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INTERNET OF THINGS IN THE SUSTAINABLE SUPPLY CHAINS: A SYSTEMATIC LITERATURE REVIEW WITH CONTENT ANALYSIS

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ABSTRACT

Sustainability is at the heart of the world's concerns and has become a major challenge in this industrialized era. Committing to more sustainable practices became imperative in all sectors, and particularly in the complex supply chain field. Many industry 4.0 technologies have proven their potential in improving organizations' performance. In this context, researchers and practitioners have showed extensive interest in the impact of shifting to a data-driven supply chain operations. However, few works have systematically reviewed how the technologies, and in particular the internet of things, impact the sustainability of the supply chains. A total of 58 papers have been reviewed and categorized in order to identify the evolution of research developments in the field of sustainable supply chain. By the bias of a systematic review, this study tried to map the correlation between the use of the internet of things technologies and the sustainability of supply chains. The findings and discussions aim at highlighting the research trends in our chosen scope of study.

Keywords: *Internet of things, Industry 4.0, Sustainability, Supply chain, Systematic review*

1. INTRODUCTION

Rapid advances in information and communication technologies (ICT) have drastically changed the business and industrial environment. The 4th industrial revolution, also known as Industry 4.0, has been powered by the recent developments in the emerging information technologies[1]. This revolution is characterized by the application of the latest technologies in order to combine the digital and physical world [2] . Industry 4.0 comprises numerous technologies, its key components are Cyber-Physical Systems (CPS) which integrates computation with physical processes, Internet of Services (IoS) which is the approach where not only products but also services are available through web or other new technologies, encouraging the intercommunication and solid relation between the users and the service providers. Another key component is the Internet of Things (IoT) which connects objects by means of the internet and develop an autonomous inter-communication between objects or as the name states it: "Things" [3].

The dynamic and constant revolution in business environment and trends continuously change how the whole value chain operates. The globalization has made the supply chain a more complex and competitive system. The advancements in technology and thus the constant increase in product customization have made customers more demanding in terms of price, flexibility and quality. Moreover, numerous natural, economic and social factors, such as an increased global interest in green and sustainable processes and products, the pandemic outbreak etc. directly affect the performance of the supply chain networks. In order to embrace these changes and face these challenges, committing to more sustainable practices in supply chain networks has become imperative.

Furthermore, with the notable progress in the ICT and the emergence of Industry 4.0 and its enablers; Internet of Things, Artificial intelligence, Big Data and CPS etc., researchers and practitioners have shown substantial interest in these technologies and their potential impact in dealing with the supply chain management shortcomings and challenges.

Researchers from various fields, construction, agriculture, textile etc., have demonstrated their interest in the Industry 4.0 technologies. [4] explored the Industry 4.0 technologies in Construction Supply Chains and investigates their impact in increasing or reducing proximity in the construction supply chains. [5] examined the impact of implementing the advanced ICTs namely: Internet of Things, big data, Cloud computing and autonomous ships/vessels in maritime transport of cargo.

A growing body of researchers and practitioners have acknowledged how Industry 4.0 disruptive technologies have the potential to alleviate SCM challenges and improve SCM global performance [6]–[9]. [10] presented in their paper an analysis of how each KPI in supply chain management's selected functions is affected by each Industry 4.0 technology i.e. Cloud technology, Internet of things, Virtual and Augmented Reality, M2M and Additive manufacturing-3D printing etc. The results of this analysis revealed that the implementation of Industry 4.0 technologies positively influence the SCM organizations, specifically in terms of increasing flexibility, efficiency and productivity, as well as a better decision making process. Furthermore, [11] have concluded in their study that the use of data analytics within appropriate algorithms lead to a notable optimization of the logistics operations' efficiency as well as sustainability, in particular CO2 emissions.

The interest in the Industry 4.0 disruptive technologies, and Internet of things in particular, have witnessed a considerable increase among scholars in 2017 [8], [12]. [13], [14] focused on the internet of things technology and its impact on the supply chain management. Moreover, they pointed out the lack of papers addressing this subject and concluded that it is still in its early stages. According to [13], only 0.5% of thousands of identified papers on Internet Of Things were related to Logistics and Supply Chain Management field. Furthermore, the latter systematic literature review reveals that papers in relation to Green supply chain and reverse logistics were not identified. Similarly, [2], [15], [16] identified a gap in dealing with industry 4.0 technologies and particularly internet of things in sustainable supply chain management field. They encouraged scholars and practitioners to further investigate how Internet of Things and disruptive technologies could impact and leverage supply chains sustainability challenges.

Accordingly, this paper will propose a systematic literature review exploring the recent research developments in the field of sustainable supply chain management in the context of Internet of Things. For this purpose, this paper will be structured as follows: Section 2 introduces the context and background of our study. Section 3 describes the review methodology and process used for the systematic literature review. Section 4 presents the findings and results of the conducted SLR. Section 5 discusses the results of the collected material, and Section 6 concludes the systematic review, and provides research insights and research limitation.

2. BACKGROUND

Beforehand, in order to strengthen our knowledge and have in depth insight on internet of things as well as sustainable supply chains, a preliminary search for recent literature reviews and state-of-the-arts on these two subjects was conducted separately. The choice for specifically searching for this type of publications of the targeted keywords is justified by their primary purpose in synthesizing the existing body of research. Table1 shows some reviews that have presented an extensive overview on Industry 4.0, Internet of Things and Sustainable supply chain, respectively.

Prior conducting systematic literature reviews, [17] asserted the need to conduct a literature review in order to determine the need for the review . It is a crucial step of this paper's chosen methodology process; i.e. planning the review (see Section 3).

A prior search for existent literature reviews on the interaction of Internet of things, industry 4.0 and supply chain management was carried out. Table 2 presents some of the existing literature reviews that are relevant to our topic. This latter specifies the year of the literature review, the time period included in the review as well the databases interrogated.

Table 1: Overview of I4.0, SSCM and IoT

Paper	Year	Type	Summary
[1]	2018	State of the art	This paper provides a detailed technical summary of industry 4.0 and its enabling technologies, namely IOT, Cloud computing CPS. Furthermore, it discusses the challenges and research trends on industry 4.0.
[18]	2019	SLR	A thorough Systematic review about Sustainable supply chain management in global supply chains SCM. It covered a 15 year period of research on the SSCM. It offers a thorough summary of SSCM classifying the existing literature into environmental perspectives, social perspectives, economic perspectives and governance perspectives and performance metrics. It also present a list of enablers as well as barriers for reaching sustainability.
[19]	2019	SLR & Theory framework	This systematic literature review synthesise the existing body on the Internet f things technology exploring its architectures, applications, priority areas and challenges. Additionally, this paper proposes an IOT theoretical framework and conceptual model.

