APPLICABILITY OF DISRUPTIVE TECHNOLOGIES IN ORGANIZATIONS. A LITERATURE REVIEW.

APLICABILIDAD DE TECNOLOGÍAS DISRUPTIVAS EN LAS ORGANIZACIONES. UNA REVISIÓN DE LA LITERATURA

***Kelly Coronado-Ahumada*[1]**
***Gabriel González-Caraballo*[2]**

RESUMEN
Las tecnologías de la información y la comunicación (TIC) han revolucionado diferentes sectores económicos desde sus inicios. En particular, las tecnologías disruptivas generan cambios radicales cuando se apropian, desplazando a otras tecnologías existentes en diferentes campos en su adopción. El objetivo principal de esta revisión de la literatura es identificar las tecnologías disruptivas implementadas hoy en día en las organizaciones y los beneficios e impacto que generan. Se definieron tres variables para realizar un análisis exhaustivo de la literatura seleccionada: Tecnologías de la información y las comunicaciones, sector y métricas. Como resultado, se pudo evidenciar que la correcta apropiación de tecnologías disruptivas genera un valor estratégico considerable a las empresas, como adquirir una ventaja competitiva frente a otras organizaciones debido a la automatización de procesos, lo que permite optimizar los tiempos de respuesta e incrementar los niveles de satisfacción de los clientes en los Stakeholders.

Palabras clave: Tecnologías disruptivas, Transformación digital, Organización, Innovación

ABSTRACT
Information and communication technologies (ICTs) have revolutionized different economic sectors since their inception. In particular, disruptive technologies generate radical changes when appropriated, displacing other existing technologies in different fields at their adoption. The primary purpose of this literature review is to identify disruptive technologies implemented today in organizations and the benefits and impact they generate. Three variables were defined to carry out an exhaustive analysis of the selected literature: Information and communication technologies, sector, and metrics. As a result, it was possible to show that the correct appropriation of disruptive technologies generates considerable strategic value to companies, such as acquiring a competitive advantage over other organizations due to the automation of processes, which allows optimizing response times and increasing customer satisfaction levels on Stakeholders.

Keywords: Disruptive technologies, Digital Transformation, Organization, Innovation

Cómo citar este artículo:
K. Coronado-Ahumada & G. González-Caraballo. Applicability of disruptive technologies in organizations. a literature review. Ingeniare, Año 19, No. 35, Julio 2023. pp. 59 - 79.

[1] Full-Time Professor, Computer Science and Electronics Department, Universidad de la Costa, Barranquilla-Colombia. Address: Calle 58 # 55 – 66, Postal code: 080002. E-mail: kcoronad@cuc.edu.co
[2] Master's Student in Computer Engineering, Computer Engineering Department, Universidad del Norte, Barranquilla-Colombia. Address: Km.5 Vía Puerto Colombia, Postal code: 081007. E-mail: caraballog@uninorte.edu.co

Fecha de recepción: 18 de marzo de 2023 • Fecha de aceptación: 2 de mayo de 2023

1. INTRODUCTION

Organizational changes are necessary for companies to persevere over time. To achieve them, companies must keep up with –furthermore, be leaders in– the usage of information and communication technologies (ICTs) and emerging operational technologies, methodologies, and approaches. This type of change requires time, investments, and expenses that most organizations are unwilling to commit.

According to [1], it is important to keep in mind three main dimensions for the application of new strategies: interaction with customers considering the approach of their own processes, adoption of emerging technologies in order to generate value for the company and, encouragement of compliance of transparency related standards.

Factors to overcoming the main barriers introduced in the context of organizational transformation include change management, convenient investments, personnel training, higher involvement of senior management, ICTs insertion. These factors vary considerably depending on the scale of the company at issue.

The fulfillment of these changes can be approached through Digital Transformation strategies. Digital Transformation, as defined by [2], is the process whereby ICTs are inserted into the company and, requires a strategic alignment between the company's objectives and the ICTs usage. Furthermore, it is required that the company "redesigns or reinvents their operative, productive and value chain models."

Clayton Christensen [3], follows by stating three main reasons why companies should adopt digital transformation processes. First, the imperative of staying relevant in the market, i.e., the threat to the company's survival –taking into account customer trends and demands. Second, the rise of new technologies that ease the extraction, storage, and processing of information. Third, the development of more efficient business models by competitors.

The fourth industrial revolution (Industry 4.0) is a trend that has changed the perspective of companies and has allowed to drastically transform the way of carrying out tasks and processes. According to [4],Industry 4.0 is associated with the informatization and digitalization of production, and with the generation, integration and analysis of large amounts of data throughout the productive process and lifecycle of products.

Benefits of appropriation of this trend include competitive advantage, employing disruptive technologies for the automation of processes, security, attention, and customer satisfaction. Value delivered to the customer can rise, given that there exist rapid answers to new requirements and multiple communication channels are deployed to facilitate access to information –thus, the exchange of knowledge.

According to Sood and Tellis [5], "disruption occurs when a technology that is superior on a new dimension that appeals to a niche, but inferior on a dimension that appeals to the mass market, improves on the latter dimension to meet the needs of a mass market". In other words, a disruptive technology is one that, despite aiming at the needs of a limited market, proves to be competent –and superior– regarding a larger market's needs. Furthermore, Pena Andres and Hernandez Ramos [6]define disruptive technologies as those that replace existent technologies and introduce abrupt changes (disruption) in organizations and society.

Disruptive technologies are beneficial for companies in the initial stages. Special care and consideration should be kept in mind when applying disruptive technologies to larger-scale –leader– companies since according to [3], this type of technologies has accelerated the fall of many [7]. The author pointsout that approximately one in ten companies successfully inserts disruptive technologies to provide above-average growth demanded by shareholders. One possible explanation is that larger-scale companies have well-defined processes, methods, frameworks, and protocolsthat have proven their efficiency over time. Changing them requires an additional effort (mainly on the company's culture) that does not necessarily yield favorable results.

The aim of this paper is to expose the results of a systematic literature review on which the main disruptive technologies adopted in organizations pertaining to different economic sectors and their positive impacts were identified. In this way, this literature review presents a state-of-the-art on the impact of disruptive technologies on organizations. Furthermore, this literature review contrasts literature findings with market indicators.

This literature review can be used as a starting point for researchers interested in digital transformation processes given that it presents the different technologies adopted and how they were adopted in order to generate positive organizational changes.

2. METHODOLOGY

A systematic literature review (SRL) allows answering questions regarding the state-of-the-art of a specific field. Representative examples of such questions are: Which are the new trends? What research is being conducted related to a particular theme? Where are possible opportunities for deepening research? Which subdivisions of the field are yet to be explored or have a reduced exploration? Answering these questions can lead to the appropriation of the matter at hand, thus allowing researchers to propose further developments. The studies that are considered on an SLR are named primary studies. The SLR itself is considered to be a secondary study [8].

