Edited by
Salvador Estrada

Digital and Sustainable Transformations in a Post-COVID World

Economic, Social, and Environmental Challenges

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ISBN 978-3-031-16676-1 ISBN 978-3-031-16677-8 (eBook)
https://doi.org/10.1007/978-3-031-16677-8

This Palgrave Macmillan imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

To my parents, Elsa and Salvador, always admired, my beloved wife Maribel, my refuge and half are her merits, to my children Greta and Chavo, my engines. Thank you for your love, patience, help, and understanding.

—Salvador Estrada

Preface

The worst of times in 50 years. Wars, pandemics, and climate change. In addition, to civil and drug wars, ethnic violence, and terrorist insurgencies, now we are suffering a Geopolitics war. Over a half billion infected people and 6 million passed away. Climate change worsens natural disasters such as floods, drought, wildfires, and hurricanes. Pain, life losses, grief and suffering, exodus, and famine. In brief a humanitarian disaster.

No doubt, these conditions exercise pressure to accelerate a transformation. Global warming warns of carbon dependence. Change demands large-scale investments in renewable energy, but this solution is not contradiction-free. This technology requires rare earth minerals and other scarce and non-renewable materials found in a few countries. In times of deglobalization, opening trade is demanded to enable such a transformation. We are living for these conditions: severe economic disruptions, higher costs of living, energy, commodities, and food price shocks.

How is the world after a persistent COVID-19 pandemic? The COVID-19 pandemic is a decreasing worry since several parts of the world are becoming endemic, but we still suffer its impacts manifested in inflation, energy prices, and supply chain disruption. Nonetheless, the outlook for the economy is perceived as dark since the conflict in Ukraine and the threat of new virus strains and variants as other zoonotic diseases. So, the 2021 economic recovery has a turndown and provokes a cautious sentiment.

Lessons learned during the confinement: we have a tough time addressing current inclusive and sustainable growth challenges. In manufacturing, innovation is required to revitalize the industries. In business, there has been a change in values expressed in a new awareness of sustainability and inclusion. A new or renewed commitment to these approaches is obligated to cope with changes in customer behaviors. Another rising topic during the lockdown was the access to financial services as a barrier to inclusive and sustainable growth. It is costly but can be affordable and accessible using digital tools. Certainly, the digitalization of the economy was a pre-existing trend before COVID-19, but the measures to cope with it accelerated the Digital Economy. The need to get together triggers the current necessity to stay in touch with people, customers, suppliers, citizens, and the government. The unpredictability of the virus evolution generates a fragility and vulnerability feeling, so a new concern of life and livelihood. The various measures designed to coexist with the virus, such as social distancing, the use of masks, confinement, testing, and vaccination, have proven useful, but they are not a definitive solution; rather, they resemble a complex world in which only temporary solutions can be achieved and the interdependencies between them and the uncertainty they generate grow exponentially. The pandemic reduces our planning horizons and shows us how unpredictable and uncertain the future may be. International cooperation must develop resilience to pursue sustainable and inclusive development, especially dealing with high uncertainty. For example, when coping with the pandemic, international collaboration has successfully developed the vaccines and treatments, but we do not know their efficacy, immunity-induced period, or policies for the next doses.

In a Post-COVID world, the economy is coupled with the epidemic; the virulence and contagion capacity indicates the economy's slowdown, disrupting the supply chains, labor markets, and inflation and interest rates. This integration affects the mobility of people and goods through international trade, the travel and tourism industry, and manufacturing and retailing activities. In this coupling, several interrelations are on stakes like climate, health care, labor needs, digitalization, and inequalities. So, an agenda emphasizing resilience for sustainable and inclusive growth is required for a better future.

The challenge for business is to involve permanent change. Strategy management must be improved, value proposals reshaped, talent renewed, capabilities recast, and leadership revamped to recover from crises. In this dynamic, evolving landscape, technology plays a critical role. Having a strong technological base is not sufficient. Continuous investment in technology and capabilities is needed to get adaptability. It is not a question of planning and budgeting; it is about predictive capabilities, agile and lean responses, and innovation. The digital transformation is embedded in all these new requirements to survive in a Post-COVID world. The academic and professional literature, the thinking tanks, the business consultants, and the international and national agencies to foster economic development talk about the configuration and irruption of a new business model, the driven-data enterprise. And this may not ignore the environmental and societal concerns. It must properly uptake its corporate DNA culture and strategy from the beginning.

This book is devoted to hope. The long lockdown and a vulnerability condition have given pace to solidarity, empathy, benevolence, and compassion—new realization and care for life and livelihood. Confinement has been made possible by digital technologies. Disruptions in how people live, work and live together have led to recent concerns about privacy and intimacy. Furthermore, the crisis has sublimed the creativity of humankind. The motto was to innovate in a time of crisis to cope with extraordinary times. Nonetheless, the complexities and tensions of digital transformation have been laid bare. Inadequate digital infrastructures, lack of skills, and access gaps were revealed as ineffective public policies for social security, healthcare, economic promotion, and a destructive relationship with the natural environment.

During the pandemic, universities and research centers have learned to accommodate their work in a digital and remote mode. And this was the case for this publication. In this complex scenario, two book-related calls for papers were made, one for a Conference and the other for book chapters. Due to the difficulties in carrying out academic work, we moved from sequential to parallel programming and from pre-publication to post-publication. Thus, most of the chapters were collected in a preliminary version at the RIDIT International Virtual Conference (ICRIDIT 2022), which has been discussed in thematic sessions. It should be noted that all the papers presented in this book were subject to double-blind refereeing.

Academics with diverse backgrounds and expertise contributed to this book. It collected the views from several scholars cultivating a myriad of knowledge areas, including Accounting, Business Management, Change Management, Development Economics, Economics of Innovation, Entrepreneurship, Financial Management, Higher Education Management, Human Resources Management, Information Systems Management, Innovation and Technology Management, Marketing, Natural Resources Management, Organizational Science, Political Economy, and Sociology.

They work under diverse conditions and circumstances, as reflected in their institutional affiliations ranging from academic departments, faculties, research institutes and centers, and doctoral programs to international advisory offices. In addition, academics are members of scientific societies, professional associations, journals, research networks, and international organizations.

A precious thing to note in this book is that intellectual contributions held gender equity. Nineteen women and eighteen men collectively reflected. And it is noteworthy that several scholars (and reviewers as well), upon reflection, writing, discussing, and retrieving, have gotten ill, convalescent, and, fortunately, healed from COVID-19. Needless to point, the shared considerations developed from the intimacy of home with the day-to-day struggles with personal lives.

This book aims to further our knowledge of "glocal" COVID-19 crisis consequences and new needs and practices in disseminating digital technologies and their potential impacts on sustainability. The book covers political, social, and economic matters and the global study of organizations and their digital and natural resources management. This story is told from other parts of the world that grants visibility to issues, processes, people, and places positioned off-mainstream. Mainly Latin America, but a few South Asia experiences, visions, and needs are expressed throughout this volume. During the COVID-19 pandemic, the businesses survive as the ecosystems evolve, the interconnectedness expands despite skills lacking as the optime infrastructure, the affordability and accessibility and imbalances persist and may deep inside countries. The book, starting from a global view, sheds light on how digital transformation can cope with a weak institutional system, how it can benefit from the resilience of organizations, and the willingness to embrace digital technologies and pursue environmental and social solutions purposefully.

This book provides a valuable resource to document history, insightful for policy making, a compass for researchers, and a keen awareness of the future for scholars and students in a myriad of disciplines, undergraduate and postgraduate, as well as to a general audience. The publication grants rich resources to discuss pertinent issues and challenges faced by governments, organizations, firms, and society. This book also may reference researchers and business executives who need both the theoretical and practical elements in understanding the subject matter about digital and sustainable transformations, innovation, culture, and business excellence to achieve sustainable and learning organizations—anyone who posits hope for a better future.

The aftermath of the crisis must provide a path to recovery. The content of this book raises alarm bells about the critical role that the government must play in upgrading the current infrastructure, training the population in digital technology, and supporting private efforts to upgrade technology and modernize facilities. These should be the propelling efforts of society and industry to embrace and leverage digital transformation resolutely oriented toward a sustainable and lasting change with a holistic and inclusive scope, encompassing not only the economic sphere but also the environmental and social spheres.

The editing of this book has been lived as an act of survival and has been done with feelings of gratitude for the life and support of colleagues, editors, and, especially, our families. We want to thank our publishers at Palgrave Macmillan for giving us the opportunity and trust to work on this book. Also, we are grateful to our authors who have prepared their chapters with loving care and hopeful perspectives, and reviewers who have read the manuscripts in high demand and difficult times and yet provide invaluable insights, as this publication, without their help and support, would not have been possible. A special thanks to everyone, stakeholders on this book, the Research and Teaching Network on Technological Innovation, members and board of directors, the general coordination of the International Entrepreneurship Lab Smart Money, the University of Guanajuato, as well as to all the people promoting, organizing, and discussing, this publication and its twin effort, the international e-Conference of the RIDIT (ICRIDIT 2022 Berlin-Celaya). Lastly, families, relatives, friends, colleagues, and students share daily struggles to keep on with academic work.

Salvador Estrada, with hopeful wishes for a better future, even living in the top ranked violent city in the World, Celaya, Guanajuato, Mexico.

Celaya, Mexico Salvador Estrada

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PART I

Introductory Chapters

CHAPTER 1

Digital and Sustainable Transformation: An Outcoming Response to the Pandemic

Salvador Estrada and Juan Reyes Álvarez

1.1 Introduction

At the end of 2019, the World was awakening from the Great Crisis. In Digital Economic, the discussion was on how to tax digital services while in climate action and sustainable development, developing the transition toward a sustainable, carbon–neutral Economy. Severe Acute Respiratory Syndrome Coronavirus 2 and its variants keep the World on a permanent fight against a health crisis leading the Economy to a permanent shock.

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S. Estrada (ed.), *Digital and Sustainable Transformations in a Post-COVID World*, https://doi.org/10.1007/978-3-031-16677-8_1

The measures for contending the pandemics have included several lockdowns of economic activities extending digital activities and restraining environmental impacts. While the first has been chosen intentionally in search of normality, the other has been a secondary effect, unintended but highly revealing of the catastrophe in progress. This double reaction encloses a timely and convenient change toward accelerating an underway transformation. Improving the knowledge of this dual Digital and Sustainable Transformation is a pending task to enhance the World's resilience capacity to cope with crises.

Since there is a lack of studies showing the emergence of digital and sustainable transformation, this work aims to pursue a systematic review to foresee a research agenda and future development of this double transformation in a Post-COVID World. A thorough examination of the state-of-art is presented to accomplish this objective. A bibliometric analysis is then prepared to structure the research topics and develop insights on the becoming of the research on Digital and Sustainable Transformation. The transformation is in transitional mode impacting the economic dimension of sustainability and gaining momentum through an ethical and relational view of the innovation process and business models crafting opportunities to pursue environmental and societal impacts on sustainability. The challenge is open to harnessing a complex and systemic phenomenon with many expectations to lead word recovery from the pandemic outbreak.

1.2 Literature Review

1.2.1 The Digital Transformation as a Point of Departure

Worldwide there has been an increasing interest in digital transformation. As soon as 2015, prominent organizations and consulting firms, such as World Economic Forum and MIT or Deloitte and Accenture [1], have stressed the irruption of the phenomena. A 2017 survey showed that at least 50% of firms planned to adopt a digital transformation strategy among multinational enterprises.

As a matter of study, digital transformation has been treated as a change process. In private and public sectors and the social domain, modern communication and information technologies have been adopted as changes in the performance, structure, and culture of individuals, organizations, and ecosystems have been taking place. These changes have not been neutral for society but threaten, replace, and complement the existing rules of the game.

The consequences on society and economics are being studied. At least three views may be mapped: an institutional focus, a business approach, and a technological perspective [2]. Digital transformation is a systemic phenomenon and, according to the first view, has been changing ground rules within organizations, ecosystems, and industries [3]. The second one warns of new and disruptive incumbent business models, value chains, organizations' advantages, and business activities, ranging from agriculture to manufacturing and tourism, among others [4]. The third venue is related to the outcomes of digital technologies adoption, provoking radical changes and driving innovation mostly when the physical World begins to be connected through the cyberspace. For example, we can mention domestic appliances, manufacturing equipment, medical devices, tourism attractions, or city utilities integrated on Internet of Things platforms [5].

Despite the potential advantages in the literature, few companies have adopted purposeful strategies to pursue significant achievements [6]. Some authors match this transformation to an Industrial Revolution or a productive paradigm named Industry 4.0 [7]. Several authors identify some outcomes of integrating digital technologies into business processes, including product efficiency, productivity increases, and the developing of new business models. These advantages go along with improved flexibility and customization. Sustainability enhancement is also foreseen as an outcome as socio-environmental functions are adopted, and triple bottom responsibility is considered in the companies [8]. Businesses must focus on energy sustainability, reducing harmful emissions, resources, waste-friendly management, and social welfare improvements [9–11].

1.2.2 The Twin Sustainable Transformation

This work must track back to eco-innovation, since digital is based on technical change, to look at the origins of the current sustainability wing in the ongoing digital transformation. Since the innovation-competitiveness paradigm originated in the 90s, eco-innovation research has been developed [12–15]. As determinants and outcomes of eco-innovation have been studied [16–20], it has been shown that the adoption of digital technologies drives this type of innovation [21].

In pursuing competitive advantages and improved experiences, the adoption of digital technologies is an allied, and extended to the ecosystem may accomplish significant gains in sustainability and quality of life, facilitating the put-on practice of Circular Economy and the improvement of safety conditions [5, 22]. As industrial plants are becoming complex digital systems, the transversal aspects of industrial management, such as sustainability and energy, shall be levered and improved as connectivity, data analysis, and automation are extensively integrated with the facilities. However, industries must note that effectively fostering implementation is not simple [23]. The use of visualization software and 3D simulation facilitates and improves human–machine interaction increasing workers' comfort and safety while anticipating mistakes and minimizing times and production costs [22]. The digital technologies let business operations servitization leading to a structural division of work where major economies move from mass to customized production, and new models of organization stem interactions of agent–machines–organization are core to production. In contrast, the ongoing digital transformation may endanger developing countries and isolate small businesses by reducing employment [24].

Furthermore, literature reviews recently conducted [2, 25], and [26] show that digital transformation is changing radically value chains and manufacturing environment, where emergent and the recurring topic is sustainability and sustainable development. The Industry 4.0 tools and applications may permit the achievement of enduring sustainability, but there is a lack of studies on the social and environmental dimensions impacts [26, 27]. Since a pre-COVID expectation was to achieve economic, social, and ecological gains due to digital transformation [28], our insight and stake are that the sustainable part of the double transformation may express on increasing resources running out and society anxiety augmenting scenario as the prevailing pandemic one we are currently facing.

1.3 Materials and Methods

The present review aims to achieve a bibliometric analysis of trends and research topics in 2018–2021. The following overview is based on a systematic literature review utilizing the academic Database Elsevier

Table 1.1 Queries for data search

Queries	*Terms in Title, Abstract, or Keywords*	*Number of hits*
1	"digital transformation" AND "sustainable transformation"	2
2	"digital transformation" AND ("sustainable transformation" OR sustainability)	239
3	"digital transformation" AND ("sustainable transformation" OR sustainability) AND innovation	75

Source Own elaboration based on Scopus queries

Scopus. We have used a network analysis technique based on the authors' keywords, and from the results obtained, we arranged a focus group discussion to identify the trends and topics.

Regarding the database used in this review, the source Scopus is one of the two main commercial-academic databases. This source asserts to be the largest (7.8 million records) in its class and offers broader coverage, according to several studies [29]. Also, it claims to keep on with the different research communities' interests and needs due to its Content Selection and Advisory Board formed by scientists, researchers, and librarians from the major scientific disciplines [30]. The quality of its metadata and the ease of information extraction make it suitable and reliable for bibliometric analysis [31]. The limitation is that English-language journals are overwhelmingly represented but show superiority in non-English literature and regional coverage compared to Web of Science [32] (Table 1.1).

We have done our research-based in three phases to get a literature corpus on digital and sustainable transformation. We have tried three different search algorithms. The first attempt was to assess the double transformation literature directly, but there were few results. Then, we broadened the search, including a much more common term, but the result folded more than a hundred times. Finally, we added a new term from this search to specify our intent for finding the trends through the newness, so we get a manageable set of entries.

1.4 Results

The conducted search algorithm throws 75 publications to accomplish all the proposed terms and restrictions. The VOSviewer software maps three keyword clusters digital transformation and sustainability, innovation and Industry 4.0, sustainable development, and smart city/cities). But there were common areas around the double transformation: the topics on innovation and Industry 4.0 while digitalization is more related to digital transformation, and smart cities to the sustainable transformation. In this array, the authors proposed 631 different keywords. Twelve occurred at least within five documents and 80 at least in two. The most common keywords are Digital Transformation appearing in 42 papers, sustainability with 26 occurrences, and development with 17 appearances (Fig. 1.1).

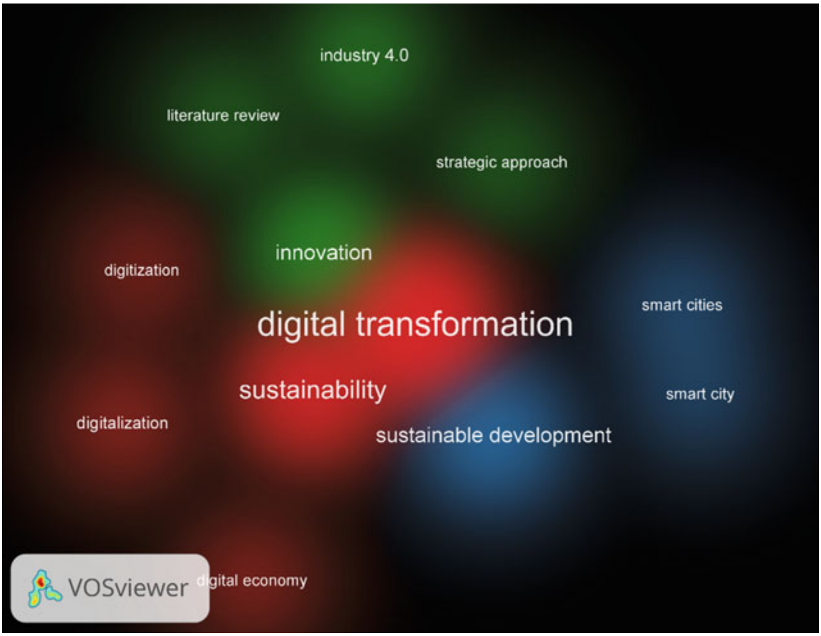

Fig. 1.1 Keyword co-occurrence map (*Source* Own elaboration based on the VOSviewer map generator)

The production is highly concentrated in Europe, particularly in the Mediterranean countries (Italy and Spain) and the German-speaking countries. Among the Anglo-Saxon countries, the United Kingdom is at the head of interested countries. In Asia, China is the leader in publications, as in Oceania, Australia has the lead. In other parts of the World, the topic seems to be nascent, as in the United States and Russia, Asian South-eastern countries, Arab countries, and Latin America.

Considering the academic institution of adscription of researchers, we have found dispersion worldwide showing a nascent topic more of the interests of the individuals or groups research located at specific universities that in many cases represents the whole country's figures. In the United States, since 2014, the Commission has provided several measures to foster a digital transformation and, later in 2020, established a digital decade while it has engaged in a neutral climate strategy to 2050. In the academic realm, our analysis highlighted the interest in Italy (groups located in Milano, Rome, and Pisa, to mention a few), Spain (mainly in Madrid and Barcelona), Germany (especially in Berlin, Baden Wurttemberg, North Rhine-Westphalia), and the United Kingdom (Newcastle upon Tyne, Manchester, and Edinburgh, among others).

The main documents, because of their number of citations, are Pappas [33], Ghobakhloo [7], Abad-Segura [34], and Savastano [6], with more than 25 publications citing each work. Nevertheless, each document provides different influences and topics to the digital and sustainable transformation field as their sharing citations referred. Several clusters appear if we use a bibliographic coupling network to measure similarity among documents. Our most cited paper, Pappas [33], is in the field's periphery. Its main ideas are to adopt big data analytics technologies and work in alliance with several actors to provide an ecosystem of change, facilitating the digital transformation of a sustainable society. This proposition is among documents highlighting the topics of precision agriculture and smart city, especially in the planning and the objective of creating value (Fig. 1.2).