Table 2 Relevant Literature Reviews

Paper reference	Year	Time period	Reviewed	Database	Focus
[20]	2019	1995-2019 (>60% after 2017)	163	EI, JSTOR, ProQuest, SD, Scopus, WoS	This paper reviews the literature on the emerging digital technologies of Industry 4.0 in remanufacturing. It focusses on the applicability of the Internet of Things (IoT), Virtual Reality (VR) and Augmented Reality (AR) in the remanufacturing process.
[21]	2019	2009-2018	–	–	A literature review exploring the aspects of SCM (GSC SSC ..) , IoT and Industry 4.0 and examining the importance of IOT in the overall supply chain. Further, it proposes a framework for assessing the SSCM readiness for Indutry4.0
[9]	2020	Until 2019- first relevant paper in 2002	93	Scopus ISI Web of Knowledge, Emerald Insights, and Business Source Premier	A systematic literature review on machine learning applications for developing a sustainable agriculture supply chain(ASCs)

[13]	2017	Until 2017	39	Web of Science (WoS)	A detailed systematic literature review on Internet of things in the field of logistics and supply chain management.
[22]	2020	Until December 2019 , papers selected :2015 until December 2019	33	Scopus	A systematic literature review about digitally enabled sustainable supply chains, particularly it explores the use of big data for a sustainable supply chain management.
[16]	2019	2008-2018	102	Science Direct, EBSCO , Emerald, ABI/Inform	A systematic literature review on IOT in the SCM , focus on the challenges and risks of IOT in SCM
[4]	2018	Before 2018, 2012 starting point of relevant papers	39	ISI Web of Knowledge; ASSIA; Science Direct; EBSCO;ACM;IEEE; Emerald and ProQuest etc.	A summary of the current state and future potential of Industry 4.0 concepts in Construction SCM- Exploring 4.0 technologies in CSC and investigate their impact in increasing or reducing proximity in the construction supply chains.
[15]	2018	_	_	_	Qualitative assessment of environmental and social potential value creation in Industry 4.0 based on a literature review and expert interviews
[14]	2019	post 2018	166	Google schcolar, SD,Springerlink, Taylor&francis, Emerald	A Systematic Literature Network Analysis about IoT and its impact on SCM with a focus on main technology enablers, and exploring IOT roles and impact on each SCOR SCM process.
[5]	2018	2010-2018	24	EI, SD, Scopus, WoS	A systematic Review to examine the impact of implementing the advanced ICTs namely: Internet of Things, big data, cloud computing and autonomous ships/vessels in maritime transport of cargo.
[8]	2018	2000-2017	689	EBSCO Business Source, Emerald, ProQuest ABI/Inform, Science Direct,	A systematic review using a latent semantic analysis (LSA) methodology for examining disruptive technologies literature, specifically big data and IOT.

				Palgrave and Web of Science	
[7]	2018	1950-2018	126	Scopus , US Library of Congress, google	A systematic review exploring the use of IOT and AI in SCM, quantifying the impact of ICTs (IOT and AI) on the SC. Further it proposes a self-thinking supply chain model combining IOT and AI technologies.
[10]	2017	-	-	-	This paper explores by means of a literature review the SCM components and their KPIs. It proposes an analysis of how each SCM KPI in warehouse, transport logistics, procurement and fulfilment functions was affected by each one of the selected list of Industry 4.0 technologies, namely, IOT, big data, VA-AR,M2M etc.

Table 2 have tried to map the previous studies broadly related to our scope of studies, i.e. the use of disruptive technologies in supply management. A number of literature reviews as well as systematic literature reviews have been identified, [7], [13], [14], [16] presented SLRs of IoT in supply chain management, whereas [5], [22] have discussed the digitally enabled sustainable supply chain, exploring various ICTs. Based on the primary literature search, we identified a lack of papers on Internet of Things in the field of Sustainable supply chain management. The main aim of our study focuses on the sustainability aspect of the supply chain, and how the Internet of things technologies have/will contribute in it. [13], [14] have expressed the need for a further investigation on the impact of disruptive technologies, in particular Internet of Things, on the sustainable aspect of the supply chain. Hence the choice of this scope of study.

Following the prior literature search, we defined the research scope and question to be investigated in this paper, the search key words to be used to interrogate the search databases, and the time frame to be included. The starting point selected was 2017. [8], [12] pointed out that papers dealing with internet of things have increased after 2017. Accordingly, a need to synthesise the recent body of literature has arisen.

3. METHODOLOGY

Literature reviews are a crucial step in every research project. However, with the exponentially expanding produced and shared research papers, it has become increasingly complex. Consequently, "Narrative" literature reviews face numerous hurdles in producing accurate and solid conclusions. Systematic literature reviews follow a standardized research methodology to synthesize research findings in a systematic, transparent, and reproducible way, reducing the reviewer's potential errors and bias. It is the ideal approach to map and assess the existing body of literature in a specific research field. Furthermore, it helps the researcher to define a pertinent research question that will further enhance knowledge in that area as well as provide practitioners and decision makers with insight and guidance [23] .

The purpose of this paper is to systematically summarise the existing data on the interrelation between the sustainable supply chains and the disruptive technology, Internet of Things. In the aim to explore the emergence and adoption of the Internet of Things technologies in the supply chains and how it affects the supply chain sustainability.

We have chosen to conduct a systematic review to analyse the developments in the adoption and use of the Internet of Things technologies for a sustainable supply chain. This paper will summarise the existing evidence and accordingly analyse the research developments in the studied stream of research as well as suggest research insights and guidelines.

Several guidelines in distinctive fields of science, engineering, education, healthcare etc., for the conduction of systematic literature reviews have been proposed. [24] stands out between the various guidelines by proposing an extensive guidance on the systematic review process in software

engineering, which is extendable to other science fields [25].

To conduct this review, we have adopted the guidelines suggested by [24] and have combined them with the 4- step structured content analysis methodology by [26] . This hybrid methodology have been chosen in order to systematically review the body of literature in our subject, and simultaneously analyse and provide a content analysis.

According to [24], we can distinguish three main steps when performing a systematic review: Planning the review, conducting the review and Reporting the review. In the following, we describe in detail each step and sub-steps of this methodology combined with content analysis.

3.1. Planning the review

The first step consists on identifying the need for a review, specifying the research question and developing a review protocol. This latter is a fundamental component of a systematic literature review. This document ensures the transparency, integrity and reproducibility of the research process.

The need for the systematic review was identified by a prior literature search (see section 2). Based on the research, we have identified a lack of systematic reviews exploring the use for Internet of things for a sustainable supply chain. Hence our review paper.