This paper is based on the methodology proposed by [8] for the development of an SLR. Broadly speaking, the steps to perform an SLR are listed as follows: identification of the necessity to conduct such SLR, the proposal of the research question, design of an exploratory protocol that includes keywords and filters, filtering and sorting of documents found by means of inclusion and exclusion criteria and, extraction and analysis of the relevant information for the study.

2.1 Methodology Development

ICTs serve a key role in the development of organizations. New technologies emerge on a regular basis. Such technologies facilitate the acquisition and management of information, thus streamlining the decision-making process. Therefore, the following research question was proposed: According to the literature, which disruptive technologies are being applied currently on organizations?

Afterwards, we established the following compound query: "disruptive technologies" AND "Digital transformation" AND "organization" AND "innovation". The query was used on three databases: IEEE Xplore, Scopus and,ScienceDirect. Besides keywords, filtering was done by year of publication (2018 to 2020) and type of paper (scientific paper)

We organized articles resulting from the first search in separate matrices by database, adding their primary metadata. Then, the three matrices were mixed in order to discard duplicate elements and filter them.

To select articles related to the study at hand, we established an inclusion criterion to select all articles that shown the application or appropriation of disruptive technologies in organizations and the outcomes of such a process. Furthermore, we established as an exclusion criterion to discard articles that did not present concrete solutions. Lastly, to analyze the selected articles, the following variables were defined: type of ICT, economic sector,andmetrics. The goal was to identify how such variables were reflected in the selected articles and their relationship. The latter was done through the operationalization of variables.

2.2 Variables Definition

The variables established to be identified in each one of the selected articles for this review are defined as follows:

Information and Communication Technologies (ICTs)

Technology can be defined as “the practical application of knowledge especially in a particular area”, according to [9]. In this sense, it focuses on the usage of knowledge to solve a need. Humans use technology to adapt and to deliver more efficient results on tasks.

UNESCO [10] defines ICTs as a “diverse set of technological tools and resources used to transmit, store, create, share or exchange information.” This literature review aims to identify which disruptive ICTs are being adopted by companies in order to meet their organizational objectives.

Economic sector

Sector is defined by [11] as “a part of an area of activity, especially of a country’s economy”. This literature review aims to identify to which economic sector pertains each article. Furthermore, we aim to classify the sectors that are most prone to adopting disruptive ICTs, how they apply them and, the related benefits.

Metrics

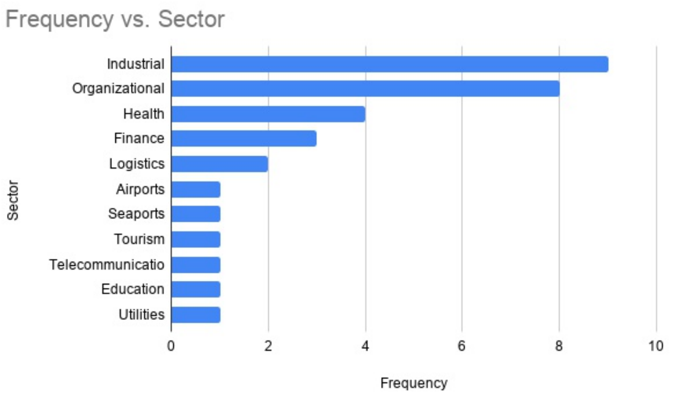
According to [12], metrics are defined as “a quantitative measurement of the degree to which a system, component or process possess a given attribute.” This research aims to identify the key metrics companies use to measure their appropriation of disruptive ICTs and their impacts. According to the results provided by the metrics, companies make required adjustments to comply with strategic objectives leveraging ICTs.

3. RESULTS

The initial search on the three databases yielded 75 articles distributed as follows: 3 in IEEE Xplore, 3 in Scopus and, 69 in Science Direct.After filtering using the established inclusion and exclusion criteria, 31 articles fitted the research at hand. The abovementioned results are outlined in Figure 1. Furthermore, Table 1 details the complete filtering process.

Selected articles were arranged in a matrix that included (as columns): title of the article, authors, publication year, abstract, access hyperlink and source database. Afterward, we extracted the methodology proposed by the authors and the selected variables for their analysis. This data is displayed in Table 2.

FIGURA 1. DIAGRAMA DE FLUJO PRISMA



FUENTE: ELABORACIÓN DE LOS AUTORES

TABLE 1. ARTICLES FILTERING PROCESS

Articles filtering process				
Source: Database	**Filter 0**	**Filter 1**	**Filter 2**	**Filter 3**
	Compound query using keywords: "disruptive technologies" AND "Digital transformation" AND organization AND innovation	***Timeframe: 2018-2021***	***Publication type: Conferences, Research articles and magazine articles***	***Abstract reading considering inclusion and exclusion criteria***
IEEE-XPLORE	3	3	3	1
Science Direct	127	115	69	28
Scopus	4	4	3	2
Total	**134**	**122**	**75**	**31**

SOURCE: AUTHORS

4. DISCUSSION

Based on the results, the following analyses were performed:

Information and Communication Technologies (ICTs)

One of the most frequent disruptive technologies in the articles reviewed was IoT [14], [20], [23]–[26], [29], [33], [39], [40], [42], [43], followed by Big Data ([14], [16], [20], [29], [34], [35], [38], [40], [42], [43]), Artificial Intelligence (AI) [14], [18], [20], [21], [23]–[25], [29], [35], [36] and, Blockchain [13], [14], [18], [20], [22]–[26]. A representative purpose of blockchain is cybersecurity, which becomes paramount in environments that handle sensitive information, e.g., hospitals [13].

Subsequent to these technologies, Cloud Computing also showed a trend in the articles reviewed [14], [18], [24], [26], [29], [37], [40], as did Industry 4.0 [14], [15], [17], [19], [20],