Concerning Abad-Segura [34], it leads a cluster of documents practicing literature review exercises, shedding light on the interaction among management, digital transformation, and sustainability. The business research provides a kaleidoscope view of the actual application of digitization technologies among management activities ranging from finance to marketing and innovation, impacting diverse economic sectors, especially manufacturing, tourism, and higher education. There is a gap in

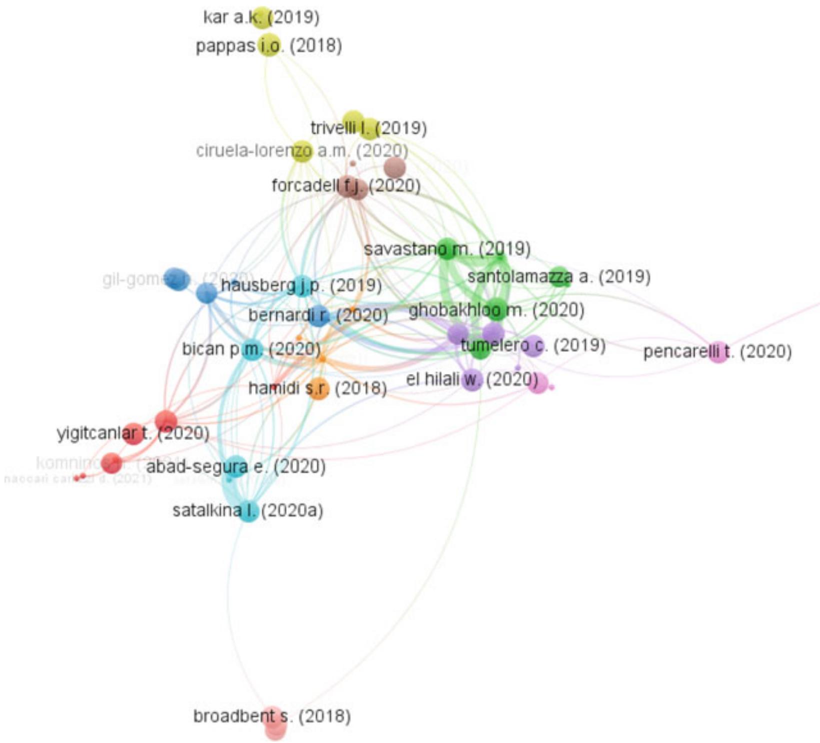

Fig. 1.2 Bibliographic coupling network (*Source* Own elaboration based on the VOSviewer map generator)

the knowledge on how digitalization is transforming other activities and sectors. However, it is core to sustainable growth and strongly contributes to other related phenomena like entrepreneurship, innovation, and business model development. These may be related to an encompassing process of digital transformation that may deploy through several stages, highlighting the importance of readiness and maturity models to diagnose the actual stake of enterprises and the feasibility of expanding ideas to models, content, and theories of superior complexity as business models, ecosystems, and innovation systems.

Finally, in this network, Ghobakhloo [7] and Savastano [6] are located close to the center, showing an important influence on digital and sustainable transformation. Their cluster of related documents underlines Industry 4.0 as a capital term, playing a structuration role in the double transformation. They signal the dramatic changes in the manufacturing environment and value chains with the use of digital technologies and the potential gains in the efficiency, customization, flexibility, and sustainability of the production and operations. In brief, they strengthen the open opportunities to improve performance and note the critical strategies to empower humans in inclusive digital solutions. Digital innovation and technology developments seem essential to harness value-added to corporate sustainability strategies. This review proposes a field synthesis according to the following terms grouped in the next subsections considering the keyword co-occurrence map and the bibliographic coupling.

1.4.1 Digital Transformation

Our review reveals that in the digital transformation literature, the topic of the double transformation appears under two notions. The first provides a vision of the future and a strategic perspective on its sustainability, and the second an environmental, societal, human, or inclusive view of sustainable development. We can derive the second interpretation of these views as a process and outcome interplay. The quest for sustainability is explained in business resilience, marketing, production and operation of products and services, and response to consumer awareness.

For Wang [35], due to the COVID-19 pandemic, the notion of recovery is consubstantial to global sustainable development, and this only can be obtained by nurturing a green and digital transformation. So, investing and planning industrial development must attain this double purpose. In their interpretation, this transformation consists of the digital technologies' usage seeking green and inclusive growth. Meanwhile, for Pappas [33], achieving digital transformation must lead to the development of sustainable development. They signal the business compromise to search for shared value and adopt a corporate social responsibility.

Another point of view is to ubicate the digital and sustainable transformation into a higher level of analysis from a macro and systemic perspective. Li et al. [36], studying the Digital Economy, argue that sustainability is an unintended effect of coupling the Digital Economy with a real-life Economy. An example may be the challenges around the sustainable production of energy, the demand for sustainable housing, the growth of ride-sharing services, or the efforts from grass-root innovations to attain the United Nations' 2030 Agenda for Sustainable Development.

For Pappas [33], the dual transformation can occur as Big Data and Business Analytics ecosystems evolve. Stakeholder needs can drive this dynamic, further stakeholder aggregation, a process of enhancing developed capabilities, and societal sustainability being envisioned as the overarching goal. Literature can suggest a more concise idea in Satalkina's [37] arguments on the impact of digitization on innovation systems, extending beyond the mere rethinking of business models to restructuring competition and forms of networking arrangements. Thus, increased interaction and aggregation are paramount to trigger the double transformation. In line with Pappas [33], Caldarelli [38] points to capabilities as key to implementing sustainable blockchain-based supply chains, addressing knowledge management capabilities as crucial in the reliability and transparency of information due to the source of origin of the information, not stored on the blockchain, but in its environment collected through physical assets.

A micro vision emerges in managing data, resources, and demand, i.e., operations and production management [25], where efficiency, savings, and sustainability are expected to be achieved simultaneously in the activities of use, exchange, organization, and recycling.

The third approach is to search for a causal relationship between digital transformation and sustainable transformation. For example, following Ghobakhloo [7], the Industry 4.0 implementation offers opportunities to achieve sustainability, but economic sustainability seems to be reachable as an immediate outcome, reflecting on the impacts on productivity and business model innovation. Meanwhile, socio-environmental sustainability outcomes remain lagging as Industry 4.0 sustainability functions, like social welfare improvement, harmful emissions reduction, or energy efficiency, are considered secondary to delivery.

Another point of departure is proposed by Wang [35], where the relationship can be seen as a double game. Digital transformation acts as an enabler of sustainable transformation, but also digital transformation performs as a challenge to sustainable development because of the share of ICTs on global energy consumption.

Zehir and Özgül [28] suggest double causation with two-way directionality. In one way, Industry 4.0, its paradigms, and related technologies have several outcomes in performance that are translated into economic, social, and environmental gains. On the other, the severe damages inflicted on the environment by productive activities (i.e., natural resources increasingly become to be exhausted, the life-cycle has been shortened by fierce competition, and mental illness is growing because of the social stress charge and anxiety) has been forcing the development of Industry 4.0.

Another position, complementary to Wang [35] but more deployed, is to look at digital technologies as enablers of sustainable transformation. This process entailed understanding how organizations must change to embrace digital technologies and reach societal changes [33]. So, these technologies may be headed by Big Data Analytics to convoy value for developing sustainable societies.

Another approach to this venue is Yigitcanlar et al. [39]. These Australian authors assert that Artificial Intelligence related technologies (Big Data, Automation, and Robotics) used in urban planning and development may lead to the digital transformation and sustainability of cities, so according to Naccari Carlizzi and Quattrone [40], public administration requires to invest purposefully on innovation and digital management to facilitate and prepare these technologies usage.

Within the Malaysian experience, Hamidi et al. [41] seek to measure SMEs' maturity level to embrace Industry 4.0. Under the expectation of gaining opportunities to sustain current competitiveness, they developed the idea that becoming proficient in digital technologies opens opportunities for pursuing sustainable industrial value creation through sustainability's economic, social, and environmental dimensions.

El Hilali [42] shed light on the drivers of the double transformation of Moroccan SMEs, customers, data, and innovation. They prove they are significant for digital transformation and, simultaneously, to the commitment to sustainability. They also support the idea that innovation, particularly radical changes in business models, plays a digital and sustainable transformation role. They underline that customer experience and client-centricity strategy, data analytics, and shifting innovation business models guide the digital transformation journey toward sustainability.

1.4.2 Innovation

The innovation category shows three factors related to the double transformation: the business model innovation, the business process innovation, and sustainable innovation. New business models are an outcome of a digital transformation—the use of data, digital technologies, and entrepreneurial mindset–of products, processes, and business. But to foster sustainable processes and practices, the management must put cognitive abilities to anticipate, visualize, and exploit opportunities on the triple bottom line dimensions of sustainable development and value creation [6, 43]. The digitalization of activities provides the opportunities to align and save resources, connect different players and machines, coordinate stakeholders in the value chain, enhance productivity, and improve product quality and organizational performance. But according to Karimi [43], the digital business model, the digital entrepreneurship, or Reis-Marques [44], the digitally enabled innovation requires a deeper understanding of where the value is and how value is created and delivered to foster sustainability and development. So, there seems to be a sequential interrelation between digitalization, innovation, and sustainability.

In resuming the second strain about business process innovation, the literature searches on the role of the "digital" in achieving the twin transformation [45]. In one part, the authors state that it is capital for sustainable development and the Circular Economy. It shall be part of any innovation in the future, and digital innovation leads to new sustainable business models. In exploring how business processes digitalize and how the digital enables innovation, they signal as fundamental drivers of this transformation, the technology, the strategy, the culture, the business model, the readiness, the entrepreneurial spirit (opportunity seeking and foresight cognitive ability) as the environmental restrains, that address the reconfiguration of the value chain and the manufacturing processes [6, 44–46]. These considerations may have positive impacts, such as saving or reducing the use of resources, deepening customer interaction and inclusion, and avoiding waste, or negative ones, like a higher energy demand, labor replacement, or customers' mistrust.

From this strain, Agasisti [46] developed a case to show how the COVID-19 outbreak prompted digital innovation and how this supports sustainability. On the other hand, Broadbent [47] proposed that innovation creates a space for a digital culture of sustainability. The most popular areas for applying Artificial Intelligence in urban development and planning are digital transformation, innovation, and sustainability [39]. In the view of Forcadell [48], the digitalization of banking services changes the business model by narrowing its boundaries due to costs, transactions, and uncertainty reduction and widening its scope through improving services design and developing new services in new markets that leads to inclusion and environmental care. In the tourism industry, digital technology usage and infrastructure have changed game supply and demand rules. These changes had reconfigured the value chain, enhancing client information and integrating destination services, putting pressure on environmental care, the quality of life, and corporate responsibility, but also on the possibilities to innovate from the diverse stakeholders intervening in the smart destination competitiveness [5, 49].

Similarly, smart cities literature refers to the innovative use of digital technologies to reach a more inclusive and sustainable ecosystem [50]. Reis-Marques and Popovic [44] consider strategy's main role in digitally enabled innovation. In this venue, Di Vaio's [51] work set up knowledge management systems as an enabler of digital innovation that may lead to value creation on sustainability. In the same venue, Mihardjo [52] signals that the core variables to drive a business model innovation toward sustainable development are customer experience orientation, organizational agility, and organizational efficiency.

In addition, another strand of the literature points to the resistance to adopting IT innovations in the healthcare sector. The problem arises in the tension between the management and the institutions [53]. So, organizations must cope with paradoxes in implementing the digital transformation and the digital innovation adoption process. According to Smith and Beretta's [54] case study of a large firm, these may be of an organizational or knowledge nature. A willingness to change and commitment is essential to change management practices and participate in learning experimentation with stakeholders [55].

El Hilali [42] points out that changes in business model innovation are essential to reach digital and sustainable transformation. De Bernardi [56] shows examples of the food sector. Li et al. [36] work on a case to show how implementing a digital twin platform network may lead to an innovative sustainable business model in the home appliance sector. In the same sense, Gil-Gomez [57] argues that CRM is a way to reach sustainable business models. Similarly, Caldarelli [38] develops a case on how blockchain adoption leads to sustainable business models in the Italian Agri-food sector.

Savastano's [6] paper surveys the digital manufacturing ecosystem and reveals that innovation processes enable digital transformation. These may occur in logistics, continuous improvement, standardization needs, lifecycle management, customer-driven activities, safety assessment, or the business model. These authors consider additive manufacturing technologies [6] as a radical innovation enabling cost reduction, shortening lead time, reconfiguring the supply chain, improving product customization, and facilitating sustainable remanufacturing practices and recycling. In the digital manufacturing ecosystem literature review, Savastano [6] highlights innovation processes as emergent technologies and innovation and technology management and process innovation as a rising research area.

The last category, sustainable innovation, refers to the purpose and impact of innovation on the triple bottom line dimension [6]. The digital innovations push organizational changes and business model reconfigurations, paving the way for sustainable gains related to faster market responses and client and user involvement. But research must review the readiness of the business models and their sustainability impacts in terms of economic and environmental effects because not all digital innovation may be manifested in a sustainable positive way [45]. Addressing innovation toward client requirements may require novel design methodologies, as proposed by Lee [58]. For another part, there is evidence that eco-innovation may represent the environmental line and that this type of innovation, related to a product or organization, positively influences the socio-economic performance of manufacturing [21]. The tourism literature believes that value creation and delivery by digital technologies and innovation must be attached to sustainability to maintain competitiveness and smartness for destinations [5, 59]. A complementary point of view is Salminen [60], who sustains that responsible business leadership drives digital innovation to respond to the Circular Economy. This ethical and socio-relational model seeks to preserve and restore resources, optimize efficiency, offer life-cycle services, foster sustainable solutions co-create, and may profit from digital technologies' potential. Living labs may be valuable in implementing these solutions, keeping innovation, digital and participation, and engaging in the Circular Economy paradigm [61].

1.4.3 Sustainability

In this branch of literature, sustainability is treated as the environmental, social, and economic complex of the triple bottom line [7, 21, 25, 62], the effort to persevere with the digital transformation of ecosystems, business models and innovation processes [63, 64], and the way to keep creating or increasing profitability [41].

Tumelero's [21] paper on eco-innovation shows that the triple bottom line environmental issue represented by this type of innovation impacted the social and economic results and raised the topic of how Industry 4.0 and the Internet of Things may trigger the efficiency of this kind of innovation. The current trends and design principles of Industry 4.0 show that this transformation is converging toward sustainability, but the economic dimensions of the triple bottom line have been much reachable. However, its environmental integrity and human impact performance take more time to achieve. There may be some unforeseen and unintended consequences, so some public policies are desired to prevent the harmful effects on Earth's ecosystems and the quality of life [7].

A clue to preserving digital transformation has to do with developing capabilities. In the base of maturity models, there is the idea that organizations may pass through several stages that represent the mastering of a series of capabilities or a performance achievement. Its first building block may be human resources, as the work of Ghobakhloo [7] suggests. The following stages may enable flexibility, productivity, and resource-friendly production. This performance may be related to strategies focusing on client experience and centricity, data analytics capabilities, and shifting innovation to business models [42].

Pencarelli [5] and Mihardjo et al. [52], in very different settings, tourism sector, and multidimensional model, propose a transitional model where digital technologies adoption is not enough to reach sustainability and underline customer and organizational agility as key issues to attend. Agasisti et al. [46] assert this view and complementary adds a strategic orientation and cultural openness based on an Italian higher education case.

Forcadell [48] states that digitalization triggers fierce competition and new technological players in the bank sector, but these processes present disadvantages. The uncertainty generated by new services and providers associated with technical changes, the clients' renewed concerns about their privacy and security, and the mistrust of non-person-to-person interactions besides fear of opportunistic usage of personal information. These can be superseded by the reputation gained through digitization and corporate sustainability. Through reputation, firms may enhance trustworthiness, provide a credence factor to clients, and facilitate people's endorsement through word-of-mouth and third-party assessment.

1.4.4 Industry 4.0 (I4.0)

This section focuses on remarking the research trends and results according to selected texts on I4.0. At least two common elements are observed. In principle, they assert that I4.0 will optimize the production and distribution processes, which leads to less use of material and human resources and a decrease in time. These savings involve cost reduction and increased productivity. So I4.0 has important effects on the economic sphere of sustainability. On the other hand, this strain of literature assumes that I4.0 will positively impact the other areas constituents of the three-bottom line.

Regarding this approach, some papers focus on a documentary review (some interviews with experts are included) to observe research trends. Savastano et al. [6] aim to analyze 156 documents on the digital manufacturing ecosystem. The authors identified five clusters of technologies within the digital manufacturing ecosystem, in parenthesis the proportional importance: additive manufacturing (46%) and digital tools (29%), followed far below by ICT (13%) and innovation processes (10%); in the end, the tools of design (2%). On the other hand, the research identified 22 research domains (research areas); the main four are innovation and technology management (16%), value chain management (15%), process innovation (9.6%), and economics of production (9.6%). It stands out that sustainable development appears in eighth place as a theme of the reviewed literature (4.5%). The document emphasizes that although there is a growing research interest, the issue of sustainability (in its different domains) is little studied.

On the other hand, the paper by Felsberger and Reiner [25] carried out a documentary review of 89 documents. It proposed a classification of four themes: smart factory technologies (57%), conceptual and theoretical elements about I4.0 (45%), data-driven technologies and process optimization (39%), and technologies for the production floor (16%). Regarding the issue of sustainability, 47 papers out of 89 address this issue in at least one of its three pillars. The document finds that 23 have the economic and environmental as their main axis, 12 refer to the economic and social, and finally, only seven to the socio-environmental, showing important evidence of the role of the economic pillar. In addition, the article points out the transversal position of the economic pillar over the other two. For example, cost reduction in floor technologies allows progress toward environmental or social sustainability, reflected in the job generation. The focus group analysis with experts makes it possible to point out trends from developing I4.0 and new business models, such as cost reduction, increased productivity, energy efficiency, CO2 reduction, or improvement in plant knowledge management (including the three pillars). In short, based on the literature review and the focus group, they can conclude that sustainability has been proven, is running, and will be deepened in the future.

In that direction, Ghobakhloo [7] focused on analyzing the impact of I4.0 on economic, social, and environmental sustainability. Based on both literature review (96 articles) and expert interviews, the work had two objectives, to identify the sustainability functions (16 in total) of I4.0 and, to recognize the sequence of determinations that enable the improvement of social welfare (through the pillars of sustainability). He states the three most studied functions in the literature reviewed were (1) energy and resource sustainability, (2) increased productivity and productive efficiency, and (3) risk management and safety. Based on graph theory, the author proposed how the functions interact, concluding that the human resource development function is the key step in giving rise to the rest of the tasks within sustainability. The following functions are digitizing global value chains, production modularity, manufacturing flexibility, and risk management. Elements linked first-hand to the economic dimension are assumed to be environmentally sustainable, as in Felsberger and Reiner's [25] research. Ghobakhloo [7] pointed out some sustainability functions as drivers, as the steppingstones toward a transition to environmental and societal sustainability dimensions, but still needed to converge toward the business model innovation that may need to prove fitness. Once these functions are triggered and act as linkage functions, the I4.0 may prompt sustainability's environmental and societal components.

Another branch of literature has linked I4.0 with specific sectors and applications. Trivelli et al. [65] aim to investigate how I4.0 and precision agriculture are connected. Precision agriculture has its axes in digitalization, efficient use of resources, productivity, monitoring, and decision-making within the agro-industrial activity. This research obtains two specific products, a dictionary of precision technologies and a graphic representation of these technologies grouped into five clusters. The research concludes that precision agriculture and I4.0 overlap. The analysis assumes that precision agriculture is sustainable, although few articles in their review analyze this issue. Another study that focuses on applying

I4.0 within or linked to a sector is Santolamazza et al. [23], which identifies opportunities for managing an industrial plant's energy systems to be transformed through I4.0. They carried out a literature review to identify the key aspects of energy management. In addition, the research identified that the technologies developed around I4.0 could favor aspects of energy management (because they already have applications in that direction). The work assumes that economic and environmental sustainability results from better energy management and that I4.0 allow it; however, it does not delve into the key technologies that could directly impact.

Ávila Gutiérrez et al. [66] propose a framework for manufacturing that is smart and *affective*, and inclusive. They present a model that uses sensors inside a steel factory to capture the difference between workplace demand and workers' capabilities to reduce demand and expand capacity. The research studies workers with autism spectrum disorder from a methodology that crosses technological elements, adaptation to work, *affectivity*, and improvement of productive activity. This work allows observing the potential of I4.0 in the pillar of social sustainability (improvement of working conditions).

Another focus developed in the literature on I4.0 is proposing a diagnosis of digitization in SMEs. Hamidi et al. [41] explore the level of maturity within the I4.0 of SMEs in Malaysia. The work is based on six dimensions; jobs, strategy, smart factory, smart operations, smart products, and data-driven services. According to the study, small businesses rank low levels in them, and given global competitiveness, it is necessary to remedy those shortcomings.

1.4.5 Digitalization

Literature on digitalization has as a starting point that it is a process that optimizes resources, production, and services, which helps economic efficiency. In addition, it agrees that this process allows the opening of business opportunities for companies.

On the other part, some of the papers grouped in this strain focus on resolving problems that can occur through digitalization. In this regard, Alves et al. [67] analyze the effects of innovation within home medical services. The authors find that while the number of patients under treatment and prescription remains stable during the period studied, the number of medications decreases drastically after implementing the digital process. That means improving hospital processes, specifically in logistics, but also real-time monitoring of patients. It is worth noting that the authors suggested that this brings with it an advance in sustainability. Another study that focuses on applying digital technologies is that of Ciruela et al. [68], which analyzes how different digital technologies would improve the activities of agro-cooperatives. The research takes up a diagnostic analysis to assess the position of two cooperatives and observe the strategies they have taken that place them at a level of digitization—the greater the depth of digitization, the greater the impact within the value chain. The article then presupposes that digitization would allow them to take advantage and acquire sustainability (on the environmental and social dimensions).