Thenceforth, we established a review protocol table 3 to describe beforehand the search strategy that we will follow for our SLR. This document comprises the research questions, the databases chosen, the time horizon for the search, types of publication as well as the search terms and keywords. Based on the defined search terms relating to IOT and SSCM, search strings were established. The search strings are generated by logically combining the search terms with BOOLEAN connecters AND, OR. When developing the search strings, Quotation marks were used to ensure the search terms will appear next to each other. The search string is composed of two categories of keywords table 4. The first one is related to the disruptive technology Internet of things and the second is relevant to the sustainability of the supply chain. The search strings were developed combining these two categories in order to establish an initial relevance to jointly both fields of interest IOT and SSCM. We started with a simple straight-forward search string that includes the search terms internet of things and sustainable supply chain. From this first search string we enriched our search terms and search string for a more thorough screening. The second and third search string were added to search for other relevant paper emphasising on the environmental and social aspect of sustainability.

Furthermore, the review protocol also comprises an including and excluding criteria form to specify the information and relevance of each potential primary study table3. The inclusion or exclusion decision are explained in table 4.

Table 3. Review Protocol

Research question	In what context & by what means does the use of IOT technologies have disruptive/ decisive impact on SC sustainability
Databases	Scopus – Science Direct – Emerald Insight
Types of publication	research papers books proceeding LR
Language	English
Date	2017-2021*
Search terms	**1.** • Internet of things • IoT • Industry 4.0 **2.** • Sustainable supply chain management • SSCM • Sustainability • Environmental sustainability • Social sustainability
Search Strings used	❖ “internet of things” AND “sustainable supply chain” ❖ (" internet of things" OR "INDUSTRY 4.0") AND ("environmental sustainability" AND " supply chain management") ❖ (" internet of things" OR "INDUSTRY 4.0") AND ("social sustainability" AND " supply chain management")

Including excluding criteria	
Include	**Exclude**
Relevant to both the sustainable supply chain field as well as the internet of things technologies.	Smart cities/ not related to any industry

The key search words in title and/or keywords	Focus in an industry4.0 tool AND not including the IOT
Explicitly addresses IoT implications on the sustainable supply chain operations	Deals with SCM without the sustainability
2017-2021*	Before 2017
Relevance to the SSCM: should focus on the sustainable part of the supply chain management, either in a specific function of the supply chain or a specific sustainable feature of the supply chain **Relevance to IOT**: should deal with the internet of things technology either solely or alongside with other industry 4.0 technologies.	
*January 2021	

Table 4: Inclusion - Exlusion Criteria

Selection decision	Criteria	Code	Criteria Explanation
Inclusion	Closely Related	**CR**	It specifically(or mainly) discusses the use of IOT(and its technologies RFID..) in sustainable supply chain (one or all sustainability dimensions)
	Partially Related	**PR**	Discusses IOT among other I4.0 technologies in SSCM (discusses the use/impact of IOT)
Exclusion	Loosely Related	**LR**	Focuses on other I4.0 technologies either excluding IOT or loosely mentioning it/ focuses on the use of IOT in the supply chain without the sustainability aspect/
	Not Related	**NR**	Not related to neither IOT nor Sustainable supply chains , not related to industry like smart cities

Table 5. The 2 Constructs Of Keywords And Search Strings

IOT construct	SSCM construct
Internet of things	Sustainable supply chain
IOT	Sustainability
Industry 4.0	Supply chain management
Smart	SSCM
RFID	Smart Logistics
ICT	Environmental sustainability
Data driven	Social sustainability

Search strings

- "internet of things" AND "sustainable supply chain"
- (" internet of things" OR "INDUSTRY 4.0") AND ("environmental sustainability" AND " supply chain management")
- (" internet of things" OR "INDUSTRY 4.0") AND ("social sustainability" AND " supply chain management")

3.2. Conducting the review

To conduct this review, we adopted the structured content analysis methodology proposed by [26]. This methodology consists on a 4 distinguished steps, namely: Material collection, Descriptive analysis, Category selection, Material evaluation.

In this section we describe each of this 4 step process and present the results in the Findings section.

3.2.1. Material collection

In this step the primary studies are collected and delimited. The selection process follows the review protocol strategy where search strings, databases to be searched as well as the time range of the search were determined. The three selected databases (Scopus, Science Direct and Emerald Insight) were interrogated using the three established search strings. The last search was done on the beginning of January 2021.

The first step of the process was to examine the title, keywords and abstract of the papers. The papers that contain one of the relevant search words; internet of things (IOT), sustainable supply chain, circular

economy, industry 4.0 technology or other words related to it such as smart or data driven etc. in the title and/or the keywords were included in the first selection process. Since IOT is one of the Industry 4.0 technologies and to make sure we do not exclude any potential relevant articles, additional words that are relevant to disruptive technologies and sustainability were considered on the first screening. Then, the abstract was explored to investigate the relevance with our research area. In the first step the paper that are judged NR are excluded.

All of the identified papers were transferred in the literature management software Mendeley. Next, we used the Mendeley functionality to perform a duplication check.

3.2.2. Descriptive analysis

The main purpose of this step is to illustrate and interpret how the selected articles are distributed based on predefined characteristics. In this paper, the primary studies are analysed as per yearly publication, Publication type, journal-wise publication, publishers, research approach, keywords and industry etc.

3.2.3. Category selection

In this step the primary studies are categorised in order to facilitate the material evaluation and analysis. The main categories were inductively derived from the selected primary studies. This explorative research design was selected based on the qualitative nature of this research and the explorative aspect of the research scope and research question.

The categories were deduced step by step from the selected papers and continuously revised to ensure their reliability (Mayring, 2014.).

The aim of this research is to explore how the IoT technology is contributing in the sustainability of the supply chains. Three main categories were selected upon iteratively analysing the body or literature; 1 Sustainability outcome 2. Data driven SSC 3. Industry

3.2.4. Material evaluation

In this step, all the primary studies selected are coded and analysed according to the identified categories. The codification was performed iteratively and continuously in order to insure the accuracy and transparency of the findings. The documentation of this work has been performed on excel sheet keeping a detailed data record.

The results are then discussed accordingly, providing a synthesis of the body of literature in this field as well a guidance for SSCM researchers.

3.2.5. Reporting the review

The final phase consists on writing and reporting the results of the systematic review and publishing it.

4. FINDINGS AND RESULTS

4.1. Material evaluation

After the first screening based on title/ keywords and abstract, the 3 search strings have given a total of **925** papers, **761** were ruled Not Related and were then excluded. The selected 164 papers were transferred to the literature management software Mendeley. The duplication check functionality in Mendeley was then performed, narrowing down the selected paper to **115**. Table 6 summarizes the first screening process results.