TABLE 2. REVIEW MATRIX

No	Title	Methodology	VARIABLES		
			Technology	Sector	Metrics
1	A Blockchain Based Proposal for Protecting Healthcare Systems through Formal Methods [13]	Authors propose a Blockchain-based architecture to guarantee the reliability of IRMs, operating through the network of the health's institution. Said architecture includes IRM-based automata generation and equivalence validation. The proposed architecture uses Blockchain to secure sensitive information on the network.	Blockchain	Health (Medical Imaging Security)	Does not apply to the study
2	A Digital Twin Reference for Mass Personalization in Industry 4.0 [14]	This article explores the possible application of Digital Twin in the context of mass personalized manufacture. Authors identify critical disruptive technologies in the development of Digital Twin.	Authors claim Digital Twin extends technologies such as: Cloud Computing, Augmented Reality (AR), Additive Manufacturing, Big Data, Blockchain, Machine Learning and Artificial Intelligence.	Industrial (manufacture)	Three I's must be considered: -Intricacy -Integration level -Interval
3	A fuzzy rule-based industry 4.0 maturity model for operations and supply chain management [15]	Authors propose a maturity model regarding the use of disruptive technologies in manufacturing, relating them to operations and chain supply management (OSCM)	Industry 4.0 and, Smart OSCM	Industrial (manufacture)	The maturity model presented includes the following dimensions in a scale that ranges from 0 to 4: customer, logistic, supplier, planning and control, quality and, maintenance
4	A knowledge management and sharing business model for dealing with disruption: The case of Aramex [16]	The authors' case study on Aramex, a logistics organization, highlights the use of disruptive technologies like the "what three words" location system. This system, more general than coordinates but less specific than addresses, divides the world into 3x3 meter blocks, each assigned three static words, optimizing goods distribution processes.	Big data and, Smart Apps	Logistics	Does not apply to the study
5	Advanced Innovation Management: Best Practice of German and American Corporations in the Mobility Sector [17]	The study focuses on examining different strategies on innovation management. The strategies are appliable for a successful transformation of the IT activities of the firm. Authors propose a qualitative framework that seeks to close the gap in research related to corporative innovation frameworks.	Industry 4.0	Corporative (Mobility)	The following dimensions are identified for an innovation framework: Innovation processes, Organizational structure, Resources, Hygiene factors/Benefits, People and Culture, Strategy and, External Ecosystem.

TABLE 2. REVIEW MATRIX (CONT.)

No	Title	Methodology	VARIABLES		
			Technology	Sector	Metrics
6	Advancing digital transformation: Integrated digital transformation framework for a successful deployment [18]	The authors propose a framework that integrates methodologies for four identified spaces (business needs, problem, solution and operational) in organizational innovation. They match each space with the following technologies: Design Thinking, Agile SDLC, Waterfall SDLC and Change Management.	Artificial Intelligence (AI), Blockchain, Smart Sensors, Cloud Computing and Mobile Technology.	Logistics	Does not apply to the study
7	An empirical evaluation of industry 4.0 applications of companies in Turkey: The case of a developing country [19]	The article presents a case study on challenges of disruptive technologies adoption (Industry 4.0) in Turkey.	Industry 4.0	Industrial	The research identified the following metrics: company size, product technological level, presence of R&D, Industry 4.0 planning and strategies, resource allocation for Industry 4.0 (past and future two years), and ERP integration.
8	An intelligent framework using disruptive technologies for COVID-19 analysis [20]	This study describes a framework that uses disruptive technologies for the analysis of COVID-19. Each one of the disruptive technologies featured in the framework has at least a representative application in the context of health. The smart framework proposed aims to help governments, mainly health organizations.	Artificial Intelligence (AI), Industry 4.0, Internet of Medical Things (IoMT), Big Data, Virtual Reality (VR), Drones and automata, 5G and, Blockchain.	Health and Society	The following standardized health systems are tested by the framework: health service, health workforce, health information, medical technologies, health financing and, leadership and governance.
9	Artificial intelligence and the future of work: Human-AI symbiosis in organizational decision making [21]	In this paper, researchers aim to prove how AI can, instead of replacing, extend human intelligence in an executive context regarding decision making and uncertainty handling.	Artificial Intelligence (AI)	Organizational	Does not apply to the study
10	Blockchain and supply chain relations: A transaction cost theory perspective [22]	This study presents a conceptually developed set of propositions regarding the way Blockchain could affect governance costs and structures in supply chain management.	Blockchain	Organizational	Does not apply to the study

TABLE 2. REVIEW MATRIX (CONT.)

No	Title	Methodology	VARIABLES		
			Technology	Sector	Metrics
11	Blockchain technology in supply chain management for sustainable performance: Evidence from the airport industry [23]	The authors investigate the main implications of blockchain technology for operations management (OM), supply chain management (SCM), and decision making. The practical-theoretical study focused on relating blockchain, technology, operations sustainability, and supply chain management. They conducted a case study in the airport industry.	Blockchain, AI, Internet of Things (IoT), A-CDM system	Airports	Does not apply to the study
12	Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal [24]	A process model composed of nine microbases is proposed to determine the generic contingency factors that activate, promote and limit digital transformation. Disruptive technologies, according to the author, enable significant business improvements. It is examined how some representative firms in traditional industries build dynamic capabilities for digital transformation. The latter is conceptualized as a process of building dynamic capabilities for continuous strategic renewal.	Mobile technology, AI, Cloud Computing, Blockchain, IoT	Organizational	Three forms of digital transformation are proposed (renewal of business model, renewal of collective approach and renewal of culture). The following are also proposed as qualitative indicators: main trigger of digital transformation, scope of digital transformation, main dynamic capabilities discussed, achievements.
13	Digital Analytics: Modeling for Insights and New Methods [25]	This paper proposes a framework that uses digital analytics to generate relevant consumer information.	AI, Blockchain, IoT and Drone technology	Organizational	Does not apply to the study
14	Digital innovations-driven business model regeneration: A process model [26]	This study examines business models driven by digital innovation using a qualitative research approach.	Cyber-physical systems, EC, IoT, AI, Data Analytics (DA), Cloud Computing, Blockchain, MTs	Organizational	The impact levels of technologies were measured in the following dimensions: activities and capabilities, channels, cost structure, market segment/customers, customer relationship, partners, resources and competencies, revenue generation model, value proposition.

TABLE 2. REVIEW MATRIX (CONT.)

No	Title	Methodology	VARIABLES		
			Technology	Sector	Metrics
15	Digital transformation and tourist experience co-design: Big social data for planning cultural tourism [27]	The article presents a framework for the application of big social data in the co-design of tourism experiences.	Big Social Data	Tourism	Does not apply to the study
16	Digital twins in manufacturing: an assessment of drivers, enablers and barriers to implementation [28]	The authors conducted a study to determine what factors cause companies to seek to add Digital Twin to their manufacturing process, as well as the factors that enable these initiatives to succeed and identify the barriers that prevent or hinder their implementation.	Digital Twin (DT)	Industrial (Manufacture)	Initiators: external and internal Enablers: systems & technologies, processes, people & competencies, culture & strategy Barriers: systems and technologies, processes, people and competences, culture, and strategy
17	Expected impact of industry 4.0 technologies on sustainable development: A study in the context of Brazil's plastic industry [29]	A study was carried out to analyze the impact of Industry 4.0 technologies on economic, environmental, and social aspects.	Industry 4.0, Big Data, Smart Sensors, Cloud Computing, Cyber-physical systems, Robotics, IoT, Mobile technology, AI, M2M and Cybersecurity	Industrial	The following KPIs are identified: profitability, manufacturing cost, market share and sales, energy efficiency, water, and raw material consumption, use of renewable resources and recycling, total waste disposal, pollutant emissions, occupational health and safety, human resources and human rights, job creation, regulatory compliance.
18	Facilitating conditions for successful adoption of inter-organizational information systems in seaports [30]	This research seeks to identify factors that influence the successful adoption of inter-organizational information systems in seaports.	Inter-organizational information systems	Seaports	Does not apply to the study
19	How corporate social responsibility activities influence employer reputation: The role of social media capability [31]	The article presents a conceptual framework on the use of social networks and their positive influence on corporate social responsibility.	Social Media and Big Social Data	Organizational	Does not apply to the study

TABLE 2. REVIEW MATRIX (CONT.)