The study by Bican and Brem [45] seeks to identify whether digitalization will impact sustainability. The authors recognize no clarity on what digitalization means at the academic level regarding digitization. Furthermore, a case study of a German corporation showed that employees do not have a common vision of these concepts. The study also proposes a simple model of what digital transformation would involve within the corporate. Changes within the company in the digital direction will be implemented if they are part of the business model. In addition, the study, based on the interviews and the literature review, found that the impact of digitalization on sustainability is not linear. Some actions could favor it (online meetings reduce resource consumption) and others not (the case of the energy demand of cryptocurrencies). In this venue, Evangelatos [69] detects that technology is not neutral nor is it without a trade-off, as some of the reviewed literature assumes.

Another part of the literature highlights the increase in risks in some parts of the Economy because of digitization. Forcadell et al. [48] state that digitization has made it possible to optimize various processes and products. Above all, it makes it possible to reduce transaction costs (costs generated by going to the market and negotiating). However, it has increased risks in financial services, which has led to a negative perception of these organizations. The authors propose building a reputation by creating signals to partners and clients to compensate. Such a reputation is based on corporate sustainability and digitization itself.

1.4.6 Smart Cities

In the literature on the smart city referred to the digital and sustainable transformation, an expression that appears frequently is stakeholder, a term that encompasses a business vision in which the town is pigeonholed. Each actor within the city is a stakeholder. In the background are the citizens or governments. If it is assumed that whoever decides within the cities will first be someone who invests and expects a return, there is no longer a place for the citizen, only for the merchant, to obtain returns. Another element that stands out is that some of the texts on this topic confirm the possibilities technology delivers for the city in terms of benefits in the economic, political, and general sustainability spheres. The importance of this literature stream lies in the fact that the design elements of smart cities could be equal to the enablers of digital transformation and the building blocks of the digital ecosystem.

Komninos et al. [63] analyze thirteen cases of European cities that the European Commission recognizes in its Blueprint for Cities and Regions as Launch Pads for Digital Transformation. Assuming that digital transformation is the basis of a smart city, they detected some common elements: (1) leadership by institutions to successfully carry out the transformation, (2) human resources with a talent for digital development and entrepreneurship that accelerate the formation of a digital ecosystem, (3) access to the management of a large amount of data and address the challenges that a city faces, and (4) investment in key infrastructures. The authors emphasize the need to create platforms (with public investment) or common infrastructures to establish a collaborative ecosystem for new processes and products needed for the city, markets, and public services.

As seen in this section and the previous ones, a strong investment is required for the digital transformation and conversion to smart cities. Much of the literature assumes public investments in products and services infrastructure. However, the financing it must resort to must be innovative, as pointed out by Canas da Costa and Popović [70]. The required investments include the communication part as a transversal element and the requirements for it to be sustainable, such as energy considered clean. In general, investment in infrastructure has two characteristics, long-term and high volume, requiring planning. The work takes as a reference the financial alternatives to which some projects have resorted, such as the well-known case of green bonds, insurance for natural disasters that allow recovering the loss of natural infrastructure due to some climatological catastrophe, or the payment for the capture of surplus value by exploitation in the use of wild land.

Complementary to the work of Komninos et al. [63], is Hämäläinen [71]. She states that the design of a smart city requires incorporating four aspects: (1) Strategy for integrating digital technology into a sustainable city, (2) Digital technologies such as infrastructure or platforms for services and products that the city requires, and high computing capacity to handle a large amount of data that needs to be used in the city, and at high speed, experimentation with technology for cities, and security, among others, (3) A governance that includes organizations of different kinds (companies, governments, non-profit organizations, citizens, all of them called stakeholders), and (4) The stakeholders that are regularly seen from the quadruple helix, which integrates citizens. For his part, Nugraha [72], through a review of the literature on smart cities, suggests that a relationship between people, the business process, and emerging technology can be observed by implementing a smart city. Furthermore, he assumes that smart cities help improve quality of life, economic growth, and sustainability.

Other research focuses on identifying the challenges for smart cities, as the case of Kar et al. [64] states that the central challenge for digital transformation is not only to transform cities into smart ones but also nations. Both urban and rural territories must have changed in the direction of digitization in which all stakeholders benefit. This position rests on the fact that social needs can be recognized at the national level and thus be the starting point. A smart nation not to continue opening the gap between rural and urban spaces in digitalization needs national governance. Complementary to Pereira [73], the new governance models required collaborative control, information exchange, evidence-based decisions, resource management transparency, and citizen participation. The authors raise the need for new governance, considering that the smart city's central objective is to create a public value that ranges from sustainability, creativity, efficiency, innovation, or citizen participation.

A challenge for developing countries is the lack of funds to transform the requirements demanded by smart cities, as stated by Alcaide-Muñoz and Rodríguez-Bolivar [74]. They started from the idea that the governments of these countries have focused on providing social support instead of involving citizens in the technological environment. This idea is contrary to the promotion of developed countries, which requires innovation and creativity or sustainability. Finally, according to the literature review, Lucelly and Marín [50] pose a series of challenges for developing smart cities in countries. Among the challenges highlighted by the authors is the low investment in R&D, as in the Colombian case, or those related to mobility, education, and qualification of human resources, not only in the technological part but also in participation that allows them to integrate.

1.5 Discussion

This paper's main stake is to devise a future for a more sustainable development hand-on-hand with the Digital Transformation evolution. First, our work states that digital and sustainable transformations are emerging in the literature. Our results show a strong coincidence with other reviewing studies. Sustainability and industry 4.0 as its related technologies (Big Data and Artificial Intelligence, and Business models) are listed among the most recurring topic in the literature reviews, and research trends are uprising around SMEs, Blockchain, Machine Learning, and Sustainable Development [2].

Regarding the co-word analysis structure, our findings on commonalities to explain digital and sustainable transformation are backed up by Wang's [35] review on how cyberspace enables green and digital transformation. This twin transformation is guided by industry 4.0 applications based on Artificial Intelligence, Cloud, Big Data, and Internet of Things technologies. Cavalieri et al. [75] find complementary results to understand the relation between eco-innovation and digital transformation in a Circular Economy framework.

According to the literature reviewed, sustainability is a companion to digital transformation, but it cannot be granted nor treated as an externality from the digital technologies' diffusion process. Several mechanisms operate systemically at the macro, meso, and micro levels to achieve the whole dimensions of sustainability.

For example, the COVID-19 pandemic has triggered a more sustainable awareness of digital transformation. Recent literature sustains the case exposed by Agasisti [46] in our review. Nonetheless, some authors do show that the booster occurs in the digitization of urban environments [76], work environments [77], or the steel supply chain industry [78]. However, the evidence is not strong enough on sustainability endeavors.

A clue may be in incorporating other variables as moderators, such as innovation, whereas business process innovation, customer engagement, and organizational resilience, among other factors, have proven incidence on the Iranian business to become more sustainable while adopting digital technologies [79].

Our work confirms that technology and its applications are backing up the digital and sustainable transformation. What about institutions and business changes? The digital transformation is not a neutral process [69], and to obtain economical, environmental, and social benefits, values, norms, and behaviors are at stake. Our review showed that reputation might avoid customers' mistrust of data usage in the banking sector and the uncertainty associated with new products or services [48]. Meanwhile, responsible business leadership is essential to include sustainability issues in the development of the new business model [60]. To corroborate, in the same sense, this kind of ethical concern shall be put in place for the development of AI technologies, as recently researched by Weber-Lewerenz [80].

How this double transformation occurs at the business level? They can be seen as growing paths, appearing in a converging way, may be simultaneously or sequentially, depending on the structural dimensions of firms [62], and are foreseen to be much more intertwined in the future in the New Normal. In our previous review on production and operations management, digital and sustainability occurred simultaneously in using, exchanging, organizing, or recycling data or materials and produced economic and sustainable results [25]. Nevertheless, other authors underline that process innovation must occur to embrace digital transformation and address sustainability [6, 33, 35] or even that mastering the digital transformation is required (or of a certain technology, i.e., data analytics capabilities harnessing) to pursue sustainable value creation [41, 42]. Other researchers went further and proposed a sequential interrelation among digitization, innovation, and sustainability [6, 43, 44], whereas digitalization ignites a businessmodel innovation, and through this model change, a sustainable business model is born. But this change may be possible only if management considers customer orientation, organizational agility, and efficiency and engage in organizational learning [52, 55]. The value obtained may fall short of an environmental or societal impact or even drive negative effects, so a purposeful guide must be addressed as a responsible business leadership that assures an ethical attitude and stakeholder inclusiveness.

Recent examples of works sustaining simultaneous or sequential modes of interaction are Lichtenthaler [81] and Ghobakhloo et al. [27]. The first author coined *digitainability* to propose a framework that simultaneously includes digitalization and sustainability in the innovation strategy and avoids negative outcomes or unintended consequences. For another part, Ghobakhloo and colleagues [27], based on an extant literature review and experts' opinions, develop sustainable innovation functions for I4.0 identifying sequences to deploy eco-innovation departing from a horizontal and vertical integration to an enhancement of the knowledge base and advanced competencies, and from developing organizational capabilities (green absorptive capacity, sustainable partnership, and sustainable innovation orientation) toward eco-friendly innovation on process and products. A complementary approach to the interdependencies of the sustainability dimensions is the work of Veile et al. [82]. They craft a model of interactions among the triple bottom line components in the digital transformation context.

The literature review showed that several cases are depicted to provide a view of how the digital transformation has occurred throughout the whole Economy and how it is related to sustainability [5, 6, 38, 39, 46, 49, 53, 56, 59, 65, 68]. The structural and size conditions are important to explain the pace and depth of outcomes of the diffusion and express sustainability as survival, aspiration, by-product, performance, or strategic results. There is still much room to envisage different changes in several industries. As the construction [83], fashion [84], lodging [85], food processing [86], agri-business [87], pharmaceutical [88], including responsible innovation approach in the digitization of a dairy farm [89]. Recently, Dalmarco et al. [90] have shown that territories are a driver to creating and delivering sustainable value along several digital-based business models spread all over Europe. Li et al. [36] argue that the I4.0-sustainability bond occurs naturally due to linking digital with real-life. However, even this process can decelerate the complexities and paradoxes of high energy consumption if sustainable designs are considered, leveraging a smart sustainability transformation [91].

The digital transformation does not linearly determine a sustainability process (economic or environmental). As can be seen, digital technology also brings challenges and new problems. Digital technology is not neutral or without a trade-off, as some reviewed literature on I4.0 states. However, it is assumed largely as a product of efficiency.

A careful strategy is required to innovate based on the digital transformation in response to reaching the whole scope of sustainability [5, 6, 21, 45, 58–60]. In this line is the work of Padua [92], who proposes a mindset to include social concerns in any sustainable innovation based on I4.0 technologies, and Ghezzi [93], who drafted a tool to enable competitive empathy with rivals to get a common ground and shared value. For business, it is not only good-will address social and environmental sustainability, but some capabilities also are required to drive the business model. In the case of capabilities, both streams of literature, digital transformation and innovation, agree that behind the transformation, there is a process of building and deploying capabilities [33, 38, 41–43]. Even though the intermediate innovation phase, the literature points out the capabilities' promotion. One of these appears reiterative in the review, with several different names. It has to do with identifying and assessing business opportunities, so it is called "opportunity seeking" or "foresight cognitive ability" [43] or, in a more recent model, "prognosis search" [94]. Other capabilities are restricted to the technological dominion. They may be more directed toward the managing of digital transformation technologies (Big Data and Analytics capabilities, platform capabilities, knowledge management, and blockchain) [5, 38, 42, 84]. Finally, the third class of capabilities is related to the organization; current literature highlights: absorptive capacity, partnership development, ambidexterity, resilience, agility, customer engagement, and leadership [27, 79, 95–97]. In the case of SMEs, to keep growing and going digital, technological capabilities are a strong moderator, especially those related to innovation and marketing [98, 99].

Concerning the evolution of the sustainable transformation through smart cities, our results are aligned with Naccari-Carlizi and Quatronne [40] and Yigitcanlar et al. [39] proposals on the digital agenda and digital applications adoption to develop urban planning and control metropolitan cities. This investment in technological infrastructure may help government and citizenship go digital, facilitate exchanges, and open opportunities to a platform-based business. Applying this infrastructure to the management of public utilities boost not only the smartness but also the sustainability of cities reflected in enhanced management of energy or water, waste collection, disposal, and recycling as the mobility with eco-friendly public transport and improvement in the control of vehicles, their emissions and heat diffusion. A new path may be open to reflect on how digital innovation change public and private relationship in terms of governance of public services and natural resources management, with real-time information, policy design and accountability, participative planning, and leadership empowering people, as is the case of water management [100].

1.6 Conclusions

Digital transformation is geared toward greater sustainability. It is undoubtedly an uprising topic as it is embodied in the current literature. The sustainable transformation appears as an aspiration to create value and merits planning. Likewise, digital transformation entails sustainability as there is a potential impact on economic sustainability performance, especially in manufacturing (production and operations), while environmental and societal constituencies can be impacted through corporate responsibility. Finally, there is a narrative on managing digital transformation and sustainability through entrepreneurship, innovation, and business model development based on functional and sectoral digitalization applications and mastery of diverse organizational capabilities.

According to our review, the major subtopics are: (1) How to assure in the whole dimensions of sustainability results and outcomes? How do we avoid negative effects? What are the main moderators of the relationship? What is the role of innovation in the relationship?

The adoption of I4.0 does not grant environmental and social sustainability. To reach these sustainable benefits is necessary that they are purposefully sought. They require investment and planning and correct responsible leadership, stakeholder participation, and the development of organizational capabilities. Effective management is necessary to engage in innovation. And to accomplish sustainable transformation, a sustainability commitment is required.

In the study of the sustainability achievement in digital transformation literature, there are several hints to feel optimistic about post-pandemic relief. The future growth of the Economy, staking on digitalization, passes through several processes. The expansion of the Digital Economy brings unintended sustainability effects and enhances the capabilities of digital ecosystems as stakeholders interact in new and diverse arrangements advocating to create social shared value. If purposeful investments and planning are put in place to reach a smart and sustainable city, knowledge management will release a capabilities challenge due to increased reliable and transparent information generated through digital technologies. Business endurance is enabled through digital technology usage and mastering. Business model and process innovations are developed through market and data analytics capabilities, and digital achievements are intended to catch up with economic sustainability. Finally, nations, industries, cities, and businesses may seek environmental and social sustainability through increased awareness, commitment, and responsibility.

The future research agenda for a digital and sustainable transformation must open a special place for innovation. The mechanisms on how digitalization enables innovation and innovation facilitate sustainability is relevant for designing and managing sustainable businesses. Is this a sequential mechanism? What are the drivers behind this process? Some of them were identified in our review, so what may be the role of technology, strategy, culture, readiness, entrepreneurship, and environmental restrains in achieving the double transformation. To change business models and address them to sustainable development, avoiding negative effects, it seems that some organizational capabilities must be developed and deployed, just to mention a few, such as knowledge management, customer orientation, or agility. Another branch of literature states that innovation processes are enablers of digital transformation, so more reflection and empirical work are required to demonstrate their role as enablers and mediators of sustainable transformation. Certainly, there are obstacles and resistance to adopting these change processes; some belong to an organization others may have a knowledge nature, so a cross-fertilization exchange with knowledge management and organizational learning research stands out as a valuable road toward a deeper understanding. Additionally, more examples from different sectors are required to understand how organizations persevere in this dual transformation.

The pandemic's disruptive effects open a pervasive diffusion of digital technologies across the Economy. The New Normal may open the way to a digital transformation based on a transitional model to address sustainability. The business organization is urged to keep a customer orientation and agility mode of decision-making and implementation. However, a pause may be needed for a strategic assessment to support efforts on the digital transformation to achieve triple bottom line sustainability. The innovation pursued efforts on processes, and the business model shall be nurtured by digital technologies, as the eco-innovation case, but seek performance gains in the whole sustainability dimensions. Corporate sustainability is critical to embedding business responsibility leadership and organizational sustainability culture. In this context, the readiness and maturity models must prove useful. Human resources are the steppingstone toward developing technological and organizational capabilities pivotal to advancing in the dual transformation.

Regarding the literature on I4.0, one element that stands out is a positive vision, failing to highlight economic, social, or environmental limitations, not even thinking of a technological trade-off approach. I4.0 could be a paradise on and off the factory floor. However, this academic promotion does not reveal the problems even in the economic field, such as the current low overall return on investment, ergo, the drop in ICT investment. To deepen our understanding of the structural role of I4.0 on the double transformation requires increasing the attention on sustainability dimensions, priority impacts, and how this sustains sequential models, developing cases and discussing applications in more sectors, and providing a new generation of diagnosis models that incorporate findings on the sustainability impacts sequential mechanisms.

Digitalization has covered manufacturing directly and areas such as services for both production and final consumption. Like the research on I4.0, digitization literature assumes that digitization allows economic and environmental efficiency. In this line, digital tools could enhance their strengths and solve their weaknesses. All this if values of self-help, self-responsibility, democracy, equality, and solidarity are present in their design. If a social-value-driven design is considered, sustainable business models embodying the whole sustainability dimensions may be favored by digitalization.

This contribution must put a warning note because of the digital-sustainable non-linearity behavior. Since digital technologies are not neutral, the impacts on sustainability are unpredictable. A complex system view of the array of digital and sustainable is required. Future research must consider that self-organization adaptive responses of business models and cities occur whenever confronted with disruptive events, and many variables interact to change or innovate in the business models, such as cultural trait as openness but also diverse capabilities, i.e., being of different nature such as infrastructural, technological, and organizational. An approximation to the literature on complexity is desired for planning and modeling the changes and the several variables interacting with a business model design.

Smart cities are sustainable cities; there is no doubt about that vision. However, some papers showed that we must make a pause, and before technologies, smart citizens are required. On the other hand, we must consider that in the face of challenges, it is necessary to focus on strategies to design and create this type of city, which, among many other problems, will require large investments for its implementation. In addition, various solutions have come into play for greening cities that should complement the digitization effort. In cities, digital technologies open opportunities for greening and bring lessons on how stakeholders articulate and aggregate demands, participate and generate social share value like an ecosystem. According to a stylized way to aggregate actors and differentiate them, this type of governance is depicted as a Quintuple Helix and can exemplify how to create and deploy digital and sustainable ecosystems in a Post-COVID World.

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CHAPTER 2

The Scope of Digital Transformation in Sustainability

Guillermo J. Larios-Hernandez

2.1 Introduction

The study of sustainability and the firm has gained scholarly relevance since Howard Bowen published Social Responsibilities of the Businessman in 1953 [1], considering it critical that business organizations take an active role in the much-needed balance between humanity's socio-economic systems of production and the earth's carrying capacity. Sustainability is a tri-dimensional concept involving social, environmental, and economic perspectives that allow organizations (and society in general) to prevail in the long term [2]. As much as the firm has become the object of study of researchers and practitioners from a growing number of analytical perspectives, sustainability gains relevance in light of the demand that prevails to include such consideration as part of business affairs. One of such perspectives is related to the potential of information

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S. Estrada (ed.), *Digital and Sustainable Transformations in a Post-COVID World*, https://doi.org/10.1007/978-3-031-16677-8_2

and communication technologies (ICT). It is generally acknowledged that organizations are going through continuous change due to the emergence of ICT, capable of achieving greater production efficiencies and modifying the conception of value and forms of wealth creation. These technologies offer products and services never seen before, more resourceful processes, and new human capabilities. The potential of ICT resides in its organizational impact by offering the ability to automate and interconnect encodable cognitive human processes for the first time in history. These technologies enable the practical elimination of distance in the communication between organizational actors, making coordination more efficient and speeding up production processes. Additionally, ICT has greatly accelerated information processing and process automation, leading business activities to what appears to be a new structural level of competition and a new systemic evolution of business affairs, challenging all logical actions of value creation [3].

The new ICT-based revolution led to the so-called digital transformation (DT), impacting many traditional non-digital organizations [4], including cases such as the implementation of several points of contact with customers (better client experience), teleworking and process automation (efficiency), or the inclusion of digital content into the current or planned product portfolio (innovation) [5]. DT is typically expected to create new value, leading to new forms of revenue generation that originate in digitalization and steer organizational change [6]. Beyond business processes, DT affects the nature of the business [7], though most scholars identify DT with digital product innovation and client experience [5, 8–10]. Nevertheless, the analysis of DT can involve a variety of perspectives in respect of organizational effects, including sustainability. In this regard, DT and sustainability are two processes of societal change whose relationship needs further exploration [11]. Expressly, the connection between sustainability and business performance requires proof [12], and little research explains the digitalization–sustainability nexus [13].

Sustainability cannot be considered a solution but a future-oriented problem that expects to take advantage of the ongoing digitalization process that affects our economic system [11]. From this perspective, DT for sustainability appears to originate in the ICT capacity to optimize resource utilization [4], as well as more efficient environmental surveillance and control systems [14], involving the creation of new social and environmental value that may attract and/or retain a new generation of consumers, employees, investors, and other stakeholders [15]. Through efficiency gains, digitalization would be expected to enable the decoupling between material extraction and economic growth, and CO2 emission reduction [16]. However, sustainability problems have proven to be more challenging than expected in that most unsolved problems are characterized by complexity and uncertainty [17]: while scholars had projected dematerialization to happen as a result of economic progress, recent academic works find no evidence of any actual dematerialization of the economy [18–20]. This contradiction appears to be another example of the Jevons paradox, in which lower prices and increased market demand trigger rebound effects, indicating that dematerialization is a necessary but not sufficient condition for sustainability [21]. A different example is provided by [16], who assert that the fulfillment of some sustainable development goals (SDG) has resulted in greater environmental degradation, which may cast doubt on the genuine impact of digitalization on societal sustainability.