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Table 6: First Screening Selected Papers Summary

Search strings	Science Direct		Emerald Insight		Scopus	
	N° of papers found	N° of papers selected	N° of papers found	N° of papers selected	N° of papers found	N° of papers selected
❖ "internet of things" AND "sustainable supply chain"	194	26	216	17	988*	34**
❖ (" internet of things" OR "INDUSTRY 4.0") AND ("environmental sustainability" AND " supply chain management")	211	22	189	10	581*	24**
❖ (" internet of things" OR "INDUSTRY 4.0") AND ("social sustainability" AND " supply chain management")	122	19	103	7	271*	36**
	527	**67**	**508**	**34**	**1840**	**72****
Total number of papers (found – selected)	**2875**		**173**			
Number of papers selected after eliminating duplicates	**115 papers**					

**Number of results in all fields without filters on keywords **Number of paper selected after filters on keywords and duplicate check*

The material selection second step was reading the introduction, results and conclusion of the papers for a better understanding of the scope of the paper. These parts of the papers were chosen because it presents the research questions, explains what gap the paper will focus on as well as the outcome of the paper. During the second step, the papers were classified based on the criteria in Table4. The papers judged LR and NR to the scope of our research are then excluded. An additional 64 papers were excluded in this step. Figure 1 presents the process of the primary papers selection.

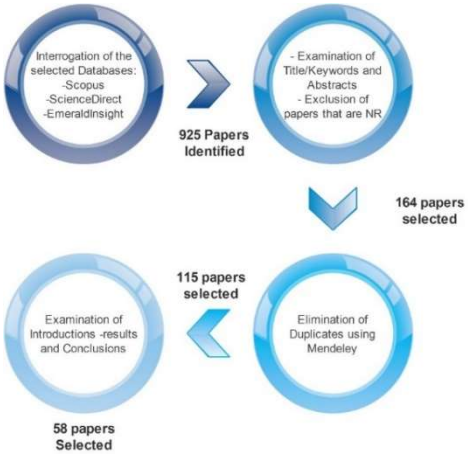

Figure 1: Material Selection Process

4.2. Descriptive Analysis

4.2.1. Year of publication

The starting year chosen for the research is 2017, this is based on the primary research done which provided a view on the development of research in IOT and SCM.

Figure 2 shows a tremendous rise in papers' production in 2020. A total of 37 papers related to our scope were published in 2020. More than half the selected papers were published in 2020 demonstrating that investigating the use of IOT for a sustainable supply chain management have caught the eye of more researches.

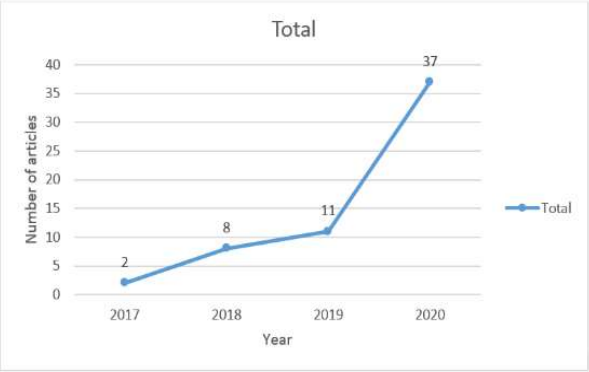

Figure 2: Distribution Of Papers Per Year Of Publication

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4.2.2. Publication type

The majority (84%) of the primary studies selected were articles published in scientific journals. Other sources were Book series and Conferences and Proceedings articles.

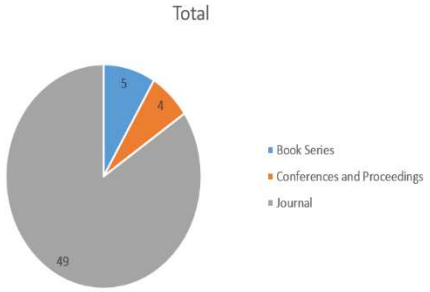

Figure 3: Distribution Of Papers Per Publication Type

- Book series, Conference and proceedings

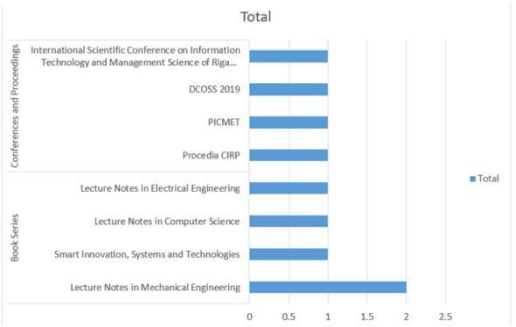

Figure 4: Conferences And Proceedings And Book Series

- Journal

Journal wise, Figure 5 shows the journals with more than one publication (>1) within our research scope. They represent 50% of the selected publications

The top 3 Journals with most articles are Journal of Cleaner Production (8 articles), Sustainability (Switzerland) (5 articles), Resources, Conservation and Recycling and International Journal of Production Economics (4 articles each). The first 3 journals are cross-disciplinary journals focusing on sustainability. While the International Journal of Production Economics is an interdisciplinary journal focusing on engineering and management. Our research scope is focussed on supply chain management sustainability and the internet of things technology, which is part of the main distinguished journals' aims.

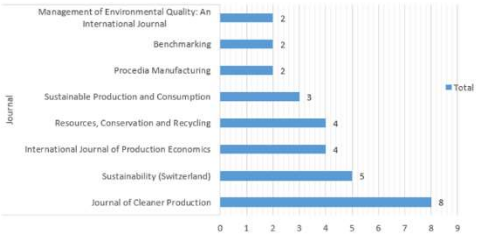

Figure 5: Top Journals With 2+ Publications

4.2.3. Publishers

The figure 6 shows the number of publication per publisher. Top 3 Publishers are Elsevier (29 publications), Emerald Group Publishing Ltd (9 publications) and Springer (6 publications). We observe a high amount of publication on our research scope from Elsevier, 29 publications from 13 different Journals.

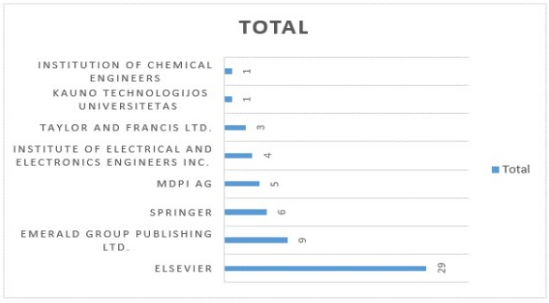

Figure 6: Distributions Of Papers Per Publisher

4.2.4. Article type

The majority of the publication (75%) are research papers (RP) while only 14 papers were review papers (LR). This low number on review papers affirm the need of a systematic literature review on IoT for sustainable supply chains.