No	Title	Methodology	VARIABLES		
			Technology	Sector	Metrics
20	Impact of IT integration on the firm's knowledge absorption and desorption [32]	The authors propose as a research hypothesis that a company's ability to integrate its own IT systems with external partners will allow a better flow of knowledge for all parties, leading to better business performance.	IT systems integration	Industrial	Composite model from the operationalization of conceptual models. A table of the structural evaluation of the model consider metrics such as: capacity to integrate information technologies, capacity to disseminate knowledge, capacity to absorb the firm's knowledge and performance, size of the firm, investment in innovation, among others, are included.
21	Improving a production site from a social point of view: an IoT infrastructure to monitor workers condition [33]	The article proposes a methodical approach for the design of industrial information systems infrastructure for the automated control of workers' well-being. The results obtained from the different sensors were analyzed for the subsequent design of strategies that would contribute to the tranquility and reduce the stress levels of the collaborators.	IoT, Smart Sensors	Industrial	Does not apply to the study
22	Integrated intelligent water-energy metering systems and informatics: Visioning a digital multi-utility service provider [34]	The paper characterizes the transformative process of a utility service provider, focusing on system architecture, opportunities, benefits, impediments, strategies, and business opportunities. It demonstrates data modeling processes and real-time computational opportunities with examples and case studies.	Smart Sensors, 5G, Big Data	Public utilities	Performance metrics
23	Large scale quality transformation in hybrid development organizations - case study [35]	The article presents a case study describing the structural digital transformation of the quality management system for a hybrid development organization.	Machine Learning (ML), AI, connected data, integrated operations and Big Data	Industrial	Authors created the PIER quality measurement system based on defect management principles. Each phase has a metric and a key question: Prevention: Are we preventing defects effectively? Identification/Inspection: Are we detecting defects early and thoroughly?

TABLE 2. REVIEW MATRIX (CONT.)

No	Title	Methodology	VARIABLES		
			Technology	Sector	Metrics
					Evaluation: Are we prioritizing defect repairs? Elimination: Are we fixing defects accurately and promptly?
24	Mapping the challenges of Artificial Intelligence in the public sector: Evidence from public healthcare [36]	The authors conduct a study of the adoption of artificial intelligence in the context of public health in China. They used in particular IBM Watson.	AI	Health	Challenges are identified in the adoption of artificial intelligence in public health with respect to stakeholders: social, economic, ethical, political, and legal, organizational, data management and technological challenges.
25	Predictors of cloud computing adoption: A cross-country study [37]	The authors designed and validated a predictor model for the adoption of cloud computing by sampling 45 countries over the period of 2010-2015	Cloud Computing	Finance	The authors propose hypotheses in which they consider factors such as: - System quality. - Inclusion of broadband. - Inclusion of the Internet - Commercial openness - Participation of the service sector
26	Security Considerations in Big Data Solutions Adoption: Lessons from a Case Study on a Banking Institution [38]	The authors conducted a case study to learn about the process of appropriation of Big Data Solutions in three banking organizations in Malaysia. Semi-structured interviews were conducted with relevant company employees (with different roles and backgrounds) to determine security-related aspects at the technological, organizational, and environmental levels.	Big Data Solutions (BDS)	Finance (Banking)	Technological security, Environmental security, Organizational security
27	The change of pediatric surgery practice due to the emergence of connected health technologies [39]	The researchers conducted a case study analysis of the implementation of technologies for the care of patients scheduled for pediatric outpatient surgery. For this purpose, data collection was carried out with nurses and leading physicians.	IoT	Health	Does not apply to the study

TABLE 2. REVIEW MATRIX (CONT.)

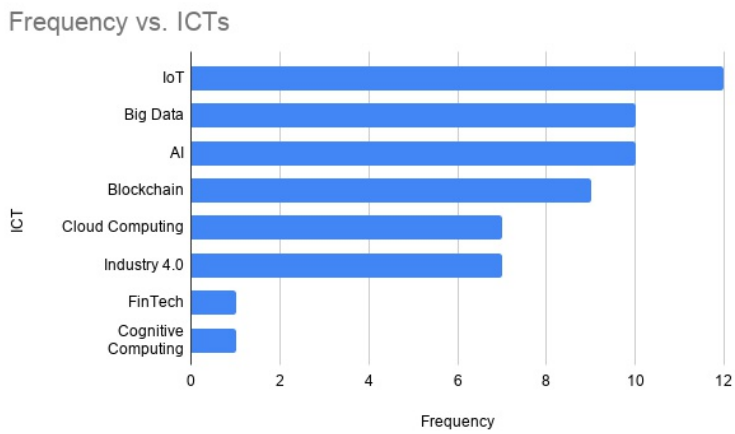
No	Title	Methodology	VARIABLES		
			Technology	Sector	Metrics
28	The effect of disruption technology, opportunities and challenges of telecommunication industry 4.0 in Indonesia [40]	The authors investigate the challenges for the implementation and standardization of Industry 4.0 in the field of telecommunications in Indonesia. A conceptual framework is proposed that relates technology orientation, market orientation, business model innovation, and examines their effects on competitive advantage	Industry 4.0, Cloud Computing, IoT, Cognitive Computing, Big Data Analytics	Telecommunications	Does not apply to the study
29	The evolution of the financial technology ecosystem: An introduction and agenda for future research on disruptive innovations in ecosystems [41]	The study defines disruptive innovation ecosystems. It illustrates the disruptive impact of FinTech as an ecosystem on the financial industry. The authors conceptually define the disruptive innovation ecosystem, analyze its impacts on the financial industry and propose a roadmap for further related research.	FinTech, Smartphone technology	• Organizational • Finance	Does not apply to the study
30	The smart circular economy: A digital-enabled circular strategies framework for manufacturing companies [42]	The authors propose a Smart CE (Circular Economy) framework that supports the conversion of key circular strategies in relation to the goals of manufacturing companies to achieve a balance of sustainable consumption and production.	Big Data Analytics, IoT	Industrial	Does not apply to the study
31	Understanding and extrapolation of disruption for engineering education-principles and problems [43]	The authors investigate the relationship between disruption, innovation, and engineering education; as well as proposing causes of failure and recommendations in the integration of disruptive technologies in the innovation-oriented engineering education system. They present Kingsmen Coffee, a start-up company located in India that relies on disruptive technologies, as a case study.	Cloud Computing, IoT	Education	Does not apply to the study

SOURCE: AUTHORS

[29], [40]. The latter, depending on the context, is used as a disruptive technology on its own merit or as a macro disruptive technology.