Part of the problem may be that only those sustainability considerations that lead to business profits have been included in the discussion [11], suggesting a lack of systemic understanding of the DT-sustainability implications. The type of solutions that can be voluntarily adopted to solve environmental problems depends on the institutional logic that drives organizational priorities, acting like a behavioral regulator that constrains the means and ends imposed by such logic [22], distinguishing sustainable from non-sustainable initiatives. DT can facilitate blending such competing institutional logics [23]. Also, the effects of external pressure (e.g., environmental regulation) on an organizational DT strategy depends on what problems ICT is expected to solve, deciding whether sustainability is a consideration in a DT initiative. In other words, the intrinsic and extrinsically motivated organizational mindset and not technological possibilities determines the direction of DT, whose scope depends on sociocultural processes of change [24]. This statement suggests that emphasis needs to be put on external and internal incentives that nudge organizational efforts toward sustainability goals. In the end, DT develops as a compendium of digitalization initiatives deriving from autopoietic decisions [25], which can implicate sustainability consequences. Hence, DT constituents can be classified according to their role from a dual perspective of reality [26]: either in the construction of decision-making information (rules) that determines the scope of DT or the realization of such information as concrete digitalization projects. Based on scholarly recommendations to deploy a DT strategy in organizations, this chapter explores several DT perspectives, such as product portfolio, stakeholder interactions, value proposition, and decision-making strategies, whose rationality is analyzed from sustainability theories. Based on the analysis of these perspectives and the identification of their key constituents, this chapter postulates theoretical observations that frame the scope of DT in sustainability, discussing how and to what extent the constructs that explain DT match the theoretical presuppositions of sustainability. There is scholarly literature that already provides a wide variety of applications of such constructs to sustainability (see [2, 13]), and it is well beyond the scope of this chapter to provide further empirical examples. In general, this chapter aims to respond to the following research question: How do main sustainability theories fit into the different constructs that endorse digital transformation?

The following section elaborates on the evolutionary path of DT in the context of sustainability, beginning with incorporating ICT into all organizational activities in the course of digitization, which turns into a meaningful process when the socio-technical nature of ICT is taken into consideration (digitalization). This argument drives Sect. 2.2 to examine DT as the outcome of the organizational principles and values (mindset), an instrumental viewpoint to explain the place of sustainability in DT. Section 2.3 aims to take DT to an abstract conceptualization of reality, characterizing relevant DT constituents identified in the literature to develop a framework proposal that recognizes the dual existence of the phenomenon, which is applied to the problem of sustainability. Section 2.4 covers DT and its implications on sustainability. The chapter ends with a general conclusion in Sect. 2.5, recognizing the importance of changing our state of mind for the common good.

2.2 The Nexus Between Digital Constructs and Sustainability

Variety of theories and conceptual frameworks have been proposed to associate the concept of sustainability with its application in business organizations. A general theoretical approach is the natural-resource-based view (NRBV) of the firm, which interrelates the logic of business profit with the firm's environmental actions, proposing three core capabilities to be nurtured: pollution prevention, product stewardship, and sustainable development [12]. Additionally, Chang et al. [1] identify Corporate Social Responsibility (CSR), Stakeholder Theory (ST), Corporate Sustainability (CS), and Green Economics (GE) as the main social theories that make the connection between sustainability and firms. According to the author, the role of CSR is rationalized by the long-term interest of the firm in securing an immediate support structure and a good reputation. In contrast, ST and CS place the figure of the stakeholder at the center of their rationale for sustainability: as members of the society, firms should respond to pressures and requests from their multiple stakeholders (ST), and embrace the tradeoff that exists between economic, environmental, and social interests to achieve performance (CS) [1]. NRBV takes the same position when it establishes that firms are compelled to develop sustainability capabilities when stakeholders put higher pressure on them [12]. NRBV, CSR, ST, and CS understand sustainability from the business logic viewpoint, while GE takes a more systemic approach.

Regarding theoretical proposals that make the connection between digital technologies and sustainability, one viewpoint originates in the field of ICT for Sustainability (ICT4S), where sustainability considerations at the micro-level are expected to affect the macrostructure by targeting resources efficiencies through process optimization, media substitution, and externalization of control [21]. From this vantage point, Townsend and Coroama [21] warn against the limitations of resource-saving process optimization and media substitution approaches, in that rebound effects exert a strong influence at the macro level, to propose the concept of push impacts as a market mechanism to induce process optimization through technological substitution purposely (e.g., cleantech and circular economy). Another proposal comes from Lenz [11], who analyzes discourses on digitalization and sustainability from the perspective of three sustainability development regimes: modernization, transformation, and control.

However, despite the variety of theories that interlink sustainability and the firm, several scholars recognize that little research has purported to make the theoretical connection between the specific digital constructs that derive from ICT adoption and sustainability [11, 13, 27, 28]. Current research has been fragmented, covering either one aspect of digitalization or only one of the three components of sustainability [13], providing a variety of examples of digital technology applications to sustainability (see [13]) or actionable fields of application (see [2]), and most frameworks that relate ICT and sustainability disregard previous theories that associate sustainability and the firm. To help fill this gap, this section analyzes the key theoretical constructs associated with the digital era, namely, ICT, digitization, digitalization, and digital transformation, contrasting them to the main tenets of sustainability theories. The term digitization is sometimes confused with digitalization and digital transformation [29, 30]. Clarifying, technological digitization is embedded in the socio-technical phenomenon of digitalization, affecting processes and business models, leading to digital transformation when the organizational mindset is ready to adapt to the digital realm [7]. Hence, the level of such transformational impact would depend on the degree of consideration that the organizational vision grants to opportunities that derive from digitalization. How should we understand DT after a long period of conceptual work around ICT development from the perspective of sustainability theories? This is a question that this section aims to discuss.

2.2.1 The Multilayered Structure of ICT

The structure of ICT can be regarded as a composition of diverse functional interactive blocks, whose role is defined by its teleological design and type of interrelation, according to certain specific standards that guarantee their interoperability. These blocks are composed of specialized software and hardware elements, depending on the function that organizations expect from them. On the side of this approach, in the field of information technology, electronics, telecommunications, or systems engineering, it is necessary to use block diagrams to identify the functional layers of any system or protocol for the description of all ICT. Each layer often constitutes a series of specific purpose technologies associated with a particular objective. This can be observed in the communications model of greater diffusion: the Open Standard Interface (OSI) model [31]. Each layer performs a specific role and is respected as the basis for interoperability between communication systems, exhibiting ICT as a highly structured technology with specific functions and relationships among them.

From an economic perspective, several scholars have tried to find a generic model that groups the various components of ICT into categories [32, 33], recognizing the structural properties of ICT, hierarchy, and multiple dimensions. Such components interact in a multidimensional and multidirectional manner [34], according to a structure constructed from functional elements that range from physical-electrical characteristics in communication to protocols for reliable data exchange and applications mounted on or interacting with other applications, whose function is the generation of other blocks of the structure. Each layer of activity derived from ICT is established with rules and laws specific to its level: there are specific rules and regulations for telecommunications, electronic commerce, free software, etc. In fact, it is the upper layers of the ICT value chain that have the property of generating a substantial change in the organization, referring to "digital processes" and not to "digital products," according to the connotation of [32]. While it is appropriate to understand ICT through a hierarchical structure of defined functions, it comprises many more layers and sub-levels with vertical and horizontal interactions within each layer. It is possible to observe that even within the same layer, different functional levels of software interact to achieve a defined application and that it may involve either the exchange, storage, or processing of information. To achieve all these functions, several technologies that complement each other are involved—a phenomenon known as technological convergence, which unifies into a common infrastructure that continues to evolve to achieve greater scales and efficiencies. It is conceivable that new technologies replace many of the capabilities of current ICT; however, these would be performing the same traits in the handling of information, still constituting ICT.

Hence, it is crucial to understand ICT as a structure of complementary technologies where, although the transistor gave its origin, it was only the first of many inventions, including new electronic and optical hardware systems, software systems, standards, protocols, etc. It is more a question of a series of technologies, not a single one, which causes digitization. For this reason, Greenstein [34] states that ICT does not build a vertical chain like in manufacturing, where activities are hierarchical, linear, and sequential that run from top to bottom. It is rather a platform, defined as an arrangement of components and activities unified by technical standards and procedural rules [34], which can be part of physically separate devices but interact according to functional layers. From the NRBV perspective, information and communication technologies are resources that firms can employ to achieve operational efficiency, deeper stakeholder integration, and product disruption, improving sustainability to gain competitive advantage. In this regard, it may be expected that ICT contributes to higher material resource efficiencies through process optimization (digitization) or product substitution. However, these actions usually lead to rebound effects [21], this being a situation usually ignored by evaluation methods relating ICT with sustainability [16]. This conflict can be explained by the multilayer structure behind ICT, which implies a complex network of industrial supply chains that place significant stress on natural resources, leading to the phenomenon known as digital rebound.

In general, ICT forms a value chain where nobody dominates all the arrangement [34], and this value chain consists of many activities necessary to deliver a digital good or final service. In other words, ICT production growth causes more aggregate consumption of material resources and waste, neutralizing any efficiency gains [16]. According to Lenz [11], vested interests and digital rebound makes sustainability and ICT growth incompatible. That is, if we consider that technology-led innovations usually involve unsustainable practices [35], the sole adoption of ICT at the firm level leads to a digital rebound, suggesting that the link between sustainability and ICT is beyond the scope of technology acceptance, even if implemented to support sustainable actions at the firm level.

2.2.2 Coding: The Essence of Digitization

The multilayered physiognomy of ICT facilitates their dissemination across the organizational structure, both horizontally and vertically. This is how they are considered general-purpose technologies (GPT), potentially being used in multiple processes and products [36]. GPT are characterized by greater horizontal penetration in organizations as well as high potential for process improvement, enabling the development of complementary innovations and increasing returns to scale, greater sectoral productivity, and lower prices [37]. For example, Greenstein [34] lists some of these activities in categories, including client applications, client operating systems, browsers, hardware, processors, distributed technologies, hardware distribution and maintenance, network access, interoperability between operating systems, data transmission facilities, local area networks, databases, servers, custom, and packaged software, etc. Many of these applications are required to manage different types of information, and the exchange of information between people is the fundamental process of achieving the coordination of different human activities at all levels in the organization. This is why ICT has become a mechanism that codifies human expressions, specifically, information handling, which involves storage and automatic processing. Converting information into digital coding is usually known as digitization [13, 14].

Digitization opens the door to many possibilities for efficiency in performing many productive tasks. It is the capacity of automatic processing that allows for greater economic productivity with all its social and economic impacts. Thus, traditional activities (learning, commerce, communication, etc.) are converted into digital applications (online learning, e-commerce, e-mail, etc.), generating an interconnected organization that demands new skills, knowledge, and infrastructure [38], i.e., digital capabilities. Presumably, functional gains from digital coding should lead to more sustainable processes, consistent with the ICT4S viewpoint in which sustainability considerations at the micro-level should affect the macrostructure. However, as discussed earlier, the sole search for micro efficiencies (firm level) from ICT-based information coding leads to a digital rebound. There is no evidence of the positive macro effects of firm-level digital initiatives around sustainability [16]. Additionally, some critics claim that simple digitization for sustainability can cause a productivity gap since organizational resources deviate from more profitable activities [23]. Clearly, to make sense of digitization in terms of sustainability, a higher order of thinking is necessary, so that the level of influence that digitization exerts on the environmental and social dimensions of sustainability depends on its functional conception and design [27], leading to the consideration of social aspects that determine the successful application of such codified information.

2.2.3 The Socio-Technical Phenomenon of Digitalization

ICT represents a physical form of existence and a logical representation of its functions [39], which are realized in the form of digitization. However, such representations cannot be complete without consideration for the social component of their application, specifically, the socio-technical system that surrounds such technologies; that is, ICT is socio-technical in nature. The successful application of the technology depends on the positive acceptance by users and, in the case of sustainability, other stakeholders. According to CSR, stakeholders' involvement would secure the support from immediate surroundings while developing a good reputation. From this perspective, ICT cannot be regarded as technological tools only but elements for creating socio-technical networks, where the line between technology and social organization is lost [40, 41]. Thus, assumptions about the organization's operation must be part of the digital design, including systemic aspects and an implementation that is a social process always in motion, whose technological effects are indirect and occur at different times [40]. In other words, when digitization is applied to organizational processes, digitalization comes in place. Digitalization is how ICT affects the firm's business model [13], adding digitization attributes to its product and service portfolio [14].

NRBV postulates that environmental actions within the organization depend on complex social processes [12]. The complexity associated with implementing ICT-based socio-technical processes limits the extent to which ICT can fulfill its purpose, this being a relevant consideration for their application to sustainability. In consequence, digitalization should be understood beyond the firm, involving a multi-level perspective (MLP) to determine appropriate conditions to affect socio-technical systems [1]; that is, beyond the prevailing technological and economic logic, digitalization should include sociopolitical processes as well [16]. This approach seems necessary to provoke a systemic change that incorporates new rules for developing ICT solutions and their implementation at the organizational level, preventing the continuity of digital rebounds. Kunkel & Tyfield [16] consider that the digital rebound is a socio-technical problem involving a type of systemic complexity that can only be addressed by revisiting the presuppositions that built such a flawed system in the first place. However, financial performance is hard to realize from digitalization strategies around sustainability, in that only productivity and efficiency improvements at the process level can be observed [28]. This is why it is harder to demonstrate how the acquisition of sustainability capabilities can relate to better performance (short-term thinking), which is why Ukko et al. [28] propose that firms need to widen the scope of their sustainability actions, involving the whole supply chain. From the theoretical perspective of ST, this approach facilitates the firm's long-term survival (and the supply chain's) by responding to pressures and requests from multiple stakeholders. If digitalization for sustainability actions gains wider acceptance among stakeholders by offering a long-term vision to encourage the adoption of sustainable practices, new rules would be established at the systemic level that set a foundational common ground for transformation.

2.2.4 *Digital Transformation: The Outcome of Institutional Logic*

Suppose the capabilities granted by ICT lead to the digitization of the product and service portfolio offering, which derives from digitalization when complex socio-technical processes in the organization are involved. In that case, we must necessarily understand DT according to the institutional logic that drives organizational priorities, beyond traditional interpretations of DT that aim to encourage the organization to drive both costs down (optimization) and product differentiation up (innovation) [9]. Additionally, due to the complexity embedded in ICT structures, their implementation implies a functional arrangement that demands high integration skills, which results in a wide variety of interpretations of what digitalization initiatives, branded as DT, can be implemented in each organization. Especially the adoption of superior technologies such as cloud computing, social networks, mobile devices, and more recently, AI has been considered a relevant indicator of the level of digital transformation achieved in the organization [42]. However, this perspective cannot be widely accepted if we bear in mind that digital transformation is a mindset-led process rather than an end, affecting the principles of how the organization does business, especially considering that the technology to be used will depend on contextual socio-technical elements in the organization. In other words, DT leads to new business models [13, 14].

Consequently, widening the application of the concept to other domains (e.g., sustainability) implies a willingness to embrace DT as a phenomenon that creates new value by redefining organizational business models [43]. In the context of sustainability, DT is commonly associated with "sustainability as modernization," in which the market logic and sustainability considerations necessarily support each other, with the expectation that better firm-level efficiency and optimization can be achieved [11], which is an insufficient approach in that it usually leads to digital rebounds, as discussed earlier in this section. Hence, beyond the search for operational efficiencies, sustainability in DT has to be a management approach [1]. Ukko et al. [28] find that sustainability principles in managerial capabilities lead to financial performance, indicating that DT for sustainability can be made profitable if it is part of the top management strategy. That is, DT requires to find the technological eco-advantage of digitalization, understood as a type of mindset that finds profitability in digital solutions that address sustainability [2], which can be made more prevalent when stakeholders embrace product stewardship (e.g., the supply chain), finding opportunities to repair the long-neglected damaging mindset of our current production system [16]. For instance, El Hilali et al. [44] find that factors such as clients, data, and firm innovation enable sustainability in DT projects, while the presence of competition does not encourage sustainability. From a theoretical perspective, the design of sustainable business models in DT has deep implications in securing the immediate support structure and a good reputation of the firm (CSR), responding to pressures and requests from multiple stakeholders (ST), and balancing the interests that exist between economic, environmental, and social factors to achieve better firm performance (CS). In a way, the organizational vision, culture, and associated rules frame the impact of ICT. Hence, these technologies' expected level of transformational impact, particularly on sustainability, would depend on the managerial business decisions and practices to seize digitalization, whose entrepreneurial mindset appears to be a requirement to lead the organization toward its digital transformation [3]. Saarikko et al. [7] highlighted that attitude, not technology, determines such transformation.

2.3 Digital Transformation from the Dual Perspective of Reality

Based on the previous discussion, we ought to acknowledge that the transformational effects on the organization go well beyond the automation and optimization of business processes, involving a variety of elements that constitute a digital transformation initiative. To take a case in point, Schwertner [5] proposes seven elements involved in digital transformation: the business model, impacts on the organization's structure, staff capabilities, process digitization, technological assets, product/service digital innovation, and customer interaction. Elements like these can be grouped qualitatively based on their effect in terms of the dual perspective of reality proposed by Dopfer [26].

This section reviews those considerations relevant to designing a digital transformation initiative that may include sustainability. The analysis of these considerations is mainly based on the works of Andal-Ancion et al. [8], Gray et al. [45], and Matt et al. [46], which is divided according to the dual perspective of reality proposed by Dopfer [26]. This section recaptures this dual interpretation of reality—the construction of decision-making information (rules) that determines the scope of DT and the realization of such information as concrete digitalization projects—to derive a conceptual framework from characterizing DT and its associated qualities. Ginters and Revathy [39] also make this distinction by recognizing that digitalization implies changes in the physical structure and the logical body, which are the basis for new sustainable business models.

2.3.1 The Construction of Rules: The Logic Behind DT

Organizational decisions guide DT in that they are information that constitutes the strategic rules that define the process of digitalization. In that regard, Matt et al. [46] identify four strategic dimensions in the development of DT (Fig. 2.1), which define the rules that support the form of DT in the organization: the technology strategy, the business model, the organizational structure and financing [46], which depend on the informational priorities defined by the organizational leadership. The first dimension reflects the value assigned to in-house or proprietary technology as a competitive differentiation strategy compared to tactics that prefer off-the-shelf ICT. According to NRBV, sustainability in product development requires the entire value chain's participation, which determines the rules that define the expected sustainability along the product life cycle (stewardship) [12]. In principle, for-profit enterprises may find an opportunity to offer "greener" products and services to gain market acceptance in developing their intellectual property.

Regarding value creation, the organizational vision should guide the best capability-acquisition strategy to attain sustainability qualities sought to be embedded in a particular product portfolio. This is the vision of the business model, which determines the organizational requirements in terms of technology, structure, and staff capabilities that would allow for the realization of digital outcomes that the organizational leadership expects from DT. According to CS theory, the search for competitive advantage is expected to encourage the development of sustainable business models, which need to include economic, environmental, and social considerations for corporate performance [1]. This theoretical perspective defines rules consistent with the discourse of modernization, in which digitalization for sustainability is accepted as long as it increases welfare [11]. In principle, competitive advantage pressures motivate the pursuit of economic sustainability. However, such pressures have proven to be more limited when social or environmental sustainability is attained in

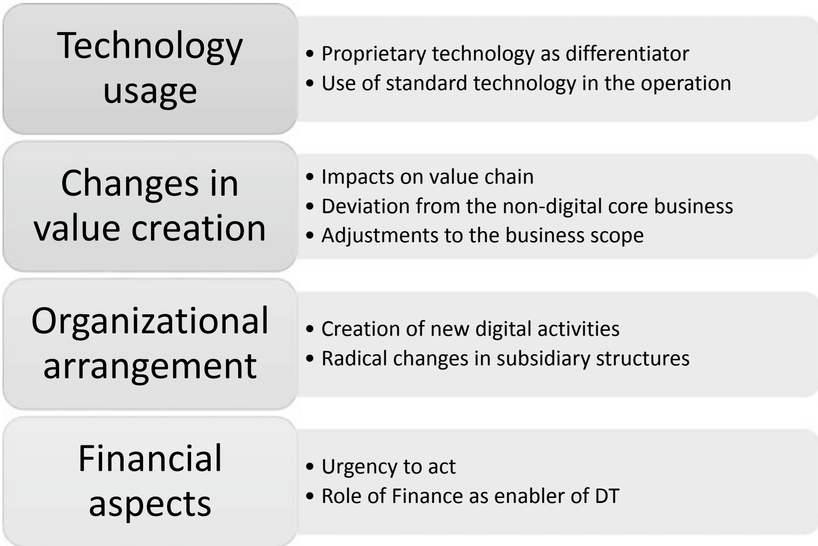

Fig. 2.1 Strategic dimensions of digital transformation (*Source* Own elaboration based on [46])

DT [2], calling into question some of the tenets that support CS. As indicated earlier, firms are induced to develop sustainability capabilities when stakeholders put higher pressure on them [12]. In the end, organizations need to respond to both pressures that originate in the market (competitive advantage) and pressures from social legitimacy (sustainability) [1] to design their business models, describing "how a business creates value, delivers it to the market and captures value in return" [3].