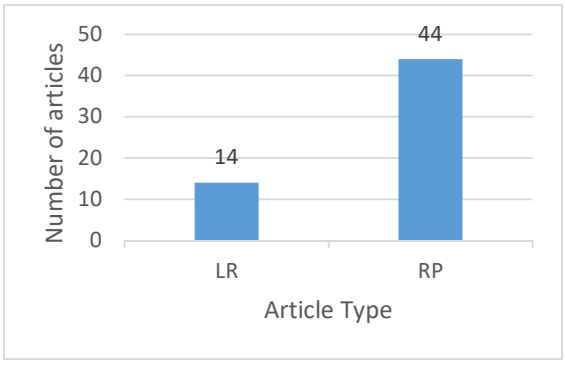

Figure 7: Distribution Per Publication Type

4.2.5. Research approach:

Figure 8 shows the distribution of research approaches used in the articles that were classified RP; research papers.

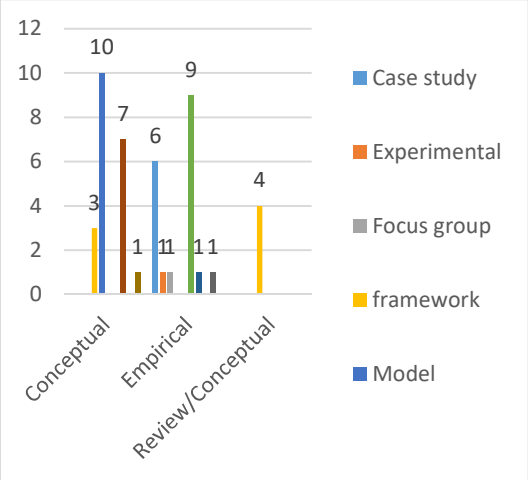

Figure 8: Distribution Of Papers Per Research Approaches

4.2.6. Keywords

In the selected papers, the top 3 most used keywords are: Industry 4.0(in 50% of the selected articles), Internet of things (39%) and Sustainability (36%). These are followed by "Blockchain" and "circular economy".

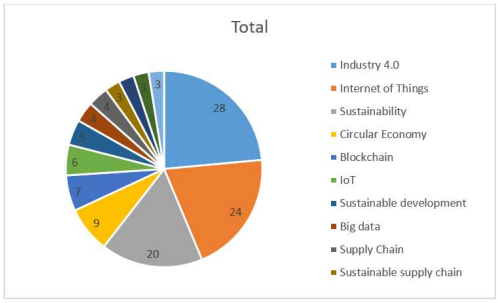

Figure 9: Most Frequent Keywords >2

4.2.7. Keywords in titles

The term "Industry 4.0" and "supply chain/sustainable supply chain" are the most frequently used in the selected publications titles (43%) followed by the term sustainable* (41%) and "IoT" (27%). Other frequently used terms are sustainability (18%), Blockchain (15%) and "circular economy" (12%).

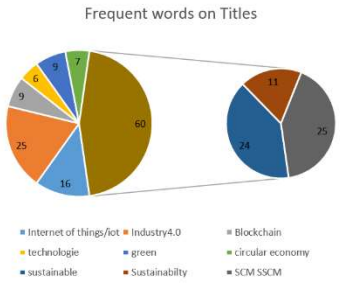

Figure 10: Frequent Words In Titles

4.3. Category selection

4.3.1. Sustainability outcome

The first category selected discern the sustainability aspect explored in each paper. In an answer to the research question, this category explores which sustainability aspect has attracted more attention as well as how it is affected by the use of the Internet of Things technology. The papers were categorised based on which dimensions of the sustainability were examined. Four sub-categories have emerged from this categorisation:

- 3 Dimensions in this paper referred to as TBL: triple bottom line. It includes the papers that discuss the 3 aspects of the sustainability; **economic environment and social**
- 2 Dimensions: This sub category includes papers that investigates 2 dimensions of the sustainability. The 2 aspects that have been jointly investigated are **Environmental and economic**
- 1 Dimension: it includes the papers that have investigated only one aspect of sustainability. **Environmental and Social** aspects have been individually explored
- Other: this sub-category includes the papers that either have discussed the sustainability as a whole not detailing the 3 aspects, or explored the Circular economy approach.

Figure 11 represents the distribution of primary studies in accordance to the sub-categories. It shows that most papers (38%) have approached the sustainability covering all its 3 dimensions. Sustainability is reached when all 3 aspects are considered. Considering each sustainability dimension, the environmental aspects have received the most attention, having 14/ 24% of the selected papers solely covering the environmental dimension, additionally 17% of primary studies has shown interest in environmental and economic dimensions.

Whereas 17% have approached the use of IoT in sustainable SC by associating with CE or have discussed how the IoT technology have affected the sustainability of the supply chain without specifying which aspect.

The sustainable outcomes of the use of internet of things as discerned in the primary studies of this systematic review will be discussed below in section 5.

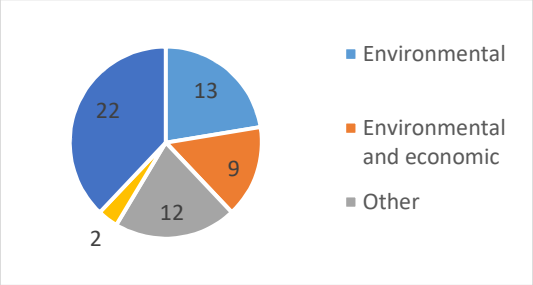

Figure 11: Number Of Papers Per Sub-Category

4.3.2. Data driven SC

This category explores the current applications of the internet of things for a sustainable supply chain. The industry 4.0 technologies are complementary and are used together for better outcomes. Hence, many studies have presented IoT technology alongside other technologies such as Blockchain, CPS etc. The selected papers have used diverse methodologies and present different results and applications. This category hence explores the current trends and applications in the body of literature.

Table 7: Technologies Explored In Each Paper

Technology explored	Number of papers
IoT	17
IoT among other I4.0 Technologies	13
Blockchain IoT	6
Blockchain IoT Bigdata	5
CPS IOT CLOUD COMPUTING	3
IoT CPS Bigdata	3
IOT AI Bigdata Blockchain	2
IoT CPS	2
Blockchain, IoT, BIM, CPS	1
IOT ,robotics, tracking systems, data analytics	1
IOT, AI, BDA, Blockchain, Cloud Computing	1
IOT VR AR AM	1
IOT Bigdata Cloud	1
IoT CPS Bigdata Cloud Computing	1
IoT AI Bigdata	1

4.3.3. Industry

This category identify the industries that were interested in using the IoT technology in order to make their supply chain more sustainable. Figure 12 shows the distribution of papers upon the distinguished industries, 20 papers have not specified an industry in their papers and are not included in the figure.