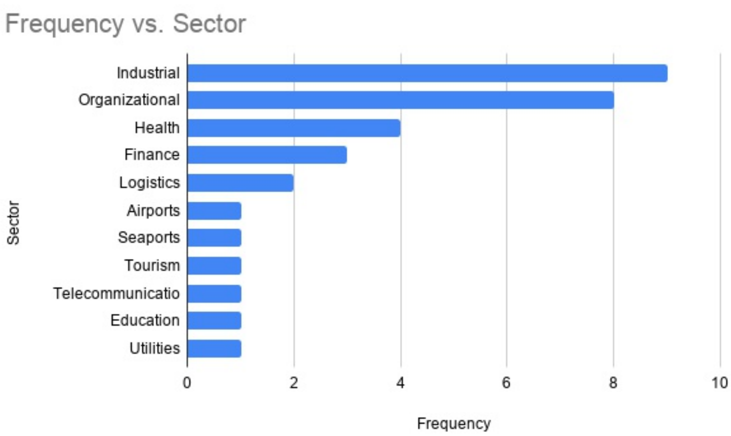
Finally, other technologies mentioned in the articles, although with low frequency, were Cognitive Computing [40]and Fintech [41]as they are found in specific market segments. Figure 2 depicts the above analysis.

Figure 2: Frequency vs ICTs



Source: Authors

Figure 3: Frequency vs. economic



Source: Authors

Economic Sector

The main sectors in implementing disruptive technologies identified in this review are: airports[23], education[43],finance ([37], [38], [41]), industrial ([14], [15], [19], [28], [29], [32], [33], [35], [42]), logistics ([16], [18]), organizational [17], [21], [22], [24]–[26], [31], [41],seaports[30], health[13], [20], [36], [39], utilities[34], telecommunications[40]and,tourism[27]. This analysis is depicted on Figure 3.
The variable referring to measurement indicators cannot be classified in the same way, since

each metric depends on the project being carried out.

4.1 Economic impact of disruptive technologies on the market

The significance of the disruptive technologies highlighted in this study can be reflected in various market indicators. The market indicators cited below suggest a high impact by disruptive technologies– the three most frequent according to the review are considered representative examples.

First, Internet of Things (IoT). According to Statista [44] global spending on the Internet of Things is projected to reach $1.1 trillion USD by 2023. There are at least 630 Internet of Things platforms registered in 2019, of which Amazon Web Service (AWS) leads in the cloud back-end segment and Cisco Jasper in the telecom segment. Continuing with other segments, in the context of home automation it is also estimated a consumption of Smart-Home systems of $115 billion USD in 2020. In the context of smart agriculture, revenues of $14.79 billion USD were recorded in 2018. In terms of data traffic, 79.74 ZB of traffic is projected globally by 2025.

Second, Big Data. According to Statista [45] revenues related to Big Data and Business Analytics were valued at $189.1 billion US dollars in 2019. Of these revenues, those related to software solutions total $67 billion US dollars in 2019. The source goes on to project a data volume generated of 149 ZB globally in 2024. Among its major segments are: analytics and business intelligence software (revenue of $24 billion USD in 2018), advanced and predictive analytics software (revenue of $3.47 billion USD in 2019), data analytics integration and integrity software (revenue of $3.37 bn USD in 2019), and Data as a Service (DaaS, a cloud computing deployment model) with market size of $8.9 billion USD in 2020. As of 2020, 541 hyperscale (sic) data centers are registered globally.

Third, Artificial Intelligence (AI). According to Statista [46] AI software market revenues totaled $10.1 billion USD in 2018. It reports a market growth of 54% in 2030 and the contribution of Artificial Intelligence to China's gross domestic product is estimated to be 26.1% in 2030. Its major segments include: cognitive and AI systems (with market valued at $12.7 billion USD in 2019), AI-based business operations (with global revenue projected at $10.8 billion USD by 2023), natural language processing (with a projected market size of $43.3 billion USD to 2025) and, chatbots with reported revenue in 2020 of $65.5 million USD.

The indicators described above show the scale and relevance of the application of the disruptive technologies identified in multiple contexts.

4.2. Industry 4.0: definition, technologies, challenges and, impacts

4.2.1. Definition

Caiado et al. [15]found I4.0 as a highly complex concept and recognize the lack of consensus in the definition of the term Industry 4.0. Authors found three different definitions in literature: the trend towards digitalization and automation of the manufacturing environment, a confluence of different digital technologies and, a new paradigm for industrial processes focused on digital transformation.

On the other hand, the definition of Industry 4.0 proposed by Yüksel [19]is: a group of collaborative technologies and concepts that embraces an organization's entire value chain. Authors [47]define Industry 4.0 as the end-to-end integration of the value chain ranging from the detection of changes in the demands of customers to their satisfaction by means of smart factories. Authors follow by stating that in the context of Industry 4.0 the usage of existing and emerging technologies is focused on the creation of smart products and services. A product (or service) is deemed smart when it can acquire data autonomously and behave accordingly to the data based on a process algorithm incorporated in the product (or service). Disruptive technologies should be present on all production related processes [47].

Based on the results, we propose the following definition for Industry 4.0. Industry 4.0 is the trend towards digitalization of industry to optimize the entire supply chain management by inserting disruptive technologies, the processes and methods used towards digital transformation. Besides, Industry 4.0 includes the technological, social, economic, cultural, environmental and educational impacts of digital transformation.

4.2.2. Technologies

There is no consensus in the literature regarding the technologies that are critical for Industry 4.0. However, several technologies appear consistently across the sets proposed by different authors. The set of technologies proposed by each author is presented in Table 3.

Table 3. Technologies proposed by authors.

Although most of the literature considers additive manufacturing (3D printing) as a key pillar of Industry 4.0, research conducted by Nara et al.[29]shows that expert practitioners in the plastic industry in Brazil did not consider additive manufacturing as a critical technology of Industry 4.0. This could be because most of companies in Brazil are SMEs. Yüksel [19] points out that for SMEs in Turkey the least frequent technology is in fact additive manufacturing.

4.2.3. Challenges

Digital transformation as a trend has introduced great challenges for companies when adopting new technologies. Besides from the expected technical insertion and appropriation challenges, resistance to change by the employees and inflexibility to change organizational processes should be taken into account.