In a sense, new value creation and capture through a digital transformation initiative would demand up-to-date organizational structures that properly respond to the new priorities of the digital business. The organizational structure represents the patterns and entity interactions that lead to the successful implementation of a given strategy [47], specifically, digital transformation for sustainability. Since digital transformation involves the integration of digital technologies across the organization, the organizational structure needs to confront the possibility of a fundamental change, including the creation of new roles like the Chief Digital Officer [5], who may be required to make the digital transformation, and the associated contribution to sustainability, a strategic priority in the organization. However, digital transformation may involve many organizational challenges, especially differences in vision, vested interests, and conflicting priorities in the leadership, whose result might include sustainability considerations or not in the new organizational structure. As purported by NRBV, cognitive framing in management determines if a given sustainability situation is seen as a threat or an opportunity. Hence, managers must believe that opportunities from environmental action exist in the first place and then search for them [12], adopting a type of governance that change the DT approach from the unsustainable present to a sustainable future [16].

Regarding the last strategy shown in Fig. 2.1, financial aspects, Matt et al. [46] highlight that the financial situation of a given organization determines the urgency to develop a strategy that transforms the organization. Without financial commitment, DT for sustainability becomes wishful thinking, and executives that aim to promote sustainability as part of a digital transformation strategy are required to align financial plans to the organizational allegiance to sustainability goals, including an understanding of potential financial benefits from sustainability, such as the positive relationship that exists between disclosure of environmental actions and the firm's risk profile [12]. In the end, financial commitment should adopt the viewpoint that supporting DT for sustainability is not about increasing operational sustainability but about decreasing unsustainable behaviors in business operations [28], which is in the long-term financial interest of the firm to maintain its support structure and a good reputation in the eyes of stakeholders, in line with CSR theory.

From the analysis of the four strategic dimensions of DT proposed by Matt et al. [46], it is possible to conclude that an organization would need to develop first its information, rules, and knowledge that bound the organizational understanding of DT in sustainability, which precedes the material realization of such decisions in digitalization initiatives. The construction of such strategic rules that guide DT in sustainability involves a variety of sensitivities, including the definition of sustainability qualities that should be part of the business model. Such qualities involve decisions in terms of sources of value creation; technology acquisition strategy; an organizational structure that facilitates fluidity, horizontality, and trust for process optimization and sustainability; the development of staff capabilities; policy actions to deal with the sustainability consequences of portfolio digitalization (externalities); and financial commitment. The fulfillment of these qualities would be contingent on how the organizational leadership overcomes its challenges, namely, differences in vision, vested interests, and conflicting priorities.

2.3.2 *The Realization of Rules: Digitalization Projects*

One of the key objectives of digital transformation is the embeddedness of digital technologies in products, services, and business models to reach higher value-added in the portfolio. Additionally, digital solutions are suitable as relational interfaces that complement or substitute existing channels. These are common reasons to assimilate digitalization in business operations and new product development strategies. Without being comprehensive, typical digital transformation strategies related to product portfolio are twofold, involving allegedly superior, even personalized, customer experience and the development of new products and services enriched or digitized [9]. In a coincidence, from a product portfolio perspective, Andal-Ancion et al. [8] suggest that effective digital transformation depends on three main categories: the nature of the product, the interaction with customers, and the level of interaction with industry players, as shown in Fig. 2.2. For each of these categories, intrinsic motivators determine the applicability of digital transformation.

Regarding the first category, that is, the inherent characteristics of a product or service, the organization would need to assess the extent

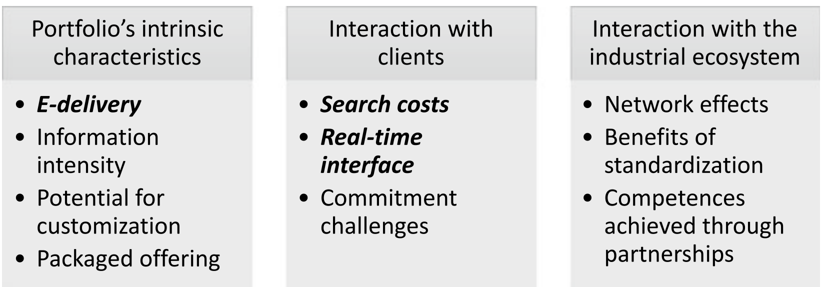

Fig. 2.2 Digital transformation product portfolio categories (*Source* Own elaboration based on [8])

to which its product portfolio can be delivered electronically, the information intensity implicit in the products, the potential for customization, and the implications of bundling products and services. Clearly, intrinsic characteristics of products and services that allow for digitization determine what part of the organizational offering can be made more sustainable through digitalization, understanding that dematerialization is a necessary but not sufficient condition for sustainability [21] and that lower costs are attainable if the focus is put on environmental damage prevention over waste management [12]. Neglecting such principles in product development would probably lead to digital rebounds. As indicated by He et al. [23, p. 3], in the context of sustainability: "digital innovation is both a process and an outcome," and assets that sustain the existing business model do not necessarily become valuable too in the digital world [48]. This is why stakeholders should be made part of the product development process, as proposed by NRBV and ST.

The second category involves the interactions between the business organization and its customers, considering improvements to the client experience in attributes such as product portfolio's search costs, real-time interface, and a decrease in the complexity of contracting or purchasing, achieving efficiencies that may derive in less resource-consuming forms of interaction (dematerialization), which reflect another type of sustainability gain. Under this category ICT efforts in organizations move away from the enterprise core (the center) to focus on digitizing customer interaction (the edge), taking advantage of the client's digital connectivity to increase information exchange and transactions [45]. Gray et al. [45] indicate that this customer interaction (the edge) has the potential to transform the enterprise core processes (the center) as clients can interact directly with the core because of a demand-pull trend. However, digitization of the customer interface does not necessarily eliminate other forms of interaction, considering that enhanced customer experience is achieved particularly through multichannel interactions [5], limiting the extent of DT's sustainability.

Thus, the analysis of digital transformation from a center-edge approach encourages the business organization to review existing ICT practices related to client interaction. Is the organization taking advantage of digital technologies to advance pull-mode interactions that start from what the client determines as valuable, including sustainability considerations? Or is the ICT focus stagnant at the core, trying to push clients toward certain business ends? This perspective demands the business organization to conduct an in-depth analysis of what represents value for its clients, not from the information technology (IT) viewpoint but especially from those responsible for the business results. This approach would allow business organizations to determine the structures that make sense to create a distinction in the value proposition that dramatically supersedes the value offered by their competitors [3], leading the business to a true digital transformation of the business model.

Lastly, the third category, indicated by Andal-Ancion et al. [8], considers interactions between the organization and its partners, which aim to generate greater network effects that lead to a larger client adoption rate, take advantage of the benefits of value chains through standardization or complement the lack of in-house skills through business alliances. In agreement with Rogers [3], who names value networks a key part of an organization's business model, digital tools would allow for more effective management of such organizational value networks, increasing organizational capabilities and market growth. Gray et al. [45] bring our attention to three sources of strategic value in digital transformation: value chains to create new products and business processes, channels to transmit solutions to customer problems (client interaction), and networks for client–partner interaction through mediation technologies, i.e., platforms, consistent with the product portfolio perspective. All these sources involve digital interactions with external stakeholders (the edge), who become resources and facilities that firms can employ [1], in line with the theoretical perspectives of ST and CS. Based on the stakeholder value-generating interaction model that the organization decides, impacts can range from operational processes and the organizational structure to the transformation of the business model [45], both influencing the center and at the edge of the organization.

However, some sustainability effects in this regard are difficult to assess, especially considering that complex qualitative attributes delineate how such a value network and associated business expansion would impact the environment, involving systemic complexities that would make simplistic assumptions about sustainability effects. Consequently, typical insights on DT for sustainability are mostly related to the two typical product portfolio strategies identified by Sanchez [9]: customer experience through a more sustainable digital interface (e.g. [44]), which might lead to less resource-consuming forms of interaction, and the design of new products and services that involve better sustainability, whose intrinsic characteristics would limit the extent of organizational offering that can be made sustainable through digitalization.

2.3.3 A Unified Framework

The dual perspectives of DT analyzed before can be put together in a unified framework that interrelates relevant considerations for designing a DT strategy in the organization. A proposed framework is shown in Fig. 2.3, which identifies strategic decisions that involve rules that the organization will follow to develop its digital initiatives, such as sources of value creation, technology acquisition strategy, an enabling organizational structure, staff capabilities identification, externalities that result from digitalization, and financial commitment, etc., affecting the business model. These rules would determine how DT would impact the organization (physical realization), including objects of impact on which specific digitalization initiatives are to be implemented. Such effects can occur at the operational, organizational, and transformational levels, following the classification proposed by Gray et al. [45]. For instance, if new rules adopted by the organization lead to new digital forms of client interaction, changes in the nature of the product, and/or innovative mechanisms to interact with ecosystem players, new transformational value creation is to be realized, corresponding to a type of edge-driven DT. In contrast, changes in processes and the organizational structure would correspond to a new operational or organizational arrangement associated with a center-driven DT.

This framework encompasses several of the characteristics surrounding DT, inviting the organization to consider as many angles as possible in the definition of a digital transformation strategy, which starts with developing an organizational mindset to take advantage of DT opportunities, including sustainability. Such decisions will have consequences in terms of ICT integration efforts, impacts on the operation, organizational structure and business model, value proposition affecting the product portfolio (digital and non-digital), client interaction and value chain, and strategic definitions about how to position ICT and DT in the organization, the new value that they bring to the business and expected financial requirements. From a strategic perspective, the digitalization of the edge would be expected to bring more value to stakeholders and lead to the update

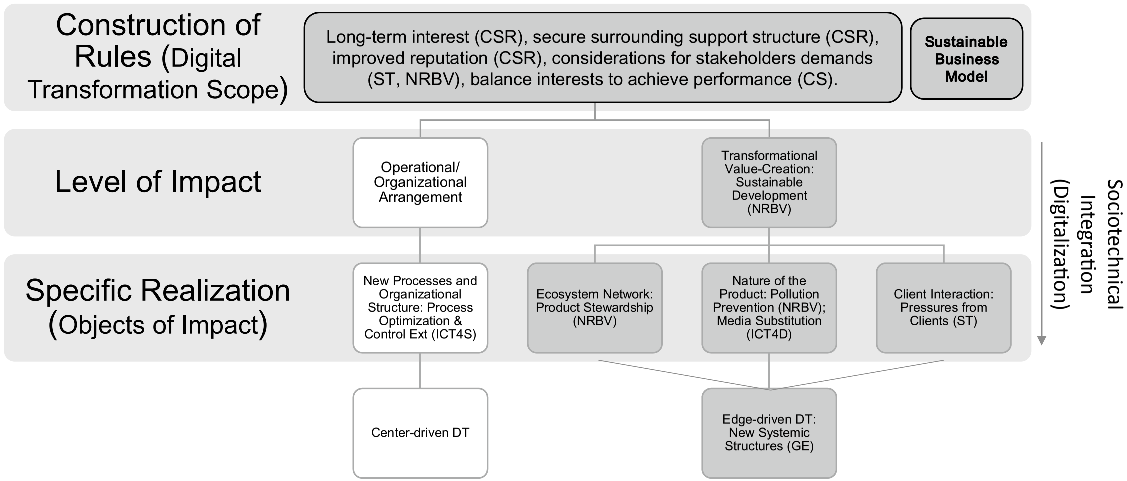

Fig. 2.3 A unified framework of the dual reality of digital transformation applied to sustainability (*Source* Own elaboration based on [5, 8, 45, 46])

of processes and, perhaps, the organizational structure (the center). Eventually, digitalization understood as the realization of DT, executes the business model's renovation, involving the product portfolio and client interaction, that is, the value proposition.

Based on this framework, sustainability criteria can also be included in the scope of DT, with rules that develop according to principles such as the firm's long-term interest (CSR), strategies to secure the surrounding support structure (CSR), sustainability actions that improve reputation (CSR), include stakeholders' demands into the firm's DT initiative (ST, NRBV), and find a balance between economic, social and environmental interests to achieve performance (CS). As indicated in the parenthesis, these considerations in the DT rule-making space match particular aspects of several sustainability theories, defining the sustainability of the new business model, whose physical realization as digitalization initiatives takes advantage of current assets to dematerialize client interaction as a potential response to external pressures (ST), design a more sustainable digitally enhanced product portfolio either preventing pollution (NRBV) or substitute unsustainable products (ICT4D), or develop sustainable value with the value chain to achieve product stewardship (NRBV), whose effects can be seen at the transformational level, i.e., sustainable development (NRBV). Hence, organizations can include sustainability objectives as part of their DT strategy, claiming potential environmental benefits to specific DT effects and defining the DT potential's scope in sustainability. In the end, the realization of DT can be another vehicle to achieve better sustainability in specific activities, which supplements other strategies and decisions at the society or organizational level.

The proposed framework is still a general model, and its components can still be broken down in further detail according to the characteristics of each organization, inviting management teams to include causal thinking in their digital transformation planning, adapting organizational processes and product portfolio, which may help also prevent some of the misconceptions and biases related to digital transformation.

2.4 Digital Transformation and Its Implications on Sustainability

Sustainability represents an instrumental consideration in defining a DT strategy, which is contingent on the mindset that governs the organization. Such a mindset can be constructed following both top-down and bottom-up development mechanisms, aiming to tap into the opportunity to act. In fact, DT facilitates distributed processes that can gain greater efficiencies. However, despite its potential for decentralization, the type of DT that many organizations embrace favors the priorities and interests of top managers, who tend to oppose decentralization and support more control power and greater involvement in subsidiary departments' operations [24]. This finding represents a relevant limitation to DT in sustainability, considering the relevance of bottom-up stakeholder involvement [49].

Additionally, the lack of a clear understanding of the DT potential in terms of new value generation can lead the organization to misbelieve that incremental changes from digitization that give the impression of novelty correspond to DT, deriving in varied forms of business myopia, socio-technical misalignment, and inertia [7]. Hence, managers must hold a systemic understanding of the organizational purpose and value proposition, bringing as much value from DT and sustainability in line with the principles of GE theory. The absence of such a mindset can threaten sustainability when managers grant great value to oversimplified quantitative analysis, ignoring problem complexities, the presence of cognitive biases, and opportunities that may originate in creative alternatives [24]. Beyond the ICT potential to collect and process environmental data that derive meaningful information for decision-making, organizations must understand in advance the decision scenarios and their willingness to implement a DT strategy that derives long-term value to all stakeholders, according to the organizational mission.

Expectedly, sustainability initiatives can contribute to facilitating a new edge-driven, DT-enabled, systemic structure. However, with the realization of DT, digitalization alone can hardly save the environment. Digitalization can be a powerful tool to gain efficiency in attending a variety of leverage points in existing defective socio-economic systems to encourage sustainability [50, 51], involving a more comprehensive understanding of the structures that shape human behavior [52]. This approach departs from the assumption that there is an intrinsic societal or organizational motivation to act on sustainability issues (e.g. [14]), looking at the realization of DT strategies as mere digital tools for the implementation of new decisional rules. However, such aspirations are bounded by the reality of human and business behaviors, characterized by small efforts to support environmental causes but unwilling to sacrifice lifestyle and expected accomplishments [53]. Under the concept of selfishness and free-rider problems, Tirole [53] alerts that such small sustainability initiatives are far from enough to solve our complex systemic challenges; hence, DT in sustainability becomes a contingent variable of higher-purpose objectives.

For that very reason, mission-driven organizations might consider a type of DT that adopts the platform business model as a solution to gain scale and engagement. Platforms as an organizational form offer distinctive characteristics, either as an object of social evaluation, involving a variety of organizing configurations [54] or as a meta-organization [47], comprising network effects and reputational systems that can encourage collective action when governance mechanisms prove to be fit for the purpose. Digital platforms require the orchestration of complex self-organizing for value creation [55], involving a bottom-up approach with tribal-type attributes [56], expressed in non-linear and self-governing behavior among platform participants. Accordingly, identifying novelty in how platforms solve sustainability problems should invite scholars and practitioners to deepen their understanding of opportunities that may derive from this type of digital business model as coordination mechanisms to drive sustainable behavior along the entire supply chain.

On the other hand, sustainability that results from digitalization may appear to be contradictory, in that, despite efficiencies gained in terms of more sustainable business models, knowledge sharing, and CO2 reduction [57], the massive growth of ICT devices involves more energy consumption and material resource exploitation [58], that is, digital rebound effects. However, despite sustainability concerns related to growing ICT infrastructure, there are already significant sunk investments in hardware solutions, making some digitalization initiatives a matter of resource efficiency usage. For instance, previous sections highlighted the importance of customer interaction (the edge) as a key consideration of DT. Since not all interactions with clients need to be person-to-person, DT can make interactions more efficient and satisfying [48], including sustainability gains as well as higher value in the product portfolio and deeper center-edge integration.

As stated in this chapter, firms should look beyond sustainability considerations that lead to short-term business profits and embrace a long-term interest in the DT- sustainability implications. What is at stake is the long-term survival of the firm, its supply chain, and society at large, and firms need to broaden the scope of DT to include sustainability actions that include stakeholders, who can develop new DT-supported production criteria that confront the presuppositions that built our flawed system. Again, it becomes necessary that DT managers believe that opportunities from sustainable actions exist in the first place and then search for them.

2.5 Conclusion

This chapter started with an analysis of the intrinsic properties of ICT that grant their transformative potential, emphasizing key functions and structure, distinguishing from a progressive viewpoint the concepts of digitization, digitalization, and digital transformation, which were confronted by varied theories that aim to explain sustainability. Digital transformation appears to be the outcome of the teleological mission of ICT, whose key qualities have been described and framed according to the dual model explained in this chapter. However, digitalization, considered the physical realization of DT, involves a socio-technical complexity that originates in ICT's multidimensional architecture, posing several challenges, especially in the context of sustainability.

First, misconceptions that have been built around the concept of DT affect the organizational strategy, whose acknowledgment would prevent misguided sustainability initiatives that may end in frustration and ineffectiveness, overlooking problem complexities, or embracing cognitive biases. Sustainability theories help explain the scope of DT from a firm's perspective and its business logic.

Secondly, this chapter has identified a variety of perspectives that help understand the impact of DT in the organization, which have been unified into a single analytical framework that recognizes a dual perspective of reality: decision-making information (rules) that determines the scope of DT, or the realization of such information as concrete digitalization projects. This is perhaps one of the key theoretical contributions of this chapter, considering that little scholarly work has related DT and sustainability [14, 59].

Third, DT is a dynamic phenomenon whose expected impact on the organization may depend on discovering new ICT with extended capabilities. As more ICT innovations find their way into the market, organizations will be in a position to advance their sustainability agenda further. Anzola-Román et al. [60] found that diversity in forms and sources of innovation leads to diversity in product and process innovation, which may enhance the expected digital transformation of the organization.

Fourth, change that originates in sustainability goals can create conflicts with other organizational actions, and policies are instrumental for it to occur. Support is always required, and the work must be articulated because not all people are illustrated in digital technologies' effective appropriation. Hence, the role of the strategic integration function is necessary to understand the organization, its priorities, processes, and leadership struggles (socio-technical approach). Kling and Lamb [40] claims that organizations are imperfect in implementing strategies, creating differences between how systems are designed and implemented. To help solve this challenge, analytical frameworks and tools are instrumental, whose elaboration demands further scholarly research and practitioners' attention.

Fifth, the DT approach chosen in this chapter invites organizations and their strategists to acknowledge that digital transformation has many characteristics, whose sustainability application has implications in any organizational strategy. This is why DT increases its potential for sustainability in the world of small businesses, which can maximize new opportunities that originate in the usage of ICT, especially for resource optimization. In the end, the fulfillment of the sustainability potential of disruptive technologies to transform the organization depends on the availability of external and internal incentives, comprehensive enough to make relevant decisions to take advantage of digitalization opportunities in all aspects of the organization, according to the characteristics of the new technology.

Finally, suppose the organizational mindset and not ICT development encourage business propositions that increase environmental value. In that case, conscious stakeholders can work together to determine systemic conditions that increase the efficacy of DT in sustainability, nudging organizations to change behavior by adopting a new institutional logic beyond simple incremental digitalization actions that become a distraction to what real problems are. COVID-19 has proved that societal and organizational change can speed up. Moreover, suppose sustainability is to be understood by the organization as a relevant criterion in designing a digital transformation initiative. In that case, real economic value has to be created to convince all organizational stakeholders, subject to the new rules that sustainability demands to solve our urgent grand challenges, directing organizations to contribute to the construction of our common good relevantly.

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PART II

Digitization Progress and SDG

CHAPTER 3

Innovation in Information Technologies for the Achievement of SDG 9 in Mexico: Technology Policy Analysis

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3.1 Introduction

In September 2015, the United Nations General Assembly approved the 2030 Agenda for Sustainable Development, which is composed of 17 Sustainable Development Goals (SDGs), 169 targets, and 231 global indicators focused on economic, and social sustainability for the 193 member states that signed it. The 2030 Agenda puts the dignity and equality of the population first through a set of global, regional, and national strategies

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S. Estrada (ed.), *Digital and Sustainable Transformations in a Post-COVID World*, https://doi.org/10.1007/978-3-031-16677-8_3

and policies to achieve greater economic growth and decent work for all, create sustainable cities, and combat climate change, among others [1, 2].