Logistics industry is the main industry in selected papers, which is explained by our scope of research which is the supply chains. Followed by agro-food and automobile industries.

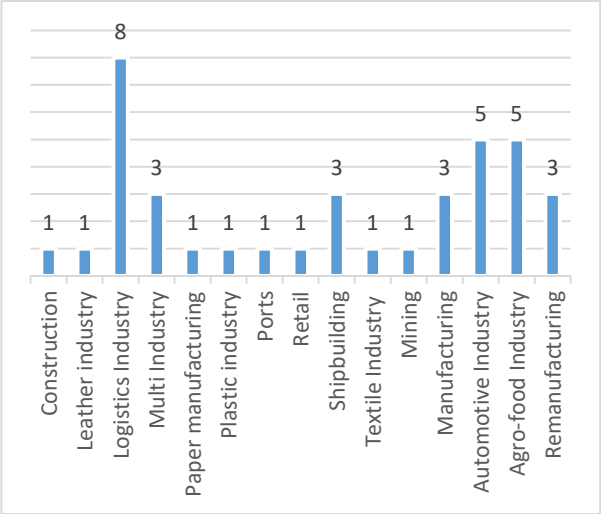

Figure 12: Distribution Of Papers Per Industry

5. DISCUSSION

5.1. Sustainability outcome

5.1.1. TBL:

When discussing the sustainability of the supply chain, it is inevitable to explore it from the triple bottom line perspective. These last decades, the people's interest has shifted from a sole interest in economic gains towards a TBL mind-set where economic, environmental and social goals are equally met [28]. In this category, the selected papers is relatively bisected into review papers and empirical papers. However [29]–[31] have however chosen the conceptual approach.[31] has identified 16 industry 4.0 sustainability functions and conceptualised an ISM model of the functions. Human resource development is considered the fundamental function that will lead the development of the other sustainability functions. Developing the right digital and modern skills is the leverage to the second step which is the supply chain digitization and integration.

[30] have presented a model of the reverse logistics examining how product diffusion dynamics in the market affect the economic and environmental performances of an inventory and production planning (I&PP) system. While [29] have proposed a Blockchain-enabled architecture that can integrate the supply chain nodes using the P2P system, Internet of Things, and cloud-based system.

The review papers have mainly explored the role of IoT among other industry 4.0 technologies in attaining the sustainability. The benefit of these technologies mainly affect the agility, integration, coordination, efficiency and resilience of the supply chain [32], [33]. The internet of things is one the main Industry 4.0 technologies that enables the SC sustainability [31].

Industry 4.0 technologies, and specifically Internet of things technologies ensures real time tracking and monitoring as well as an end to end communication between different parts of the value chain. These latter functions strengthens the flexibility, visibility and efficiency of the supply chain, and thus contribute to the sustainability of the supply chain. [34], [35]

[36] has proposed a data-driven AFSCM framework (Agro-Food Supply Chain) explaining how with ensuring a reliable SCV, integration of resources and a proper Data analytics and consequently appropriately using the right data can improve the sustainable performance of the ASC .

[37] has also proposed Sustainable Industry 4.0 Framework pointing out how process integration; i.e. human machine collaborations and shop floor equipment integration, through industry 4.0 technologies generate more sustainable outcomes.

The review papers in this category all conclude that visibility and resources integration leads into a more sustainable supply chain

On the other hand, a number of papers have used an empirical approach, conducting surveys and case studies in various industries.

[38] has identified and validated through surveying over 400 industry practitioners the performance measures for smart manufacturing systems. The implementation of SMS improves, among others, flexibility, integration, real-time diagnosis and prognosis as well as promote social and environmental sustainability. [38].
[39] has proposed an evaluation model based on sustainable KLPS in accordance to TBL pillars. Whereas ref28 has enumerated the main performance factors to assess the sustainability of an organisation. These surveys and case studies has demonstrated that IoT is a major influential performance factor that can improve the sustainable development of multiple industries. [39], [40].

5.1.2. Environmental and economic

This sub-category identified comprises the papers that have examined only 2 aspects of the sustainability; environmental and economic. The economic gain has always been the main concern of organisations, however, the ecological awareness has risen these last decades. The environmental and green concerns has considerably attracted attention of practitioners and researchers.
17% of the selected papers have only focused on these two aspect of the sustainability through different methodological approaches.
[41] have explored through an ample survey of manufacturing firms in china the industry4.0 technologies influence on economic and environmental performance. Responding to a highly dynamic environment characterised by active changes in customer demands, regulations and production modes, [41] recommend incorporating the digital technologies across the supply chain

[42] developed a reference framework for green logistics to reach the sustainable operations, [43] proposed an RFID system that alleviate the lack of information and data of product life cycle problem, in the aim improving the profitability and environmental-friendliness of the closed loop supply chain. Whereas [44] have proposed a model of the sustainable food security system using different IoT technologies.
Moreover, [45], [46] have proposed mathematical models for a sustainable reverse supply chains.

[45] conjointly implementing industry4.0 principles as well as ReSOLVE model have suggested a roadmap to enhance the economic and environmental performance of the supply chain. While ref 40 designed an IoT-enabled real time sensing model optimising the logistics costs energy consumption and reducing environmental pollution.
[47] have suggested an IoT-enabled smart indoor parking system using A BLE beacon enabled self-learning genetic tracking architecture. While ensuring an improved location accuracy, higher logistics efficiency, lower emissions were attained [47].

5.1.3. One dimension

The third sub-category comprises the papers that explore individually one dimension of the sustainability aspects. 24% of the identified papers

have shown more interest on only the environmental and green aspect. While only two papers examine the social aspect in the SCM.
[48] developed a system architecture allowing the monitoring of social sustainability. This system allows Production and logistics traceability, Supply chain transparency as well as monitoring the labour and human rights and workplace health and safety.
Meanwhile [49] approached the social inclusion of the industrial world with from an empirical perspective. They proposed a theoretical framework that would help to develop an inclusive strategy for industrial development.
[50]–[52] have conducted reviews of the use of IoT for the greening and sustainability of the supply chains of different sectors, i.e. shipbuilding, healthcare, agriculture, waste management smart grid transportation etc.

Traceability, enhanced communication and cooperation across the supply chain route planning and optimization, collaborative decision making, CO2environmental monitoring, energy-efficient operations are one of the enumerated benefits of IoT on the supply chain sustainability [50]–[52].