Caiado et al.[15]identify as a critical research challenge related to I4.0 the definition and validations of its constructs, such as I4.0 maturity and readiness. Authors confront this challenge by proposing a fuzzy rule-based I4.0 maturity model (MM) in the context of operations and supply chain management. Maturity models aim to help organizations by assessing and tracking the process of improvement initiatives, such as digital transformation. In this sense, digitalization is expected to add value to the company.

Yüksel [19]points out the difficulty for companies “to understand the concept of Industry 4.0 and how the transition can be accomplished.” The author also identifies the high degree of uncertainty over the “achievement criteria and performance measurements of the Industry 4.0 transformation”. Thus, companies may be unwilling to promote digital transformation initiatives as the gains of such transformation processes are unclear to them and its potential consequences in industry are not clearly defined.

According to Nara et al.[29]SMEs face more significant financial and economic challenges than large companies in the appropriation of Industry 4.0 practices. Thus, there exists a correlation between the size of the company and the level of Industry 4.0 appropriation. Yüksel [19]agrees, there is a strong correlation between company size and level of implementation of I4.0 initiatives, where large companies are associated with a higher

TABLE 3. TECHNOLOGIES PROPOSED BY AUTHORS.

Reference	Selected technologies	Application sector
[15]	Authors identify the following technologies as the main technologies that enable I4.0: 3D printing, Big Data and advanced algorithms, augmented reality/wearables, Cloud Computing, IoT and robotic systems. Furthermore, authors present cyber physical systems, cybersecurity and, Blockchain as I4.0 technologies	Operations and Supply Chain Management
[19]	The author identifies as critical technologies for I4.0: Cyber-physical systems (CPS), Internet of Things and, Internet of Services. The author defines CPS as the aggregation of smart machines, warehousing systems, and production facilities developed digitally and featuring end-to-end ICT-based integration. According to the author, I4.0 and CPS are sometimes used as synonyms. Furthermore, the author quotes as additional technologies: cloud computing, 3D printing, Big Data, autonomous robots, simulation, horizontal and vertical system integration and, augmented reality.	General Industrial
[29]	Technologies selected by the author as part of Industry 4.0 are: vertical and horizontal integration, autonomous robots, simulation, IoT, AR, Cloud Computing, Big Data, additive manufacturing, Cybersecurity. However, ICTs such as Blockchain, AI and, 5G are not considered part of the Industry 4.0 but as enablers of the change from mass production towards mass personalization.	Plastic Industry
[48]	The author claims the list of Industry 4.0 technologies grows as new technologies emerge and mature according to market trends. Next, he presented the following technologies as the most common in the literature: Machine Learning, Big data and analytics, IoT, Industrial IoT, Augmented reality, Additive manufacturing, simulation and, autonomous robots.	General Industrial
[47]	According to the author the following technologies will transform positively the production: Autonomous Robots, simulation, horizontal and vertical integration, IoT, Cybersecurity, Cloud computing, Additive manufacturing, Augmented reality and, Big data.	General Industrial
[14]	Authors include as Industry 4.0 technologies: autonomous robots, cloud, Big Data, IoT, AR, simulation, horizontal and vertical integration, cyber security and, additive manufacturing. Blockchain, AI and 5G are excluded from Industry 4.0 according to the authors.	General Industrial

SOURCE: AUTHORS

degree of appropriation. However, in their survey they found that the technological level of the products manufactured, and the existence of an R&D department have a higher impact on the level of Industry 4.0 practices than the size of the company. Other factors that affects considerably the level of Industry 4.0 practices, identified by the author, are the social and economic conditions of the countries.

On the other hand, Müllerand Voigt[49]conducted a series of interviews to experts partitioners of different areas of companies. They found the most common expected challenges to be: breakdown susceptibility, insufficient data quality, insufficient IT infrastructure, access to technologies, Insufficient data security, inconsistent standards, technological dependence, fear of employees to be replaced, insufficient financial resources, insufficient Know-how and, Insufficient understanding. Furthermore, Niewöhneret al. [50]outline the following challenges for digital transformation: low barriers to market entry, sales loss, strong focus on everyday business, synchronization innovation cycles, internal company processes too rigid and too lengthy, lack of motivation, limited resources for innovative work, limited adaptability in the development process and, identification of new ways of thinking and approaches.

We consider that the challenges outlined by the authors are relevant as digital transformation in the context of Industry 4.0 is a process that demands a considerable investment that many companies, especially SMEs, cannot cope with. In addition to this, digital transformation also requires social and cultural efforts to handle challenges such as employees fearing displacement by new technologies. Furthermore, organizations and people are interested in keeping their privacy thus introducing resistance to change and a high demand for cybersecurity.

4.2.4. Impacts

Industry 4.0 as a trend has brought several economic, social, cultural, educational and environmental impacts. Hirte and Roth [17]claim that new digital technologies (disruptive technologies) “significantly facilitate firms’ business processes, including for instance the communication between employees and electronic systems or the customer experience”. Usually, companies are applying disruptive technologies in the context of Industry 4.0 across the entire supply chain management processes set. Garrell and Guilera[47]identify the following six stages of production: design, fabrication, distribution, acquisition and purchase, usage and, recycling. In the context of Industry 4.0 all stages should be managed digitally in aims of achieving integral management.

According to Peña and Hernández [6],Industry 4.0 technologies generate value in the supply chain management, in all organizational processes and, in the company’s environment through innovation by focusing changes in improvement opportunities. Niewöhneret al. [50]claim that the fourth industrial revolution will increase the willingness to innovate. They identified seven impacts of I4.0: digital market services, high volume of data, fast changing customer requirements, shortening innovation cycles, rapid technological change, increased use of software and, stronger service orientation. Niewöhneret al.[50]points out the speed at which customer requirements change following to the inclusion of disruptive technologies and changes in the market. This happens more frequently when the development initiatives involve long periods of time. Following, Caiado et al.[15]claim I4.0 introduces innovation in three senses: horizontal integration, vertical integration and, end-to-end integration. In the context of I4.0, traditional (hard or technical) skills are not as important as before and adaptability to new job requirements (including non-technical skills) becomes paramount to the survival of employees.

According to Yüksel [19], Industry 4.0 will augment companies’ production processes through the integration of intelligent and automated mechanisms in the industrial environment. Furthermore, the author identifies possible advantages of I4.0 such as increased productivity, efficiency and flexibility, and reduced costs. Appropriation of Industry 4.0 applications can include benefits such as digital individualization, company flexibility, demand orientation, sustainability, consistent process, automated knowledge and learning, and productivity optimization [19].

In terms of sustainability, Nara et al. [29] claim that technological changes introduced by the fourth industrial revolution could lead to the creation of circular economies as smart systems provide better energy consumption at a factory level. Yüksel [19]also outlines the sustainability contribution of Industry 4.0. On their study, Nara el al. [29]demonstrate that technologies such as IoT, CPS, sensors and Big Data can boost the sustainable development of industries.