For the fulfillment of the goals of the 2030 Agenda, the progress of technology is fundamental and, even though all SDGs are highly relevant, it is in the interest of this research to focus on goal 9. *Build resilient infrastructures, promote sustainable industrialization, and foster innovation*, because this is a cross-cutting goal that participates in all productive, economic, social, technological, cultural, and environmental activities.

In Mexico, the Specialized Technical Committee for the SDGs was created, made up of the Office of the President of the Republic, the National Institute of Statistics and Geography (Instituto Nacional de Estadística y Geografía, Inegi by its acronym in Spanish), and the Ministry of Finance and Public Credit (Secretaría de Hacienda y Crédito Público, SHCP by its acronym in Spanish), together with the United Nations Development Program, which within the framework of this collaboration defines the mechanisms for linking the Federal Expenditure Budget with the 2030 Agenda [3]. The 2030 Agenda is a roadmap that serves to chart the path toward various strategies that will serve to eliminate poverty, protect the environment, guarantee access to quality education, create added value through innovation, and generate conditions of wellbeing for all people, among others, without jeopardizing the resources of the population in the future. To achieve the mentioned above, the development of digital technology has been a fundamental tool, especially in the current pandemic scenario.

In Mexico, the 2030 Agenda agreement came into force on January 1, 2016; one of the main actions in the framework of SDG compliance has focused on identifying *the linkage* of federal spending policy through budgetary programs, with the SDG targets. This exercise began with the integration of the Federal Expenditure Budget Program (Presupuestos de Egresos de la Federación, PPEF) 2018 and has continued to date [3]. In the PPEF 2021 budget programs, the SDG 9 is an objective aimed to reduce gaps in the management of technology, with the purpose of ensuring that information and knowledge are included in productive

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processes, to offer different innovations or improvements in products, processes, and services. This objective aims to overcome the existing limitations between the population and companies, increase productivity, and improve competitiveness. Also, it makes it possible to solve important global problems such as saving natural resources in production processes and creating more competitive jobs. To achieve the mentioned above, the development of technological capabilities such as the use of and access to technologies is fundamental among the population.

According to the UN, SDG 9 has five targets to be met by 2030: the development of sustainable and resilient infrastructure; inclusive and sustainable industrialization; support for SMEs and their integration into value chains; modernization of infrastructure and industrial sustainability; and increasing scientific research and technological capacity to foster innovation [1].

In Mexico, the 2021 budget indicates that there are eight targets related to SDG 9, linked to programs in 19 areas, including 09 "Communications and transport" and 16 "Environment and natural resources." For this goal, 134 linkages were identified (89 direct and 48 indirect contributions). The 2021 budget allocated to it amounts to 79,610.5 million pesos, of which 42% was allocated to branch 09 "Communications" with 33,450.6 million pesos and 33 "Federal Contributions for Federal Entities and Municipalities" with 9419.9 million pesos, which represents 11.8% of the total [4]. The budget for previous years is unknown, since the reports focus more on the number and percentage of linkage of objectives (Fig. 3.1). According to SHCP et al. [3], between 2018 and 2021, the number of programmatic programs linked to SDG 9 has decreased from 70 to 62, while the percentage of targets of the goal linked to some budgetary programs is 100% throughout the period.

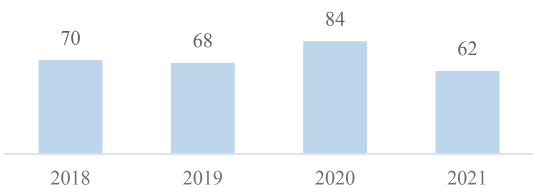

Fig. 3.1 Number of programmatic programs linked to SDG 9. Innovation, infrastructure, and industry in Mexico (*Source* Own elaboration with information from SHCP et al. [3])

With respect to budget distribution, the direct contribution in 2021 was lower at 65%, compared to 70.2% in the 2020 budget; while the indirect contribution in 2021 was higher at 35%, compared to 29.8% in the 2020 budget [4]. The 2020 Sustainable Development Goals Report of Mexico, prepared by the Government of Mexico and Inegi [5] mentions that the evolution of SDG 9 indicators, which are composed of passenger and cargo transportation, manufacturing value-added with respect to GDP, manufacturing employment as a proportion of total employment, R&D spending, among others, does not present a very encouraging picture (Table 3.1).

With the emergence of the pandemic in December 2019, a multidimensional crisis never seen before in the world was presented, which will undoubtedly impact the fulfillment of the SDGs, that forced countries to reorient their strategies to try to reduce the impact on the population, especially on the most vulnerable, as well as on the different sectors of the economy and other areas of human endeavor.

Covid-19 highlighted the importance of technological advances, particularly innovation in information and communication technologies (ICTs), which played a preponderant role in the development of most activities of different kinds. As is well known, the Covid-19 exposed the weaknesses of many economies in the world and Mexico was no exception, it also showed the problems to comply with the SDGs, which in the case of goal 9, the repercussions were profound, because it impacted all sectors and activities, among the most relevant are [6, 7]: lack of infrastructure, digital services, and computer equipment for teleworking; fracture in value chains in various sectors; impact on manufacturing production; labor inequalities, there were activities that could not be performed remotely; lack of digital skills; insufficient health and social security system, among others. This represents a major challenge in meeting the targets of SDG 9, to achieve sustainable, inclusive, and resilient development.

According to Schatan [8], technological progress proved to be one of the key elements in resisting the effects of the pandemic, so that having a generalized and quality digitalization service is a requirement for a functional socioeconomic environment, a situation that has become evident since the appearance of Covid-19. Access to ICTs depends on the availability of the service, the population's capacity to use it, and the cost of the service. Promoting digitization is a core part of an industrial and technological policy for the production of goods and services,

Table 3.1 Evolution of the SDG 9 indicators in Mexico

Goals	*Indicator*					
9.1 Develop reliable, sustainable, resilient, and quality infrastructure, including regional and cross-border infrastructure, to support economic development and human well-being, with a particular emphasis on affordable and equitable access for all	9.1.1 Proportion of the rural population living less than 2 km from a road that is passable all year-round	**2020** 99.85			**2010** 97.73	
	9.1.2.a. Volume of passenger transport, broken down by means of transport. (millions)	**2016** 3776.8	**2017** 3865.6	**2018** 3946.7	**2019** 3928.9	**2020** 2362.1
	9.1.2.b. Volume of cargo transport, broken down by means of transport* (millions)	955.4	982.4	1001.7	981.6	900.6
9.2 Promote inclusive and sustainable industrialization and, by 2030, significantly increase the contribution of industry to employment and gross domestic product, in accordance with national circumstances, and double this contribution in the least developed countries	9.2.1.a Value added by manufacturing as a proportion of GDP	15.77	15.89	–	–	–
	9.2.1.b Value added by manufacturing per capita	22,864	23,260	–	–	–
	9.2.2 Employment in manufacturing as a proportion (%) of total employment, broken down by gender G (TOTAL)	16.30	16.60	16.64	16.57	16.42
	9.2.2 Men	16.54	16.76	16.80	17.04	16.57
	9.2.2 Women	15.91	16.34	16.38	15.83	16.19

(continued)

Table 3.1 (continued)

Goals	*Indicator*					
9.4 By 2030, upgrading infrastructure and converting industries to make them sustainable, using resources more efficiently, and promoting the adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities	9.4.1 Total carbon dioxide emissions per GDP per purchasing power parity	–	–	–	–	–
9.5 Increase scientific research and improve the technological capabilities of industrial sectors in all countries, in particular developing countries, including by promoting innovation and significantly increasing, by 2030, the number of people working in research and development per million inhabitants and public and private sector expenditures on research and development	9.5.1 Expenditure on research and development as a proportion of GDP	0.38	0.32	0.30	0.28	0.30
	9.5.2 Researchers (full-time equivalent value) per million population G	317.99	316.59	342.93	354.28	351.86
Target 9n.3 Increase the contribution of micro, small and medium-size enterprises to employment and GDP	9n.3.1 Percentage of Employed Personnel generated by MSMEs (MIPyMEs)	–	–	67.88	–	–

Source Own elaboration with information from Gobierno de México e Inegi [5] through increased investment in research and development and infrastructure, which will foster technological, industrial, and social development, economic growth, and a sustainable economy, which, consequently, will contribute to the fulfillment of SDG 9 [9].

The Sustainable Development Report 2021 prepared by the University of Cambridge [10] indicates that Mexico ranks 80th out of 165 countries in the fulfillment of the SDGs. According to this report, SDG 9 is stagnating basically due to the fall in several items such as the Logistics Performance Index: related to the quality of trade, transportation, and infrastructure; the decrease in investment in R&D with respect to GDP; the reduction in patent applications; and the stagnation in the publication of scientific and technical journal articles per thousand inhabitants.

One of the strategies to achieve compliance with the SDGs in some countries is to align them with government plans, through a public policy that promotes them. In the case of Mexico, public policy, and in particular, technology policy is a central element for the fulfillment of SDG 9, which contributes through various instruments to the promotion of STI to promote the creation of innovation that has an impact on industrial and infrastructure development. However, for decades, the generation of innovation and technological development has been limited in Mexico by the reluctance of the private sector to invest in R&D, as well as by the lack of interest and poor vision of the country's policymakers, which has resulted in industrial backwardness, lack of infrastructure, and the generation of innovation.

In this context, the objective of this chapter is to analyze Mexico's STI policy in the area of ICT and its challenge to meet the sustainable development objective 9. Innovation, infrastructure, and industry. To this end, the chapter is made up of six sections: the first is an introduction that provides a general outline of the progress of SDG 9 in the country; the second, is a review and analysis of the specialized literature used in the study; the third refers to the materials and methods used for the development and analysis of this research; the fourth, mentions the evolution of Mexico in terms of ICT and 5G; the fifth, presents the results and discussion, which analyzes the public and technological policy and its articulation with the fulfillment of SDG 9; and finally, the sixth, presents the conclusions.

3.2 Literature Reviewed

Nowadays, technological progress is essential for the development of digital technology, since the demand for connectivity through mobile networks maintains a growing trend, given that the digital economy, industry 4.0, and other activities will depend on this infrastructure for better performance.

Information and communication technologies are a sector that is constantly innovating at an accelerated rate, because the technological change and innovation that contributes to economic growth and development [11]. The technological change that has allowed the evolution and penetration of ICTs in all human activities has transcended the knowledge generated in R&D departments [12], creating a techno-economic paradigm due to the presence of a technological revolution [13–15]. Technological innovations revolutionize markets with the presence of new products and services, thanks to this, new industries are created, while established industries are forced to innovate if they want to remain in the market, which in turn reconfigures economic sectors globally, this dynamism creates great waves of economic growth [16].

According to Freeman [17], ICTs are constellations of innovation with an economic and technical articulation that influence various economic and societal activities and socio-institutional structures [15]. These socio-institutional changes occur in three interrelated moments, but in different contexts: (1) the generation of technological innovations; (2) the economic reconfiguration from the introduction of new technologies; and (3) the change in society and institutions forced by the diffusion and expansion of technological innovations, which tend to solve problems of various kinds, derived from technological change. As a technological system evolves through the participation of the various agents that contribute to the development of innovation, it creates what has been called a national innovation system [18, 19], a structure that has also been studied at regional or sectoral levels [20, 21]. Thus, the combination of ICTs, infrastructure, and services, together with knowledge and learning processes, create externalities and competitive advantages for the economy as a whole [22].

The literature that addresses the topic of ICTs has always pointed out their relevance in the economic growth of nations, competitiveness and as facilitators for the integration of new technologies (such as the internet of things, 5G, and additive manufacturing, among others). Likewise, the impact that ICTs currently have on practically all activities of daily life and their potential to improve the health, communication, and education conditions of the population in general. The analysis of the literature shows that the countries that have made the greatest progress in ICT development have defined public policies that, in general, have the following characteristics [23, 24].

1. They are explicit, which gives the opportunity to have clarity in their scope and objectives, in addition to making them known to the different stakeholders.
2. Many of them began with the issue of access to telephony, but as other technologies and elements have been incorporated, they now cover issues ranging from infrastructure, hardware development, software, spectrum, Internet, privatization of services, etc. This has made this issue increasingly complex.
3. Negotiations between the public and private sectors; although the State is the leader of public policy processes, the greatest successes have been observed in those countries where agreements have been reached between the different actors, including civil society.
4. Public policies have also focused their attention on how to provide the general population with the benefits derived from ICTs so that they do not become a factor of inequality (for example, between the rural and urban sectors; digital illiteracy; between the young and the elderly, etc.).
5. Continuity in public policies and their integration with sectoral plans (education, production, telecommunications).
6. Consideration of national aspects, but also of global aspects (for example, compliance with standards).

3.2.1 Public Policies Aimed at STI Represent a Fundamental Tool for the Progress of Nations

In terms of STI, public policies are defined as the set of relationships and instruments articulated between scientific change and economic development [25], while, in particular, innovation policies refer to the articulation of elements of scientific and technological policy that promotes the development, dissemination, and use of product, process or service innovations in companies and public organizations, which allow generating a supply of knowledge, which, through its dissemination, will have an impact on the economy [26–28]. The construction of innovation policy has a direct impact on CTI, through various elements such as qualified human resources (education policies), financing (economic, fiscal, and credit policies), and the creation of intellectual property, among others [29–31].

The most important milestones in terms of public policies related particularly to telecommunications are located during the period 1974–2015 [32], which reflects additional elements mentioned above, for example, the withdrawal of monopolies (whether public or private), greater participation of the private sector, the concept of the information society (which implies access to ICTs and their benefits for the entire population), and the incorporation of ICTs in different aspects, such as the use of the Internet in everyday life and its regulation, national plans for the use of the broadband spectrum and spectrum bidding (Tables 3.2 and 3.3).

Jorgenson and Vu [33] identify seven key dimensions in the context of ICT public policy, these represent the different areas to be considered which are pointed out punctually in Table 3.4. The relevance of the PCTI in the solution of national problems must take into account the complexity of its composition, among the agents and institutional relations, since it implies establishing consensus and negotiations; generation and transfer of knowledge, availability of financing, and sensitivity among human relations.

Table 3.2 Milestones in telecommunications policy 1974–2015

Year	*Region*			
	United States	*Europe*	*Asia/Pacific*	*Global*
1974	AT&T antitrust lawsuit			
1980	FCCSecond Computer Inquiry final decision			
1982	Commission decisión condemning BT's abuse of dominant position in the telex market			
1984	Breakup of AT&T (Baby Bells)	UK: Privatization of BT/Creation of a duopoly		
1985			Japan: Privatization of NTT and creation of new common carriers	
1987	Green Paper on the development of the common market for telecommunications services, and equipment			
1989		Television without frontiers Directive	Japan's KDD lost its monopoly on international communication activities	

(continued)

Table 3.2 (continued)

Year	*Region*			
	United States	*Europe*	*Asia/Pacific*	*Global*
1991	Gore report: National Information Infrastructure			
1992	Cable Act	Review of the situation in the telecommunications services sector		
1993		White Paper on growth, competitiveness, and employment		
1994	Start of spectrum auctions	Bangemann report on Eu and the Information Society	China: First private operator (UNICOM)	
1995	Remaining FCC prices control over AT&T basic residential services are eliminated			
1996	Telecommunucations Act		Japan: Major package of deregulation announced and final agreement of restructuring NTT	
1997	Green book on convergence between telecoms, information technologies, and audiovisual			

Source Adapted from Gómez et al. [32]

Table 3.3 Milestones in telecommunications policy 1974–2015

	United States	*Europe*	*Asian Pacific*	*Global*
1998				WTO agreement on basic telecommunications services
1999	FCC adopted rules for gradual deregulation of incumbents' provision of local service for interstate communications Price regulation of Cable Act expired	Communications Review Launch of "eEurope An Information Society for All"	Lunch of i—mode	
2000		1st generation Information Society plans: eEurope 2002 Biggest 3G spectrum auctions	3G Launch	
2001			e-Japan strategy	
2002		2002 telecoms package review Launch of eEurope 2005	China Telecom is Split geographically	
2004			Korea: BcN (broadban convergence network)	
2005		Launch of i2010		2nd pase of the World Summit on Information Society
2008			China Antimonopoly law	4G Standarization

(continued)

Table 3.3 (continued)

	United States	*Europe*	*Asian Pacific*	*Global*
2009		Telecoms package review	Australia: National Broadband Network Japan: i-Japan strategy 2015	
2010	Connecting America: National Broadband Plan	Digital Agenda for Europe		
2012	Regulation on roaming		Korea: Giga Korea project	
2015	Open Internet Order (net neutrality)	Digital Market strategy		

Source Adapted from Gómez et al. [32]

Table 3.4 The seven dimensions of a typical policy framework

Dimension	*Focused areas for promotion, upgrading, and progress monitoring*
(i) ICT connectivity and access	Broadband connectivity; Mobile phone coverage; Cost and quality; Competition among ICT products and services providers
(ii) ICT usage	Use by individual; use by business; and use by government
(iii) ICT legal and regulatory framework	Telecommunications regulation; Spectrum frequency allocation; E-commerce laws (digital signatures, intellectual property laws, e-payment); Cybersecurity laws and regulations; ICT trade tariff and regulations; Access to data and cross-border data transfer; Investment regulations
(iv) ICT production and trade	Ict-enabled services and ICT content provision; SMEs in the ICT sector (financing, investment, and capacity building); E-market places; Innovation and R&D in the ICT sector; Special industrial Parks/zones/villages for ICT sector development (such as software, high-tech, call centers)
(v) ICT skills and human resources	ICT skills in primary and secondary schools; ICT graduates and programs at universities and vocational schools; Training projects to enhance the ICT workforce; Incentives for private sector companies to organize/support ICT capacity building
(vi) Cybersecurity	Minimization of vulnerability to ciber-attacks; National Cyber Security Exercise programs; Emergency Response to Cyber-Attack plans
(vii) New ICT applications	Smart City development; Big data análisis; Internet of things

Source Jorgenson and Vu [33]

3.3 Materials and Methods

This research was based on a literature review through desk research. It starts with the collection of secondary sources related to the topic of digitization, information and communication technologies, and 5G (fifth generation of mobile networks), as well as the importance of the fulfillment of SDG 9. Innovation, infrastructure, and industry of the 2030 Agenda.

This research addresses four instruments of public policy and technology policy of the current federal administration, referring to the work that has been done in Mexico for the fulfillment of the SDGs, in particular, for SDG 9. The documents that were examined consist of the National Development Plan 2019–2024; the National Digital Strategy 2021–2024; the Law of Science and Technology LCyT 2002–current; and the Special Program for Science and Technology (Peciti) 2021–2024. In addition, the technological policy for the 5G network is analyzed. It also uses information from UNCTAD databases on some indicators related to access, availability, coverage, digital knowledge, and use of ICTs in Mexico and their comparison with other countries.

We participated in the working group for the preparation of the Legislative Strategy for the 2030 Agenda, precisely in the evaluation of the feasibility of achieving SDG 9. Additionally, a consultation (workshop) was held with experts on digitalization, 5G, and new technologies and their impact on different economic activities, which also addressed the issue of current policy related to these technologies and their performance in order to achieve SDG 9.

To contrast the information obtained from the literature, 19 interviews were conducted with digital technology specialists, 67% belonged to the government sector, 28% to the private sector, and 5% to academia. The areas of specialization of the interviewees are shown in Fig. 3.2.

The information obtained directly related to the policy and regulation of 5G technology focuses on: spectrum allocation and cost, cybersecurity and data projection, infrastructure, digital literacy, digital divide, investment promotion, promotion of the digital economy and innovation, and protection of health and the environment. Issues that in general are part of the SDGs of the 2030 Agenda.

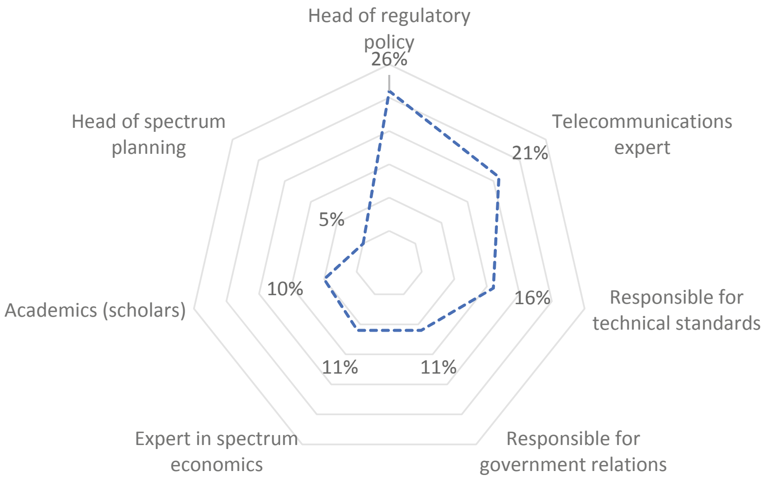

Fig. 3.2 Distribution of interviewees by area of specialization (percentage) (*Source* Own elaboration with information from interviews)

3.4 5G Technology Development in Mexico

Several reports state that one of Mexico's greatest challenges is to provide internet to the entire country, in order to increase its competitiveness through the use of digital technology in the different sectors of the economy and society, but, to do so, it must develop sufficient infrastructure to provide coverage throughout the country, with the necessary support for new technologies such as the 5G network, a cutting-edge technology that will be a global trend in the coming years.