[53] has developed a Blockchain-based life cycle assessment system exploiting two main source of data; input resource consumption data and output waste emission data.
[54], [55] have shifted their attention to key performance indicators where [54] has developed a new KPI to determine the energy consumption of machine tools, while [55] have enumerated the critical success factors that should be regulated to attain a proper integration of industry 4.0 and environmental sustainability in the manufacturing organisation.

[56] discusses an innovative solution to reduce the environmental footprint of ports while enhancing their productivity. This system is based on new ICT technologies upon an interoperable open IoT platform
Meanwhile [57] have identified the acquired capabilities of certain industry 4.0 technologies when used in four different scenarios, and then distinguished their positive and negative impacts.
[58], [59] have suggested new models in an IoT environment for the green delivery and green procurement respectively. Meanwhile [60] proposes a decision-making assessment system of traceability and eco-sustainability of industrial companies.

5.1.4. Other

This last sub-category comprises the papers that have discussed the sustainability of the supply chains as a concept without detailing its 3 aspects, as well as papers that examine the sustainability form a circular economy perspective.
[61] have developed an intelligent platform based on CPS, IoT, BIM, and Blockchain for SPSS innovation in Prefabricated Housing Construction.
While [62]–[66] have adopted an empirical approach using case studies and surveys.

Through extracted data from interviews, [64] tried to map the manufacturing data that will ameliorate the remanufacturing process. [62]have discussed how the adoption of Blockchain and IoT help meet SCM objectives. The data used was extracted from eleven cases/firms selected through diverse case method strategy.
Furthermore, [65], [66] focused on extracting the setbacks and barriers of the implementation and adoption of industry 4.0.

5.2. Data driven SC

The internet of things technology has originally evolved from the Radio Frequency Identification (RFID) networks concept. Its primary functions includes data management from acquisition, processing to transmission. [67]. IoT technology is considered one of the main Industry 4.0 enablers establishing a connected environment. It is mainly consists of sensors, actuators, BLE, network and cloud platforms etc.[68] .

Our scope of study is the internet of things technologies, hence 29% of the selected papers focus on the IoT technology. [51], [52], [69]–[71] have presented reviews on the architecture, opportunities applications, challenges and impact on the sustainability.

The impact of IoT in different industries have intrigued many scholars and practitioners. Through survey and case studies, [40], [64], [65], [72]–[74] tried to map the experts and industrials' feedback and assessment on the use of the technology for the sustainability of their firms. Meanwhile, [43], [46], [47], [56], [58], [60] were more interested in developing novel system architectures and models in an IoT environment. These latter have adopted a conceptual approach aiming at enhancing the environmental aspect and greening of the supply chain, by improving the connectivity, visibility and fleet management.

On the other hand, the remainder of the papers have considered the IoT technology among other industry 4.0 technologies. Although the scope in the IoT, this technology cannot be completely isolated from the other industry 4.0 technologies. 22% of the primary studies have explored IoT along various industry 4.0 technologies. While investigating the industry4.0 technologies for a sustainable supply chain, the internet of things emerge as one of the prominent technologies [33], [39], [75].

The main technologies that have been notably associated with IoT are Blockchain, Big Data, CPS, AI and Cloud. 25% of the selected papers have associated IoT with Blockchain technology with 10% solely investigate the use of Blockchain and IoT.

While focusing on the Blockchain technology, [29], [35], [62] have introduced the IoT as a complementary technology for their study. Meanwhile [59], [76] have suggested Blockchain-IoT integrated architectures.

Blockchain has been associated the most with IoT considering their complementarity. IoT systems and platforms face many challenges and risks, security attacks remains the major hurdle faced while designing IoT based systems. Blockchain offer prominent solutions and opportunities to overcome IoT challenges[77] . Ergo the extensive linkage of these two technologies.

The second technology is Big Data which was also extensively associated with IoT. Considering the abundant amount of data the IoT captures, a system technology for analysing these data is needed. Big data Analytics is majorly used to process and analyse the data from IoT devices[68]

[42], [48], [53] have proposed systems and frameworks combining IoT, Blockchain and Big Data analytics. The combination of these three technologies have proven substantial results considering their complementariness in strengthening each technologies effectiveness.

Following Blockchain and Big Data, CPS Cloud computing and AI have also been used along IoT. [39] have pointed out that CPS IoT and Big Data are drivers for sustainable development.

5.3. Industry

This categorisation aims to highlight the industries and countries that showed their interest in the adoption of Internet of things technologies and industry 4.0 technologies in general for sustainable supply chains. Although 23 papers (39%) haven't specified the industry concerned in their study, the empirical papers [49], [66] in this segment have targeted experts in sustainability and industry 4.0 transition and Mexican small and medium enterprises respectively.

Furthermore, only 3 papers have explored multiple industries in the aim to answer their research topics. [62], [78] have adopted a multi-case study approach reuniting firms from different industries and degree of adoption of IoT and industry 4.0 technologies. While [52] have reviewed IoT opportunities and applications in multiple industries such as agriculture, transportation, smart grid etc.

The most interested industries about technology adoption to reach sustainability are the Logistics with 8 papers followed by Agro-food and Automobile industries with 5 papers each, and shipbuilding, manufacturing and remanufacturing with 3 papers each. Papers in logistics industry were identified the most in this review considering the scope of our paper; sustainable supply chain. The papers categorised under the Logistics industry include reverse logistics, green logistics and delivery, vehicle management and waste management.

Logistics industry can considerably benefit from the novel technologies in increasing their efficiency flexibility and sustainability [69] . Real time data sharing and visibility are crucial for a better logistics operations [42] . [69], [79], [80] proposed IoT enabled solutions to improve the waste management operations and their sustainability. [46], [47], [58] have suggested, respectively, novel systems and models to enhance the efficiency and sustainability of the delivery, reverse logistics and vehicle management operations within an IoT environment.

[36], [81], [82] have shown interest in data-driven agro-food industry proposing reviews investigating which and how the industry 4.0 technology advancements can affect the agriculture and food collaborators and the sustainability of the industry. Transparency and traceability are crucial in the agro-food industry considering its distinguished challenges and complexity that can involve customer safety [82].

Meanwhile [29], [44] have suggested IoT enabled system architecture to ensure the information management and security of the food supply chain.

The automotive industry have also showed interest in the adoption of IoT for the greening and

sustainability of their supply chain. [38], [40], [74], [76] have adopted an empirical approach collecting data from automotive companies of their respective countries; India and Iran. The data was used to

Shipping and shipbuilding sector plays an important role in the worldwide economic growth [51]. [33], [51], [83] have investigated how the shipbuilding sector can benefit from the adoption of the new technologies. Companies face several sustainability challenges that could be overcome by the adoption of industry 4.0 technologies. These latter provide the visibility connectivity of the supply chain and promote the sustainability of the companies in the shipping sector [33], [83].