CONCLUSIONS

This paper reports on state of the art in terms of the adoption of disruptive technologies, specifically those related to Information and Communication Technologies (ICTs) in the framework of organizations from different economic sectors.

In order to carry out the literature review, a sample of 31 articles was selected out of 75 found after filtering using established inclusion and exclusion criteria, which were published in the last five years and were scientific articles. During this search, the emergence of literature on this topic, which is becoming more relevant every day, became evident. At the same time, there was a scarcity of literature reviews on the subject, which makes the present one even more valuable.

The 31 articles selected and addressed in this study present success stories in the inclusion of ICTs in a disruptive way in organizations. Although [3] states that the adoption of disruptive technologies can, in many cases, lead to failure in large-scale companies, the studies reviewed fit the model presented by the author in [7] for success in the process of such adoption in the face of the imperative of growth. These, as well as this literature review, can be taken as a starting point for future research and development in this area.

Regarding Industry 4.0, this study shows findings regarding the definition of Industry 4.0 in the literature and proposes an integral definition. Following, we analyzed which disruptive technologies were considered by authors and practitioners as part of Industry 4.0. Finally, we show the main challenges and impacts of Industry 4.0 reported in literature. Further research should be aimed at studying how future disruptive technologies affect Industry 4.0, which are the most common and their application fields and, how can companies use digital transformation towards the achievement of Industry 4.0.

REFERENCES

[1] N. Jesse, “Organizational Evolution - How Digital Disruption Enforces Organizational Agility,” IFAC-PapersOnLine, vol. 51, no. 30, pp. 486–491, 2018, doi: 10.1016/j.ifacol.2018.11.310.

[2] H. C. D. Pablos, H. A. J. J. López, and R. S. Martín-Romo, Organización y transformación de los sistemas de información en la empresa, 4th ed. 2019.

[3] C. Christensen, The innovator’s dilemma: When new technologies cause great firms to fail. Harvard Business Review Press, 1997.

[4] A. I. Basco, G. Beliz, D. Coatz, and P. Garnero, Industria 4.0: Fabricando el Futuro. 2018.

[5] A. Sood and G. J. Tellis, “Demystifying disruption: A new model for understanding and predicting disruptive technologies,” Mark. Sci., vol. 30, no. 2, pp. 339–354, Mar. 2011, doi: 10.1287/mksc.1100.0617.

[6] C. Pena Andres and E. M. Hernandez Ramos, Cadena de suministro 4.0: beneficios y retos de las tecnologias disruptivas. Marge Books, 2018.
[7] C. Christensen and M. Raynor, The innovator's solution: Creating and sustaining successful growth. Harvard Business Review Press, 2013.
[8] B. Kitchenham, "Guidelines for performing Systematic Literature Reviews in Software Engineering," 2007.
[9] "Technology | Definition of Technology by Merriam-Webster." https://www.merriam-webster.com/dictionary/technology (accessed Apr. 08, 2021).
[10] "Information and communication technologies (ICT) | UNESCO UIS." http://uis.unesco.org/en/glossary-term/information-and-communication-technologies-ict (accessed Apr. 08, 2021).
[11] "sector noun - Definition, pictures, pronunciation and usage notes | Oxford Advanced Learner's Dictionary at OxfordLearnersDictionaries.com." https://www.oxfordlearnersdictionaries.com/us/definition/english/sector?q=sector (accessed Apr. 08, 2021).
[12] The Institute of Electrical and Electronics Engineers, "IEEE Standard Glossary of Software Engineering Terminology." 1990.
[13] L. Brunese, F. Mercaldo, A. Reginelli, and A. Santone, "A blockchain based proposal for protecting healthcare systems through formal methods," Procedia Comput. Sci., vol. 159, pp. 1787–1794, 2019, doi: 10.1016/j.procs.2019.09.350.
[14] S. Aheleroff, R. Y. Zhong, and X. Xu, "A digital twin reference for mass personalization in industry 4.0," Procedia CIRP, vol. 93, pp. 228–233, 2020, doi: 10.1016/j.procir.2020.04.023.
[15] R. G. G. Caiado, L. F. Scavarda, L. O. Gavião, P. Ivson, D. L. de M. Nascimento, and J. A. Garza-Reyes, "A fuzzy rule-based industry 4.0 maturity model for operations and supply chain management," Int. J. Prod. Econ., vol. 231, no. November 2019, 2021, doi: 10.1016/j.ijpe.2020.107883.
[16] L. v. Alberti-Alhtaybat, K. Al-Htaybat, and K. Hutaibat, "A knowledge management and sharing business model for dealing with disruption: The case of Aramex," J. Bus. Res., vol. 94, no. November 2017, pp. 400–407, 2019, doi: 10.1016/j.jbusres.2017.11.037.
[17] R. Hirte and P. Roth, "Advanced innovation management: Best practice of German and American corporations in the mobility sector," PICMET 2018 - Portl. Int. Conf. Manag. Eng. Technol. Manag. Technol. Entrep. Engine Econ. Growth, Proc., 2018, doi: 10.23919/PICMET.2018.8481904.
[18] M. Majdalawieh, "Advancing digital transformation: Integrated digital transformation framework for a successful deployment," Proc. Int. Conf. Ind. Eng. Oper. Manag., no. 2012, pp. 439–447, 2019.
[19] H. Yüksel, "An empirical evaluation of industry 4.0 applications of companies in Turkey: The case of a developing country," Technol. Soc., vol. 63, no. September, p. 101364, 2020, doi: 10.1016/j.techsoc.2020.101364.
[20] M. Abdel-Basset, V. Chang, and N. A. Nabeeh, "An intelligent framework using disruptive technologies for COVID-19 analysis," Technol. Forecast. Soc. Change, no. July, p. 120431, 2020, doi: 10.1016/j.techfore.2020.120431.
[21] M. H. Jarrahi, "Artificial intelligence and the future of work: Human-AI symbiosis in organizational decision making," Bus. Horiz., vol. 61, no. 4, pp. 577–586, 2018, doi: 10.1016/j.bushor.2018.03.007.
[22] C. G. Schmidt and S. M. Wagner, "Blockchain and supply chain relations: A transaction cost theory perspective," J. Purch. Supply Manag., vol. 25, no. 4, p. 100552, 2019, doi: 10.1016/j.pursup.2019.100552.
[23] A. Di Vaio and L. Varriale, "Blockchain technology in supply chain management for

sustainable performance: Evidence from the airport industry," Int. J. Inf. Manage., vol. 52, no. October 2019, p. 102014, 2020, doi: 10.1016/j.ijinfomgt.2019.09.010.