The 5G technology (fifth generation of wireless cellular networks) allows for transmitting a large amount of data over shorter distances in real time, improving the speed and consistency of the connection signals. The network has the capacity to support more devices—internet, sensors, and devices such as video streaming cameras, etc.—thanks to the use of new signal spectrums, as well as Ultra Reliable Low Latency Communication (URLLC) applications that require real-time responses (autonomous cars, drones, smart cities, robotic medicine for surgery, industrial automation, etc.) and the energy efficiency of the technology that saves energy, being environmentally friendly [34].

With the pandemic, the need to improve connectivity to access different platforms and services to remotely perform various types of activities grew; thus, data traffic grew by about 50% in a few weeks after the pandemic began [34]. According to the Ericsson Mobility Report 2021 [35], the first quarter of 2021 recorded a total of 290 million subscribers to 5G networks and estimated that by the end of the year this figure will rise to 580 million subscribers. In the global ranking of average fixed broadband speed, the countries that top the list of 180 countries are Singapore and Hong Kong. In Latin America, the level of 5G penetration is low, the best positioned countries are Chile (31), Brazil (57), Uruguay (65), Peru (69), Argentina (71), and Mexico (75). Swain et al. [34] estimate that by 2035, 5G penetration in Mexico will reach a revenue of 730 billion dollars (mdd), especially through the ICT (137 mmd), manufacturing (134 mdd), services (113 mmd), retail (75 mmd), real estate (52 mmd), and construction (51 mmd) sectors.

In Mexico, the pandemic favored the consumption of digital technology. According to the Digital 2021 Global Overview Report [36], by January 2021, there were 115.4 million connected mobile devices in the country, representing 89% of the population; and 92 million people connected to the Internet. However, Mexico lost 407 thousand connections in January 2021 with respect to the same period of the previous year, this means a loss of 0.4% in mobile devices; internet users grew by 4% to reach 3.5 million new users; while social networks—Facebook, Instagram, Twitter, YouTube—registered 11 million new users, that is 12.4% [36]. This report notes that the greatest use of digital platforms is directed by 90.5% to meet the needs of goods and services of users, while 92.4% sought retail websites or digital stores. Also, the annual expenditure that records the highest growth is the purchase of food and personal care with 42.5%, which generated 1.93 billion dollars in 2020 [36], which exemplifies the increase in the use of information technologies and the increase in the use of platforms for more economic activities. This demand for goods and services through the Internet necessarily requires more infrastructure to improve connectivity and speed.

The hyperconnectivity resulting from the 5G network foresees the emergence of a new production model, which will impact the creation of new jobs, processes, and business models that will emerge once it has been deployed, as it will have the capacity for an infinite number of devices to connect to the Internet and communicate with each other instantaneously. 5G technology[1] is considered an accelerator for the advancement of Industry 4.0, ensuring the connectivity of technology whose demand is increasing. The development of a digital economy requires an environment with a solid infrastructure and digital capabilities, so the deployment of high-speed broadband is essential to ensure global access to meet the needs of Industry 4.0 [37].

The combination of digital technologies will determine the conditions in which services are provided for supply chains, logistics, banking, digital commerce, health, education, and entertainment; the transformation of productive processes of some economic sectors such as industrial—manufacturing—, agriculture; the way of managing large cities—transportation, traffic, lighting, security, assistance, etc. [38].

The development of 5G does not only depend on technology, it also needs laws, regulations, and a public and technological policy that together allow the creation of infrastructure, the generation of knowledge and technology transfer, training and digital literacy, among other components, to ensure its adoption and assimilation of the benefits for the country's population. In Mexico, 5G technology faces great challenges, since for it to work properly it requires investment in infrastructure—installation of antennas for the connection—, however, this is lacking, additionally digital literacy is also a challenge, having qualified human resources for the management of this technology requires special attention from the actors involved in its development. The lack of these resources presents an additional problem, digital security, which puts information and infrastructure at risk, causing large losses of money and the disappearance of companies [39].

Technological innovation not only promotes industrialization and contributes to the construction of infrastructure in a sustainable way, but also promotes job creation, better working conditions, protects the environment, creates more competitive and sustainable economies, and fosters well-being in society. In this way, the development of 5G

[1] The main applications of the 5G network focus on virtual and augmented reality in the cloud, automotive connectivity, interconnected drones, smart manufacturing, interconnected energy, e-health, wirelessly connected entertainment, social networking, smart cities, personal assistants [37].

technology would contribute to the fulfillment of SDG 9, as it would favor the creation of infrastructure, boost industry, and drive innovation. But all this requires a deliberate policy.

3.5 Results and Discussion

The digital transformation in Mexico requires a more dynamic policy than the one that has been applied for years, in order to make up for the backwardness that has existed up to now. Although investments have been made to expand ICT infrastructure and services and provide internet access to a greater number of people, the process to reduce the digital divide in the country has been very slow. Something similar has happened with the assimilation of technologies such as 5G that, without the deployment strategy, the construction of the necessary infrastructure and digital knowledge, progress will be slow and uncompetitive [8]. It is clear that public policies that are designed in combination with the interests of society, investors, and government are required.

3.5.1 Public Policy for the Fulfillment of SDG 9: National Development Plan 2019–2024

In Mexico, the guiding policy instrument is the National Development Plan 2019–2024, which establishes priority objectives and goals for the six-year period. The National Development Plan 2019–2024 is made up of three General Axes: Justice and Rule of Law; Well-being; and Economic Development. The Plan also includes three Transversal Axes: Gender Equality, Non-discrimination, and Inclusion; Combating Corruption and Improving Public Management; and Territory and Sustainable Development, which refer to issues related to the General Axes [40] and the SDGs of the 2030 Agenda. According to the comparative matrix between Annex XVIII-Bis—prepared by the Ministry of Finance and Public Credit (SHCP), published in the Gazette of the Chamber of Deputies (Cámara de Diputados) in 2019 [41], of the PND 2019–2024 and the SDGs of the 2030 Agenda, there are 204 related goals. As can be seen in Table 3.5, despite the importance of SDG 9, it is barely related to 12 PND goals. According to researcher Alma Ríos [42], the adoption of the SDGs in national policy is precarious, due to a lack of resources, in addition to not having defined objectives and goals, which will result in a greater lag in the country.

Table 3.5 Comparative matrix of the Annex XVIII-Bis Axes and the SDGs of the 2030 Agenda (number)

National Development Plan (PND) 2019-2024	Sustainable Development Goals (SDGs)																	Number of SDGs in relation to the PND Axes
General Axes	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
1. Justice and the rule of law	1	0	0	0	6	0	0	5	1	7	2	2	1	0	0	8	7	40
2. Well-being	8	2	6	6	6	1	0	3	6	11	6	3	4	2	2	6	8	80
3. Economic development	6	1	3	4	3	1	2	10	5	9	7	4	4	3	5	9	8	84
Total	15	3	9	10	15	2	2	18	12	27	15	9	9	5	7	23	23	204

Source Cámara de Diputados [41, p. 219]

In SDG 9, innovation, the creation of infrastructure, and the strengthening of industry are considered pillars of the other sectors that should have a greater weight within the strategies that allow companies, organizations, and the country to be more productive and competitive through the creation of added value in the various economic activities, in order to achieve greater economic growth and social well-being. However, the PND focuses more on the development of social policy than on economic policy, as can be seen in Table 3.6, where it can be seen that Axis 2. Well-being, records more objectives aimed at the SDGs.

Table 3.6 shows that Axis 3. Economic Development, establishes the objectives that are directly related to SDG 9, but does not determine the strategies to carry them out, let alone how their effectiveness will be evaluated. It also sets out a set of actions—growth, job creation, austerity, etc.—without explaining how they will be transformed into a set of actions—without explaining how to transform them into real facts. "… the development of the document lacks an objective assessment of the circumstances in which the national situation is diagnosed, which gives a sense of subjectivity in the treatment of the issues" [42, p. 45].

In addition to the lack of a technical and methodological structure in the NDP, there are other events that have an impact on the fulfillment of SDG 9. A clear example of this is the lack of a roadmap to guide the way to achieve an estimated economic growth of 6% at the end of the six-year term; the consequences of the pandemic with a historical contraction of the economy of 8.2%; the loss of companies, which in 2020 were 1,010,857, while in 2021 they were 1.6 million [43], where the most affected sectors were non-financial private services (38.1%), commerce (29.8%), and manufacturing (25.6%). The federal government refused to design and implement countercyclical policies to stimulate the productive sectors. In terms of science and technology, the NPD does not mention strategies to promote STI activities, or to increase investment in R&D. On the contrary, in the last decade, spending on R&D has been consistently reduced, from 0.49% in 2010 to 0.30 in 2020, although there is a commitment from the federal government to reach 1%, this has not happened.

The budget allocated to science and technology increased 4.47% (102,720.8 mdp) in 2021, compared to 2020 (98,724 mdp); however, it does not exceed the amount received in 2015 of 117,351 mdp. The budget received in 2021 was aimed at increasing the capacities of activities in technological development and linking science with improved quality

Table 3.6 Comparative matrix of the Axes of Annex XVIII-Bis and SDG 9. Industry, innovation and infrastructure of the 2030 Agenda (number)

General Axes	*National Development Plan (Plan Nacional de Desarrollo, PND) 2019–2024 Objectives*	*Objective 9 with the General Axes of the PND*
Axis 1. Justice and Rule of Law	19. To build a more resilient, sustainable, and secure country	1
Axis 2. Well-being	2.2. To guarantee the right to *secular*, free, inclusive, pertinent, and quality education in all types, levels, and modalities of the National Education System and for all persons 2.4 To promote and guarantee effective, universal, and free access of the population to *health services, social assistance,* and medicines, under the principles of social participation, technical competence, cultural relevance, and non-discriminatory treatment 2.5 To guarantee the right to a *healthy environment* with a focus on the sustainability of ecosystems, biodiversity, heritage, and biocultural landscapes 2.8 To strengthen the steering role and linkage of *territorial and ecological planning* of human settlements and land tenure, through the rational and balanced use of the territory, promoting accessibility and efficient mobility	6

(continued)

Table 3.6 (continued)

General Axes	*National Development Plan (Plan Nacional de Desarrollo, PND) 2019–2024 Objectives*	*Objective 9 with the General Axes of the PND*
	2.9 To promote and guarantee *the human right of access to culture* of the population, taking into account cultural diversity in all its manifestations and expressions with full respect for creative and linguistic freedom, freedom of choice, or belonging to a cultural identity of beliefs and participation	
	2.10 To guarantee *physical culture and the practice of sports* as a means for the integral development of individuals and the integration of communities	
Axis 3. Economic Development	3.1 To promote an inclusive development of the financial system, prioritizing the attention to the backlog of the unserved population and the more efficient allocation of resources to activities with greater economic, social, and environmental benefits	5
	3.3 To promote innovation, competition, integration in value chains, and the generation of greater added value in all productive sectors under a sustainable approach	

General Axes	*National Development Plan (Plan Nacional de Desarrollo, PND) 2019–2024 Objectives*	*Objective 9 with the General Axes of the PND*
	3.4 To promote an environment of macroeconomic stability and sustainable public finances conducive to public and private investment 3.6 To develop, in a transparent manner, an accessible, safe, efficient, sustainable, inclusive, and modern communications and transportation network, with a vision of regional development and logistic networks that connects all people, facilitates the movement of goods and services, and contributes to safeguarding national security 3.7 To facilitate the population's access and transparent and sustainable development of broadcasting and telecommunications networks, with emphasis on the Internet and broadband, and promote the integral development of the digital economy	

Source Own elaboration with information from Cámara de Diputados [41] in education and promotion. Of the budget, public education received 43.6%, while Conacyt received 29.5%; both sectors account for 73.1% of the total. The amount granted to SEP generates uncertainty about the orientation of the budget to actually increase capacities [44]. Conacyt allocated 94% of its budget to postgraduate scholarship programs and the National System of Researchers (Sistema Nacional de Investigadores, SNI), which leaves research projects, laboratory maintenance, development of new infrastructure, and the dissemination and promotion of linkages in the STI system without funding. To exemplify the contrast in the allocation of resources between six-year periods, in the 2012–2018 period, around 5000 million pesos were allocated annually to calls for research projects; in the 2022 budget, 1200 million pesos were granted, particularly for the National Strategic Programs (Programas Nacionales Estratégicos, Pronace) [45].

3.5.2 National Digital Strategy (Estrategia Digital Nacional, EDN) 2021–2024

The National Digital Strategy (EDN) 2021–2024 is part of the PND 2019–2024, under Axis 3 Economic Development. From the EDN stems the "Internet for All" program, which seeks to define federal policy related to the deployment, expansion, and adoption of information and communications technologies (ICTs) in Mexico. Its objective is the adoption and development of ICTs in Mexico. This project aims to promote the social, cultural, and economic development of the country through information and communication technologies (ICTs), broadband access, and Internet for all [46].

The EDN states that "Through the installation of wireless Internet throughout the country, the entire population will be offered connection on highways, public squares, health centers, hospitals, schools and community spaces. It will be essential for combating marginalization and poverty, and for the integration of depressed areas into productive activities" [47]. The EDN proposes the construction of a welfare republic with technological sovereignty, autonomy, and independence that guarantees democratic and universal access to digital resources, infrastructure, and open, standardized, and secure government services that are used efficiently and rationally. The five guiding principles of the EDN's technology policy are: austerity, combating corruption, efficiency in digital processes, information security, and technological sovereignty. The issue of resources, once again, is the core issue for the achievement of objectives. According to the SHCP, the budget allocated for the EDN for 2022 will grow 187% with 42,481,399 pesos, with respect to 2020 when it budgeted 14,760,324; this is the first time in five years that it exceeds the amount received in 2018 which was 21,430,441 [48].

The Strategy was published three years after the current administration began. The description of the "Internet for All"—key project in the area of ICT—expected information on the technologies to be used, the deployment schedule, and clear objectives and indicators, areas of greatest need for digitization and the strategies to do so. Instead, it describes the usefulness of ICTs for government procedures, actions within a company, and the lack of digital skills in the poorest areas. There is also no reference to a specific radio spectrum frequency, nor to the technology, no mention of the role of the devices to be used, and much less to the training that would be necessary for the population to access the digital skills needed to benefit from the new Internet access networks. Nor does it address how the infrastructure will be made sustainable [46]. Thus, the program to make wireless Internet service available throughout the country is confusing. Experts in the field define the EDN as a purely qualitative document.

The federal government, in its internet for all program, created in 2020 the company CFE Telecomunicaciones e internet para todos (CFE Telecomunications and Internet for all), exclusively to guarantee the right of access to ICTs, including broadband and internet throughout Mexico, as well as the capacity to provide technological goods and services incorporating developments in computer and telecommunications systems [49]. According to the ITU, the coverage of internet services in the country is very low since, in order for the population to have internet access by 2030, an investment of 14 billion dollars is required, which is far from the 986.2 million pesos approved for 2021 [8].

For Efrén Páez, from the organization Policy & Law, the "Internet for all" program has not defined what the Internet should be used for; in this sense, it would be important to consider that the connectivity strategy should influence economic activity, productivity, and/or communication in local communities, in addition to being an entertainment tool. Since there is insufficient investment in the program, its objective is unlikely to be achieved.

According to the latest report from Inegi and the Federal Telecommunications Institute (Instituto Federal de Telecomunicaciones, IFT by its acronym in Spanish), there are 84.1 million internet users in Mexico, representing 72% of the population over six years old, an increase of 1.9 percentage points compared to 2019 [45]. If this rate continues, it would take 15 years for everyone over the age of six in Mexico to have access to the Internet.

The national digital strategy needs to consider elements such as infrastructure, digital skills, coverage, availability, internet access, and government procurement, as well as recognize the cost reductions derived from the use of advanced technologies such as 5G in different sectors of the economy, in order to plan and promote their adoption [50]. In Mexico, a Digital Development Agenda (Agenda de Desarrollo Digital, AND by its acronym in Spanish) that responds to infrastructure and technology needs is still pending [46].

3.5.3 Science and Technology Law

Science, technology, and innovation (STI) policy is a decisive factor in productive and social development in the world. Technology policy designs and implements a set of actions that directly influence various sectors to create, access, adopt, assimilate, and transfer knowledge, technology, and generate innovation [25].

The objectives of STI policy have generally been linked to the development and strengthening of STI capabilities; the availability of qualified human resources; the promotion of investment and R&D activities; and the contribution of STI to competitiveness and economic growth, as well as social development. It is important to mention that STI is also a key element in social welfare, since it participates in the solution of problems of different kinds, such as combating climate change, health care, food security, improving telecommunications, education, and contributing to poverty reduction, among others [25]. However, these objectives are not always met because decision-makers often sacrifice resources for STI activities.

One of the most important national legal instruments within the STIP is the Law on Science and Technology (LCyT) [51], approved in 2002. This law regulates section V of Article 3 of the Political Constitution of the United Mexican States (CPEUM), its objective is to promote scientific research, technological development and innovation; foster scientific culture; generate conditions for the linkage between knowledge-generating institutions, and create and regulate the bases for the application of resources destined to S&T, among others. These activities contribute to improve the productivity and competitiveness of companies, generate knowledge and its transfer (knowledge transfer) for the benefit of the economy and society, through the articulation of knowledge-generating institutions [52].

STI are high-value activities that should be considered a priority for Mexico, due to the fact that in the context of globalization, production, marketing, and distribution patterns have changed, creating a new dynamic in the world economy with the adoption of new technologies. For the last five years, Mexico has been following the sustainable development alignment of the 2030 Agenda, a context in which scientific and technological research are essential factors for the country to achieve the Agenda's goals, in the particular case of goal 9, for the improvement of productivity, economic growth, creation and expansion of infrastructure, creation of added value in companies, with greater attention to MSMEs, use and adoption of new technologies to perform activities in different sectors and environmental protection, all in search of greater economic, social, and environmental benefit. However, objective 9 is far from achieving its goals, since the current STIP does not have a defined direction, on the contrary, it is full of ambiguities, in such a way that the public policy instruments that mark the course to follow only remain in good wishes, since the current law has been left aside, resorting more and more to budget cuts, eliminating programs and trusts oriented to STI. At present, the tendency is to centralize decisions and programs, and to reduce resources. Sectoral funds and mixed funds were eliminated when the STI trusts were canceled in 2020.

Since 2019, Conacyt has been promoting the creation of a new General Law of Science, Technology, and Innovation, whose main sign is the idea of centralizing decisions in a State Council. This situation is of great relevance, since the development of this law initiative takes place in the framework of an exercise of simulated democracy, in which the voices of the scientific community have been expressed, but not heard, except for those who had political and ideological coincidence with the authorities of Conacyt. The new law has not been approved, which has created a gap that has already lasted three years since the current law has been relegated.

Meeting the goals of the 2030 Agenda in a context where there is no long-term planning is very complicated, especially for SDG 9, with innovation being a pillar in the development of productive capacities and STI in the country. It should be noted that, according to the STI General

Report 2019 [53], federal spending on STI has reduced in innovation activities by 85.6%, scientific technological services by 10.1%, and scientific research and experimental development by 8.6%, while it increased in education and scientific and technical education by 14%, with respect to 2018. It is important to note that many of the programs and reports related to STI were published only halfway through the six-year term.

3.5.4 Special Program for Science, Technology, and Innovation (2021–2024)

On December 28, 2021, the Federal Executive Decree approving the Special Program for Science, Technology, and Innovation (Peciti) 2021–2024 [54], it was published in the DOF and came into force one day later, a fact that violates Article 30 of the Planning Law, which indicates that it should have been published six months after the National Development Plan (PND) was presented in 2019. This program is framed within the Axis 3. Economic Development of the National Development Plan 2019–2024, which highlights the transformation of the Humanities, Science, Technology, and Innovation (HCTI) sector for the solution of the problems presented by the country and which require the articulated collaboration between Conacyt, the productive sector, public institutions, and the HCTI system; and the LCyT. In this case, Conacyt is the institution in charge of coordinating the National Innovation Plan [55].

Peciti is based on the idea of vindicating the role of the Mexican government as the guiding axis of national development, where science, technology, social sciences, and humanities tend to play a strategic role, under the criterion of republican austerity. Under this scenario, the purposes of this program are not very feasible, not only due to the implementation of a policy of scarce resources, but also due to the short planning time of Peciti 2021–2024, which does not fulfill or transcend the six-year period. Peciti 2021–2024 addresses highly relevant issues such as insecurity, justice, peace, etc., but these are more related issues in the political and social spheres whose attention depends on other instances. The problem is that the Peciti falls short in the objectives to improve competitiveness, development, generation of added value, support for technological development in companies, etc. [56].

The SDGs of the 2030 Agenda related to Peciti 2021–2024 are only stated in a very general way in a footnote; there are 14 SDGs[2] that, according to the criteria of this program, have some linkage [54]. Briefly, in the so-called Specific Action 3.5.10 of Strategy 3.5, the 2030 Agenda is alluded to: Specific Action 3.5.10 To contribute through calls for scientific research and technological development projects to the fulfillment of the Sustainable Development Goals, within the framework of the 2030 Agenda [54, 90–104].

As can be seen, this action is very ambiguous, since it does not indicate what type of projects, sectors, times, conditions, beneficiaries, etc., will be targeted. Peciti's priority objectives are strengthening the scientific community, frontier science, strategic national programs (PRONACE), development and transfer of technology, promotion of universal access to knowledge and its benefits, scientific information, and foresight with social impact. According to specialists, these objectives are not very viable because they lack sufficient resources, basic science that generates knowledge has been relegated by frontier science, there is a line of research defined by the government and the execution time is very limited, among others[3] [56].