6. CONCLUSION

The industrial revolution and continuous advancements in technology remains a major interest in the business world. All fields and industries have showed their interest and has exploited these cutting-edge technologies, each from a different perspective and with different level of implementation. Industry 4.0 technologies have proved their potential and proficiency in improving the organisations' overall performance and sustainability. Sustainable supply chain management is one of the fields that have considerably benefitted from shifting to data –driven operations.

In this study, a systematic literature review on Internet of things and sustainable supply chain has been carried out. A total of 58 papers have been selected and analysed in order to summarise and identify the evolution of research developments in the field of sustainable supply chain. Subsequently, the findings have highlighted the research trends in terms of sustainability aspects majorly explored, industries most involved as well as the interrelationship between IoT and other industry 4.0 technologies. Annexe1 presents a summary of the findings of the systematic review.

Nonetheless, the findings of this study have to be seen in light of some limitations. The primary limitation to this study is the chosen excluding criteria. The study focused on the manufacturing sector, excluding smart cities. This could be addressed in a future research, where the focus will be on the sustainability of smart cities and urban logistics. Second, the production of papers evolve drastically and rapidly, the time period restriction could have limited our findings and data. Furthermore, since sustainability is a wide concept that encompasses all three aspects; environmental, social and economic, the related papers and researched can't be limited by few keywords.

In the light of our research, the literature agrees on the great potential Internet of things technologies hold for accompanying organisations in their path to make their supply chains more sustainable. IoT main advantage is its ability to sense, capture and manage a great amount of data. This plays a major role in helping organisations make more decentralised and real-time monitoring and decision making [72]. Supply chain visibility traceability, efficiency and transparency are the main advantages of exploiting IoT. With these capacities IoT has proven to be one of the most influential industry 4.0 technology on sustainable development [34], [39], [69], [81]. However, the adoption of a data driven supply chain still faces many hurdles, mainly high investment, data security, lack of technical skills and workers cooperation [65].

The majority of papers were of conceptual nature, proposing frameworks and system architectures in an IoT environment. More studies should focus on the applicability of the technology in the diverse sectors such as transportation, textile

Environmental sustainability have attracted the most interest of researchers, demonstrating the vital role IoT plays in the greening the supply chains. However, social sustainability have been explored the least, and has also been associated to the setbacks and challenges of the data-driven shift. More studies should investigate in depth the impact of the IoT on the social aspect of the sustainability.

Nonetheless, the findings of this study have to be seen in light of some limitations. The primary limitation to this study is the chosen excluding criteria. The study focused on the manufacturing sector, excluding smart cities. This could be addressed in a future research. Second, the production of papers evolve drastically and rapidly, the time period restriction could have limited our findings and data.

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Annexe 1: SLR summary

Code	Reference	Sustainability outcome					Technology	Industry
		Environmental	Environmental and economic	Other	Social	TBL		
1	[61]			*			blockchain, IoT, BIM, CPS	Construction
2	[42]		*				Blockchain IoT Bigdata	Logistics Industry
3	[58]	*					IoT	Logistics Industry
4	[38]					*	IoT among other I4.0 Technologies	Automotive Industry
5	[32]		*				IOT VR AR AM	Remanufacturing
6	[21]					*	IOT Big data Cloud	Not specified
7	[75]			*			IoT among other I4.0 Technologies	Not specified
8	[33]			*			IoT among other I4.0 Technologies	Shipbuilding
9	[36]					*	Blockchain IoT Bigdata	Agro-food Industry
10	[81]					*	IOT AI BIGDATA BLOCKCHAIN	Agro-food Industry
11	[72]					*	IoT	Paper manufacturing
12	[69]			*			IoT	Logistics Industry
13	[34]					*	IOT AI BIGDATA BLOCKCHAIN	Not specified
14	[35]					*	Blockchain IoT	Not specified
15	[29]					*	Blockchain IoT	Agro-food Industry
16	[53]	*					Blockchain IoT Bigdata	Not specified
17	[62]			*			Blockchain IoT	Multi Industry
18	[84]			*			IoT among other I4.0 Technologies	Not specified
19	[70]					*	IoT	Not specified
20	[54]	*					CPS IOT CLOUD COMPUTING	Not specified
21	[30]					*	CPS IOT CLOUD COMPUTING	Not specified
22	[50]	*					Blockchain IoT	Not specified
23	[39]					*	IoT CPS Bigdata	Plastic industry
24	[49]				*		IoT CPS	Not specified
25	[43]		*				IoT	Automotive Industry
26	[59]	*					Blockchain IoT	Not specified
27	[85]			*			IoT among other I4.0 Technologies	Not specified
28	[40]					*	IoT	Automotive Industry

29	[45]		*				IoT among other I4.0 Technologies	Manufacturing
30	[57]	*					IoT among other I4.0 Technologies	Not specified
31	[63]			*			IOT CPS	Mining
32	[86]	*					IoT CPS Bigdata Cloud Computing	Textile Industry
33	[79]					*	IoT CPS Bigdata	Logistics Industry
34	[78]					*	IOT robotics tracking systems data analytics	Manufacturing
35	[31]					*	IoT among other I4.0 Technologies	Not specified
36	[51]	*					IoT	Shipbuilding
37	[71]					*	IoT	Logistics Industry
38	[52]	*					IoT	Multi Industry
39	[73]					*	IoT	Retail
40	[46]		*				IoT	Logistics Industry
41	[47]		*				IoT	Logistics Industry
42	[64]			*			IoT	Remanufacturing
43	[44]		*				IOT AI BDA BLOCKCHAIN CLOUD COMPUTING	Agro-food Industry
44	[74]					*	IoT	Automotive Industry
45	[65]			*			IoT	Multi Industry
46	[37]					*	IoT among other I4.0 Technologies	Remanufacturing
47	[76]	*					Blockchain IoT	Automotive Industry
48	[83]					*	IoT among other I4.0 Technologies	Shipbuilding
49	[87]					*	IoT among other I4.0 Technologies	Not specified
50	[88]					*	IoT among other I4.0 Technologies	Not specified
51	[66]			*			IoT among other I4.0 Technologies	Not specified
52	[48]				*		Blockchain IoT Bigdata	Not specified
53	[80]		*				IoT AI Bigdata	Logistics Industry
54	[41]		*				IoT CPS Bigdata	Manufacturing
55	[56]	*					IoT	Ports
56	[82]			*			Blockchain IoT Bigdata	Agro-food Industry
57	[60]	*					IoT	Leather industry
58	[55]	*					CPS IOT CLOUD COMPUTING	Not specified
Total		**13**	**9**	**12**	**2**	**22**		