[24] K. S. R. Warner and M. Wäger, "Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal," Long Range Plann., vol. 52, no. 3, pp. 326–349, 2019, doi: 10.1016/j.lrp.2018.12.001.

[25] S. Gupta, A. Leszkiewicz, V. Kumar, T. Bijmolt, and D. Potapov, "Digital Analytics: Modeling for Insights and New Methods," J. Interact. Mark., vol. 51, pp. 26–43, 2020, doi: 10.1016/j.intmar.2020.04.003.

[26] A. Coskun-setirek and Z. Tanrikulu, "Technology in Society Digital innovations-driven business model regeneration : A process model," Technol. Soc., vol. 64, no. March 2020, p. 101461, 2021, doi: 10.1016/j.techsoc.2020.101461.

[27] M. T. Cuomo, D. Tortora, P. Foroudi, A. Giordano, G. Festa, and G. Metallo, "Digital transformation and tourist experience co-design: Big social data for planning cultural tourism," Technol. Forecast. Soc. Change, vol. 162, no. September 2020, p. 120345, 2021, doi: 10.1016/j.techfore.2020.120345.

[28] A. A. Neto, F. Deschamps, E. R. Da Silva, and E. P. De Lima, "Digital twins in manufacturing: An assessment of drivers, enablers and barriers to implementation," Procedia CIRP, vol. 93, pp. 210–215, 2020, doi: 10.1016/j.procir.2020.04.131.

[29] E. O. B. Nara et al., "Expected impact of industry 4.0 technologies on sustainable development: A study in the context of Brazil's plastic industry," Sustain. Prod. Consum., vol. 25, pp. 102–122, 2021, doi: 10.1016/j.spc.2020.07.018.

[30] C. Vairetti, R. G. González-Ramírez, S. Maldonado, C. Álvarez, and S. Vo$β$, "Facilitating conditions for successful adoption of inter-organizational information systems in seaports," Transp. Res. Part A Policy Pract., vol. 130, no. January, pp. 333–350, 2019, doi: 10.1016/j.tra.2019.09.017.

[31] J. Benitez, L. Ruiz, A. Castillo, and J. Llorens, "How corporate social responsibility activities influence employer reputation: The role of social media capability," Decis. Support Syst., vol. 129, no. November 2019, p. 113223, 2020, doi: 10.1016/j.dss.2019.113223.

[32] J. Braojos, J. Benitez, J. Llorens, and L. Ruiz, "Impact of IT integration on the firm's knowledge absorption and desorption," Inf. Manag., vol. 57, no. 7, p. 103290, 2020, doi: 10.1016/j.im.2020.103290.

[33] F. Gregori, A. Papetti, M. Pandolfi, M. Peruzzini, and M. Germani, "Improving a production site from a social point of view: An IoT infrastructure to monitor workers condition," Procedia CIRP, vol. 72, pp. 886–891, 2018, doi: 10.1016/j.procir.2018.03.057.

[34] R. A. Stewart et al., "Integrated intelligent water-energy metering systems and informatics: Visioning a digital multi-utility service provider," Environ. Model. Softw., vol. 105, pp. 94–117, 2018, doi: 10.1016/j.envsoft.2018.03.006.

[35] S. Pradhan and V. Nanniyur, "Large scale quality transformation in hybrid development organizations – A case study," J. Syst. Softw., vol. 171, p. 110836, 2021, doi: 10.1016/j.jss.2020.110836.

[36] T. Q. Sun and R. Medaglia, "Mapping the challenges of Artificial Intelligence in the public sector: Evidence from public healthcare," Gov. Inf. Q., vol. 36, no. 2, pp. 368–383, 2019, doi: 10.1016/j.giq.2018.09.008.

[37] K. Vu, K. Hartley, and A. Kankanhalli, "Predictors of cloud computing adoption: A cross-country study," Telemat. Informatics, vol. 52, no. November 2019, p. 101426, 2020, doi: 10.1016/j.tele.2020.101426.

[38] K. A. Salleh and L. Janczewski, "Security Considerations in Big Data Solutions Adoption: Lessons from a Case Study on a Banking Institution," Procedia Comput. Sci., vol. 164, pp. 168–176, 2019, doi: 10.1016/j.procs.2019.12.169.

[39] R. Niemelä, M. Pikkarainen, M. Ervasti, and J. Reponen, “The change of pediatric surgery practice due to the emergence of connected health technologies,” Technol. Forecast. Soc. Change, vol. 146, no. April, pp. 352–365, 2019, doi: 10.1016/j.techfore.2019.06.001.
[40] L. Arifiani and L. Arifiani, “The Effect of Disruption Technology, Opportunities and Challenges of Telecommunication Industry 4.0 in Indonesia,” Int. J. Recent Technol. Eng., no. 6, pp. 808–819, 2019.
[41] M. Palmié, J. Wincent, V. Parida, and U. Caglar, “The evolution of the financial technology ecosystem: An introduction and agenda for future research on disruptive innovations in ecosystems,” Technol. Forecast. Soc. Change, vol. 151, no. November 2019, p. 119779, 2020, doi: 10.1016/j.techfore.2019.119779.
[42] E. Kristoffersen, F. Blomsma, P. Mikalef, and J. Li, “The smart circular economy: A digital-enabled circular strategies framework for manufacturing companies,” J. Bus. Res., vol. 120, no. August 2019, pp. 241–261, 2020, doi: 10.1016/j.jbusres.2020.07.044.
[43] R. S. Chandu and S. G. S. Chandu, “Understanding and extrapolation of disruption for engineering education-principles and problems,” Procedia Comput. Sci., vol. 172, no. 2019, pp. 1066–1076, 2020, doi: 10.1016/j.procs.2020.05.156.
[44] S. Liu, “Internet of Things (IoT) - Statistics & Facts | Statista,” Jul. 2020. .
[45] S. Liu, “Big data - Statistics & Facts | Statista,” Oct. 2020. .
[46] S. Liu, “Artificial Intelligence (AI) worldwide - Statistics & Facts | Statista,” Mar. 2020. .
[47] A. Garrell Guiu and L. Guilera Aguella, La industria 4.0 en la sociedad digital. Marge Books, 2019.
[48] J. Martinez Aguilo, Industria 4.0: la transformacion digital en la industria. Editorial UOC, 2019.
[49] J. M. Müller and K. I. Voigt, “The Impact of Industry 4.0 on Supply Chains in Engineer-to-Order Industries - An Exploratory Case Study,” vol. 51, no. 11, pp. 122–127, 2018, doi: 10.1016/j.ifacol.2018.08.245.
[50] N. Niewöhner, L. Asmar, D. Röltgen, A. Kühn, and R. Dumitrescu, “The impact of the 4th industrial revolution on the design fields of innovation management,” Procedia CIRP, vol. 91, pp. 43–48, 2020, doi: 10.1016/j.procir.2020.02.149.