doi.org/10.1109/CBI.2017.56

Pagell, M. (2004). Understanding the factors that enable and inhibit the integration of operations, purchasing and logistics. *Journal of Operations Management*. https://doi.org/10.1016/j.jom.2004.05.008

Pai, S., Buvat, J., Lise, O., Karanam, T., Sevilla, M., Schneider-Maul, R., … Puttur, R. (2018). *Does blockchain hold the key to a new age of supply chain transparency and trust?*

Panayides, P. M., & Venus Lun, Y. H. (2009). The impact of trust on innovativeness and supply chain performance. *International Journal of Production Economics*. https://doi.org/10.1016/j.ijpe.2008.12.025

Pfeffer, Jeffrey and Salancik, Gerald, R. (1978). Chapter 1- An external perspective on organizations. *The External Control of Organizations a Resource Dependence Perspective*.

Raza, S., Shafagh, H., Hewage, K., Hummen, R., & Voigt, T. (2013). Lithe: Lightweight secure CoAP for the internet of things. *IEEE Sensors Journal*. https://doi.org/10.1109/JSEN.2013.2277656

Reyna, A., Martín, C., Chen, J., Soler, E., & Díaz, M. (2018). On blockchain and its integration with IoT. Challenges and opportunities. *Future Generation Computer Systems*. https://doi.org/10.1016/j.future.2018.05.046

Risius, M., & Spohrer, K. (2017). A Blockchain Research Framework: What We (don't) Know, Where We Go from Here, and How We Will Get There. *Business and Information Systems Engineering*, *59*(6). https://doi.org/10.1007/s12599-017-0506-0

Sadhya, V., & Sadhya, H. (2018). Barriers to Adoption of Blockchain Technology. *Proceedings of the 24th Americas Conference on Information Systems*, 1–10.

Samaniego, M., & Deters, R. (2017). Blockchain as a Service for IoT. *Proceedings - 2016 IEEE International Conference on Internet of Things; IEEE Green Computing and Communications; IEEE Cyber, Physical, and Social Computing; IEEE Smart Data, IThings-GreenCom-CPSCom-Smart Data 2016*. https://doi.org/10.1109/iThings-GreenCom-CPSCom-SmartData.2016.102

Schrauf, S., & Berttram, P. (2016). Industry 4.0: How digitization makes the supply chain more efficient, agile, and customer-focused. *Strategy &Technology*, pg. 1-32. Retrieved from https://www.strategyand.pwc.com/media/file/Industry4.0.pdf%0Ahttp://www.strategyand.pwc.com/reports/industry4.0

Sheu, C., Yen, H. J. R., & Chae, B. (2006). Determinants of supplier-retailer collaboration: Evidence from an international study. *International Journal of Operations and Production Management*. https://doi.org/10.1108/01443570610637003

Simatupang, T. M., & Sridharan, R. (2002). The Collaborative Supply Chain. *The*

International Journal of Logistics Management, *13*(1), 15–30. https://doi.org/10.1108/09574090210806333

Siyal, A. A., Junejo, A. Z., Zawish, M., Ahmed, K., Khalil, A., & Soursou, G. (2019). Applications of Blockchain Technology in Medicine and Healthcare: Challenges and Future Perspectives. *Cryptography*, *3*(1), 3. https://doi.org/10.3390/cryptography3010003

Suresh, P., Daniel, J. V., & Aswathy, R. H. (2014). *A state of the art review on the Internet of Things (IoT) History , Technology and fields of deployment*.

Svahn, F., Mathiassen, L., & Lindgren, R. (2017). Embracing digital innovation in incumbent firms: How Volvo Cars managed competing concerns. *MIS Quarterly: Management Information Systems*. https://doi.org/10.25300/MISQ/2017/41.1.12

Swan, M. (2015). *Melanie Swan*.

Szabo, N. (1997). Formalizing and securing relationships on public networks. *First Monday*. https://doi.org/10.5210/fm.v2i9.548

Tapscott, D., & Tapscott, A. (2016). The Impact of the Blockchain Goes Beyond Financial Services. *Harvard Business Review*.

Treiblmaier, H. (2018). The impact of the blockchain on the supply chain: a theory-based research framework and a call for action. *Supply Chain Management*, *23*(6), 545–559. https://doi.org/10.1108/SCM-01-2018-0029

van der Vaart, T., & van Donk, D. P. (2008). A critical review of survey-based research in supply chain integration. *International Journal of Production Economics*. https://doi.org/10.1016/j.ijpe.2006.10.011

Vyas, N., Beije, A., & Krishnamachari, B. (2019). *Blockchain and the supply chain - concepts, strategies and practical applications.* KOGAN PAGE.

Wacker, J. G. (1998). A definition of theory: Research guidelines for different theory-building research methods in operations management. *Journal of Operations Management*. https://doi.org/10.1016/s0272-6963(98)00019-9

Wang, Y., Han, J. H., & Beynon-Davies, P. (2019, January 14). Understanding blockchain technology for future supply chains: a systematic literature review and research agenda. *Supply Chain Management*, Vol. 24, pp. 62–84. https://doi.org/10.1108/SCM-03-2018-0148

Wang, Y., Singgih, M., Wang, J., & Rit, M. (2019). Making sense of blockchain technology: How will it transform supply chains? *International Journal of Production Economics*. https://doi.org/10.1016/j.ijpe.2019.02.002

Wessling, F., Ehmke, C., Hesenius, M., & Gruhn, V. (2018). How Much Blockchain Do You Need ? Towards a Concept for Building Hybrid DApp Architectures. *2018 IEEE/ACM 1st International Workshop on Emerging Trends in Software Engineering for Blockchain (WETSEB)*. https://doi.org/10.1177/1545968309353328

Wong, C. W. Y., Wong, C. Y., & Boon-Itt, S. (2013). The combined effects of internal and external supply chain integration on product innovation. *International Journal of Production Economics*. https://doi.org/10.1016/j.ijpe.2013.08.004

Woodside, J. M., Augustine, F. K., & Giberson, W. (2017a). Blockchain Technology Adoption Status and Strategies. *Journal of International Technology and Information Management*.

Woodside, J. M., Augustine, F. K., & Giberson, W. (2017b). Blockchain Technology Adoption Status and Strategies. *Journal of International Technology and Information Management*, *26*(2), 65–93. Retrieved from http://scholarworks.lib.csusb.edu/jitim/vol26/iss2/4

Wust, K., & Gervais, A. (2018). Do you need a blockchain? *Proceedings - 2018 Crypto Valley Conference on Blockchain Technology, CVCBT 2018*, 45–54. https://doi.org/10.1109/CVCBT.2018.00011

Yeoh, P. (2017). Regulatory issues in blockchain technology. *Journal of Financial Regulation and Compliance*. https://doi.org/10.1108/JFRC-08-2016-0068

Yin, R. (2003). CASE STUDY RESEARCH - Design and Methods. In *Social Research* (Vol. 5).

Zailani, S., & Rajagopal, P. (2005). Supply chain integration and performance: US versus East Asian companies. *Supply Chain Management*. https://doi.org/10.1108/13598540510624205

Zhao, X., Huo, B., Selen, W., & Yeung, J. H. Y. (2011). The impact of internal integration and relationship commitment on external integration. *Journal of Operations Management*. https://doi.org/10.1016/j.jom.2010.04.004

Zheng, Z., Xie, S., Dai, H. N., Chen, X., & Wang, H. (2018). Blockchain challenges and opportunities: A survey. *International Journal of Web and Grid Services*, *14*(4), 352–375. https://doi.org/10.1504/IJWGS.2018.095647