Finally, one aspect that can be considered a setback is that Peciti is once again using indicators to measure its effectiveness in an endogenous manner, moving away from external instances that contribute to the credibility of the information. In summary, this current program is a document far removed from the scientific community, without direction, with scarce resources, and whose success will be less than the previous ones [57]. It is not expected that Peciti 2021–2024 can have favorable impacts on SDG 9, mainly because it does not contemplate support for the technological development of companies.

3.5.5 *Technology Policy for the 5G Network*

During the expert consultation and interviews, the principles of the 5G policy that should govern national policy were identified by consensus, in order to the technology can be used to promote the maximum benefit for society, creating mechanisms for its application under fair and competitive

[2] The SDGs not included are 1, 15, and 17.

[3] See Valderrama y Solleiro [56].

conditions, where decision-making is based on evidence and following the principle of technological neutrality, so that its adoption is promoted based on performance criteria, in the pursuit of the public good and sustainable competitiveness. The technology policy recommendations for the 5G network in Mexico compiled from the experts' opinion are conclusive in terms of the priorities required by the sector, which is close to what is established by law. Article 6 of the CPEUM [50] states that the "State shall guarantee the right of access to information and communication technologies, as well as to broadcasting and telecommunications services, including broadband and internet."

The interviewees also pointed out that it is important to have a National Digital Agenda that offers clear objectives that frame the technological policy that determines the path to follow to manage the 5G technology that is intended to be promoted. The findings derived from the interviews and the workshop provided a glimpse of the critical elements needed for the design of a 5G policy (see Table 3.7).

In addition, the specialists consulted also expressed the opinion that it is important to consider the trend in terms of the density of installations expected to arise in the context of 5G deployment, and therefore it is recommended that

- Generate actions aimed at minimizing the possible negative impacts of the deployment of the new 5G infrastructure, carrying out adequate planning and risk assessment, sharing infrastructures, and involving all the agents involved in the process in the responsibility of following standards and guidelines issued by the authority.
- Promote the development of a code of good practice for the deployment of facilities in urban environments, to ensure that safety guidelines are followed.
- Encourage mobile operators to develop programs for managing their electronic waste (sustainability and social responsibility).
- The set of systems that make up 5G must adopt the radiofrequency exposure limits established by the International Commission on Non-Ionizing Radiation Protection (Comisión Internacional sobre la Protección contra las Radiaciones no Ionizantes, ICNIRP by its acronym in Spanish) and the standards arising from the revision of Technical Provision IFT-007-2019.
- Evidence of risk and mitigation measures should be derived from scientific research, so projects in this area should be supported.

Table 3.7 Recommendations for the design of a technology policy for 5G Technology

Access to and cost of the radio spectrum	The high cost and tax rate undermine the competitiveness of the industry, as it is one of the most expensive in Latin America, which discourages the participation of operators and makes the service inaccessible to the user. Therefore, the policy should focus on promoting the use and allocation of spectrum and not on collection; create a long-term plan for broadband development that is a roadmap for the release of low and medium spectrum bands, allowing companies to plan their operations, investments, and profits; provide regulatory clarity to outsource infrastructure as a business model; develop an inventory and rules on unused bands to see what can be done with them; streamline the bidding process for bands to take advantage of their use

(continued)

Table 3.7 (continued)

Construction of infrastructure	The deployment of infrastructure is required mainly in rural areas and suburbs; standardization of norms for the deployment of telecommunications infrastructure in the country, therefore a policy that incorporates the following elements is needed: provide incentives for mutual cooperation between the private sector and the government at different levels, either with Internet and telecommunications service providers; infrastructure owners and operators and network equipment manufacturers, and large industrial sector users (e.g. automotive and aerospace companies); promote the generation of public–private partnerships to create works with a long-term perspective and broad regional scope; promote infrastructure sharing agreements—mainly passive—that guarantee regulatory clarity to network operators and independent infrastructure providers; facilitate the coexistence of network operators and infrastructure providers; facilitate the coexistence of network operators and infrastructure providers with the private sector. private partnerships to create works with a long-term perspective and broad regional scope; promote infrastructure sharing agreements—mainly passive—that guarantee regulatory clarity to network operators and independent infrastructure providers; facilitate the coexistence of community networks or Wireless ASPs to connect rural communities with quality; promote the national development of low-cost equipment and systems (antennas, radio bases, etc.); simplify concession procedures, permits, and facilities to mobilize equipment and workers in the municipalities; standardization and cooperation among the three levels of government regarding costs, times, and concession processes in telecommunications

Cybersecurity and data protection	Despite the existence of the IFT, there is still no entity focused on the protection of systems and devices related to networks and the software and data they contain. It is necessary to define protocols for the protection of technical infrastructure, workflow procedures, physical assets, national security, the confidentiality, integrity, and availability of information. Therefore, for 5G cybersecurity it is recommended to: create a legal framework with powers of surveillance, security, and data protection in physical infrastructure, security, consumer fraud (identity, financial, and confidential data); robust processes of collaboration between judicial bodies, competent authorities and the digital and telecommunications industry; create regulatory testing grounds for the development of innovative services with high levels of security; promote active cooperation between government and international regulators to create mechanisms for exchange and coordination in cybersecurity and data protection

(continued)

Table 3.7 (continued)

Digital literacy to extend the benefits of 5G adoption	Harnessing the potential of 5G requires knowledge to apply this technology in various fields. Currently, Mexico does not have the qualified human resources that can be integrated into companies that incorporate 5G. Likewise, users also need to learn digital skills to exploit these technologies. To this end, collaboration must be sought between the Ministry of Public Education (SEP), universities, training centers, and companies, to acquire digital skills at different levels, for which specialists recommended: incorporating knowledge in 5G and its applications from secondary education; providing training to professionals in digital technology (IOI, artificial intelligence, simulation, data science, etc.); design continuous training programs for the training, updating, and specialization of professionals in the industry capable of using 5G-based ICT; promote and finance research for the development of 5G-based information technology applications in fields such as education, health, Industry 4.0, smart cities, mobility, etc
Bridging the digital divide	There is a deep geographic and generational digital divide, which deepens inequality and social and regional differences. Therefore, the following recommendations are assigned: quality connectivity throughout the country—article 6 of the Constitution—coincides with the Internet for All program; unlicensed use of the spectrum to lower the cost of bringing internet to remote communities[4]; develop public–private mechanisms and technological solutions that support the obligation to invest in the deployment and coverage of infrastructure and quality services throughout the country; adjust taxes to promote digital inclusion, so that more users have access to mobile services and the affordability barrier is reduced

[4] The company Altan Redes is a case of a shared network; however, coverage is concentrated in three entities with an average of 90%, leaving the south of the country with an average coverage of between 5 and 20%. Unlicensed use only applies as long as there is monitoring and surveillance.

Promotion of investment in networks	5G technology requires greater investment in fiber optic networks and better equipment for handling information flows. The policy must promote the right economic conditions to favor investments in this area, so specialists recommend: encourage long-term investment, offer long-term licenses, clear procedures for their renewal and roadmaps for spectrum allocation; promote the rational reallocation of network assets in accordance with long-term objectives that should be included in a National Digital Agenda; apply the criterion of technological neutrality to make decisions regarding network development; design economic and fiscal incentives to favor private investments in networks; the regulatory framework should encourage infrastructure sharing to increase territorial coverage and address segments that are unattractive for large companies; and encourage research focused on the optimization of network use

(continued)

Table 3.7 (continued)

Promotion of the digital economy	The State must improve the country's digitalization drive at the individual, industrial, and governmental levels. This should be done in accordance with a Digital Agenda that sets objectives and general strategies. The COVID-19 pandemic has shown that the introduction of ICTs must be promoted in multiple areas, as connectivity has been fundamental to prevent its collapse. Therefore, the following recommendations have been agreed upon: release a sufficient amount of spectrum, in such a way as to promote the digitalization of companies and ensure widespread and high-quality affordable services for all industries; generate incentives for research and development of 5G solutions applicable to health, education, financial management, industrial and logistics operations, etc. Promote cooperative agreements between companies, governments, universities, and research centers for the development of new 5G applications to solve specific problems; promote the construction of research infrastructure on 5G applications, as well as entrepreneurship to have local technology-based companies dedicated to offer the aforementioned applications and solutions
Health and environmental protection	There is currently concern about the risk of radiation exposure intensification. The IFT issues Technical Provision IFT-007–2019: Maximum exposure limits for humans to non-ionizing radiofrequency electromagnetic radiation in the range of 100 kHz to 300 GHz in the environment of radiocommunication stations or emitting sources. It was issued to protect the population near the exposure zones. It is worth mentioning that in Mexico there is an Official Mexican Standard NOM-013-STPS-1993, issued by the Ministry of Labor and Social Welfare, whose objective is to establish preventive and control measures in workplaces where non-ionizing electromagnetic radiation is generated

Source Own elaboration with information from interviews

These actions in collaboration with an inclusive and effective STI policy would support the fulfillment of SDG 9.

3.6 Conclusions

In Mexico, public policies on STI require a profound change, which begins with the PND, which should be aligned with other laws, programs, and instruments, elaborated with appropriate scientific and technical language, and with greater methodological rigor that does not give rise to ambiguities or exclusively ideological discourse.

From the analysis of the STI policy and observing the performance of the indicators of the SDG 9 report for Mexico, the fulfillment of SDG 9 is not very feasible, because the main categories of the goal: industry, innovation, and infrastructure, have not performed well in recent years, and as evidenced, STI, industrial and digital development policies do not have a defined direction or adequate resources and instruments.

The needs illustrated by the deployment of 5G technology should alert the current administration to a change of approach, as there is consensus that a comprehensive effort is required to advance the development of the 5G network, without which the country will fall behind in this technology. A policy of promotion is required, as the development of infrastructure, the generation of digital innovation, and its application to improve the performance of the industry are crucial to promote the fulfillment of SDG 9.

In addition, the analyzed programs have a maximum life span of three years, since they were published at the end of 2021; therefore, the planning of the six-year term lacks a vision of the future and long-range schemes that lay a firm foundation for the development of infrastructure, innovation, and industry.

In terms of an STI policy for the ICT area, it is evident that a comprehensive intervention is required, from software development, the promotion of innovations in equipment, information security, the creation of digital technological capabilities, the promotion of public–private agreements to build modern infrastructure, as well as collaboration between creators and users of knowledge.

Integral articulation between all key elements is very important, otherwise policies will lack strategic alignment, will not induce synergies, and will contribute very little to the achievement of SDG 9.

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PART III

Developments in Digital and Sustainable Learning

CHAPTER 4

Resilience and Capabilities Adopted by Enterprises to Cope with Disruptive Events

Laura Villasana-Arreguín
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4.1 Introduction

Businesses confront multiple risks and challenges throughout their life cycle as a result of disruptive events such as financial crises, world wars, and pandemics, which have a considerable impact on their economic performance, leaving them vulnerable [1]. The current economic depression, which stems from the SARS-CoV-2 health epidemic that erupted in 2019, has thrown businesses into disarray, revealing massive social and economic costs at the local and macro levels around the world [2–4]. As a

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S. Estrada (ed.), *Digital and Sustainable Transformations in a Post-COVID World*, https://doi.org/10.1007/978-3-031-16677-8_4

result, these types of disasters, as well as everyday problems like resource constraint [5], the lack of resources optimization [6], little investment in technology [7], market segments [8], low performance in innovation [9–11], lack of expertise [12], or high taxes [13], have an impact on businesses.

A significant term in the preceding context is resilience, which is described as a company's ability to dynamically reinvent its strategy and business model in response to changes in the environment. A resilient company can effectively change its strategy, business model, management system, governance structure, and decision-making direction, recognize and adapt to changing risks, tolerate interference with major revenue sources, and gain a competitive advantage by changing its strategy, business model, management system, governance structure, and decision-making direction [14].

The capability of an organization to deal with obstacles and find solutions to problems determines if it is resilient or not [15]. Therefore, the disruptive events in organizations' daily lives make us rethink the elements that allow companies to be resilient and survive. At the World Economic Forum, the SARS-CoV-2 concern was brought up, emphasizing the need for businesses to review their plans, including aspects such as 3R resilience, response capability, and the likelihood of reconfiguration [16].

In general, firms must be aware of both internal and external changes. The institutional theory states that an organization's adaptive potential is dependent not only on its internal capabilities but also on its external environment (for example, the social, political, and economic) [17]. In addition, the dynamic capabilities theory asserts that an organization's ability to respond to rapidly changing environments is based on its ability to integrate, build, and reconfigure internal and external competencies [18, 19].

Moreover, Nassim Taleb's black swan theory, also known as the black swan theory of events, indicates that unexpected occurrences, also known as disruptive events, have a significant socioeconomic influence and three characteristics: They are explainable and foreseeable because (i) they are an atypical case, (ii) they entail a severe impact, and (iii) they cause us to rationalize their presence in retrospect [20]. These three theories are the foundation of this research.

4.1.1 Problem Statement

The most common management issue is that firms do not plan for and implement the necessary capabilities to deal with disruptive events; that is, unexpected conditions or events place them in a position where they are unable to survive. For example, due to the terrorist attack on September 11, 2001, the United States government closed the country's borders and all incoming and outgoing flights. The impact it had on the supply lines was disastrous, and Ford Motor Co. had to idle several assembly lines as trucks loaded with components arrived late from Canada and Mexico [21, 22]. Although, there are studies such as the one developed by Giancontti and Mauro [15], which notes the constant changes that force businesses to seek effective survival strategies, and the one developed by Sanchi et al. [21], which proposes a conceptual framework for improving organizational resilience. Both studies analyze the survival or failure of firms under crisis, emphasizing that no universal principles exist to determine whether capabilities are sufficient for organizational resilience in the face of disruptive events.

It is worth mentioning that Mexico's response to the SARS-CoV-2 crisis in terms of economic policy has not been enough, unlike other countries in Europe or the American continent, such as Canada and the United States, which have immediately and extensively strengthened their economies in the face of the pandemic.[1] On the other hand, the World Bank expects that the global GDP per capita will fall by 6.2% this year,

[1] In Europe, from the European Parliament, the Commission, and the European Central Bank, response funds have been created to deal with, corona bonds for financing, a European rescue fund, and others that have only been put on the table like the Marshall Plan for public investments, European unemployment fund, minimum income, tax cut, to name a few. Monetary policy and macro-prudential policies have been essential to facilitate favorable financing conditions for all sectors of the economy. The cuts in monetary policy rates, the easing of the conditions under which banks can obtain liquidity and the reduction of bank reserves of liquidity, and capital have helped guarantee the flow of credit, especially towards small and medium-sized companies.

According to his minister, Justin Trudeau, Canada has authorized an emergency cash injection package that addresses direct relief for residents and businesses, as well as tax deferrals.

The United States Congress passed three stimulus packages to contain the impact on households and businesses. New laws were passed in April and June to improve the effectiveness of the programs included in the three fiscal packages. The Federal Reserve slashed interest rates to zero percent, and used a variety of policy instruments—some existing and some new—to keep financial markets running.

more than double that recorded in the monetary crisis of 2008; this, contraction puts the survival of companies even more at risk. The difficulty arising from SARS-CoV-2 crisis is determining what competencies companies acquired to survive.

4.1.2 Research Questions

What capabilities did companies take to face the impact of SARS-CoV-2?

How are companies surviving the economic crisis caused by SARS-CoV-2?

4.1.3 Research Purpose

This research aims to review the literature on the resilience capabilities adopted by companies to face disruptive events, using the current economic crisis caused by SARS-CoV-2 as a case study.

4.1.4 Justification

Natural catastrophes, pandemics, and economic depression are examples of sudden extreme events that pose a serious threat to a company's survival. Unexpected events in a firm's economic environment can have substantial effects and, in the long term, cause problems with an organization's resilience capability [23].

Developing organizational resilience has become a major concern for businesses, which have expressed a greater desire to improve their capability to handle unexpected business interruptions and ensure their long-term viability, which entails confronting risks and threats to protect critical business assets, whether physical, intangible, environmental, or human [24].

Enterprises that have a spread leadership structure and workforce, as well as the ability to react to change, are better equipped to handle crises. However, more research is needed to understand how to strengthen a company's resilience from a business strategy [14].

Organizations must examine the many stages of reaction involved in a crisis, establish a crisis management strategy before, during, and after the critical situation, and limit the negative effects of the disruptive event to comprehend and handle a crisis, and be able to work for a controlled recovery, evaluating the actions taken by the organization [15, 21].

4.1.5 Study Limitations

Organizations must consider a variety of conditions and markets, as well as their geographic breadth and economic sector (manufacturing, commercial, services). It is also necessary to undertake a more in-depth retrospective study in order to establish which competencies are most suited to various business sizes.

4.2 Literature Review

4.2.1 Organizational Resilience

Organizations must be effective and produce the results for which they were created. In addition, they need to achieve their goals effectively, which means that decisions must be made in the proper sequence, at the proper time, and with the right intensity. In the long term, a well-managed organization must adapt to its external environment [25–27].

On the other hand, there are different key economic indicators of an industry's prospects for expansion or contraction; market size and growth rates often vary markedly by region and demographic segment. Observing external conditions can support managers pinpoint the various growth opportunities and their limits [28, 29]. Consequently, the challenges that an organization faces have ramifications in both its specific (micro) and general (macro) external environments, as well as its internal operations because it affects itself directly or indirectly [4, 30]. For this reason, organizations have been subjected to numerous adjustments since their inception in order to streamline operations and fulfill goals [31, 32]. Companies use a variety of strategies to achieve continuous improvement, including ISO quality management and quality assurance standards, lean manufacturing, SWOT analysis, balanced scorecard, and six sigma, among others [33].

However, being resilient is the ability of a system to adapt to new risk environments, which means the capability for continuous reconstruction, keep up a positive adjustment under challenging conditions, and absorb disruptions to capitalize on events that potentially threaten organizational survival, transforming them into opportunities to maintain the positive performance of the organization [29, 34–41].

The term resilience has increasingly been seen in the research literature. Resilience is studied in various fields, with its earlier origins in the field of ecology. In management, the ability of a corporation to renew itself through innovation, change, and reinvent itself by changing its reactions to political, social, economic, and competitive influences or difficulties is known as organizational resilience [29, 42]. A resilience vision focuses on a company's ability to withstand disruptions. Some researchers call strategic resilience the ability of a company to dynamically reinvent its business model and strategies as circumstances change [43, 44].

Resilient enterprises can effectively adjust their strategy, business, management system, governance structure, and decision-making direction; identify and adapt to changing risks; tolerate interference in their main revenue drivers; and create advantages [14].

4.2.2 Disruptive Events

Negative consequences caused by disruptive events emphasized the need to address efficient management and promote resilience [40]. Studies that have conducted literature on the topic of resilience caused by a disruptive event provided a review in its widest context and later its application within the organization [45–47]. Disruptive events are random events that occur as a result of internal and external factors that have a detrimental impact on a system's operations [22]. Quantifying the cost of a disruptive event means knowing how much it costs to implement preventive and corrective actions to overcome this issue [22, 41].

The theory of the black swan understands a disruptive event like an unexpected situation that has consequences on the company's performance. These events are called black swans and are unpredictable events beyond what is normally expected of a situation and have potentially severe consequences [48, 49]. In this review, disruptive events are assimilated as black swan events. Black swan occurrences are distinguished by their exceptional rarity, tremendous impact, and broad acceptance; they were predictable in retrospect. Despite the last characteristic, it is observed that even robust modeling cannot prevent a black swan event. As for the consequences, black swan events can cause catastrophic damage to an economy by negatively impacting markets and investments [50, 51].

The economic depression caused by SARS-CoV-2 is the disruptive event used in this research to address the research problem. As organizations relate to different stakeholders, such as suppliers, manufacturers, customers, or shareholders, any significant disruption event affects company performance. Therefore, that increases the impact caused on the economy and the likelihood of organizations facing risks [52].

4.3 Methodology

The method applied is the systematic literature review. It is argued that the systematic review provides the most efficient and high-quality method for identifying and evaluating large literature. Consequently, it allows for minimizing bias and subjectivity. The objective is to identify scientific contributions to a field or question and present the results in a descriptive way [53].

For a literature review to be effective has to (a) analyze and synthesize quality literature methodically, (b) be a good foundation for the research topic, (c) provide the basis for the selection of a particular research methodology, and (d) demonstrate that the research to be done contributes to the body of knowledge or advances the knowledge base of the research field [54].

The following criteria were used: be an article published in a journal. Thus, other publication forms (conference proceedings, books, newspaper articles, unpublished works) were not considered. Four databases were consulted to identify studies allowing to achieve the aim of this research: Science Citation Index (Web of Science), JSTOR, EBSCO, and Emerald. The search was conducted from the start of the pandemic in 2019 through December 2021. Resilience, capabilities, enterprises, organizations, and firms have been used as keywords within the search function. One hundred ninety-three relevant articles were retrieved for an in-depth analysis of the main topic, entire articles were examined, and some did not match the inclusion criteria. After that, there were 105 studies that met these criteria.

4.4 Results

So far, this literature study has looked at resilience from the standpoint of a business. This research looks at the impact of the SARS-CoV-2 crisis in the enterprise dimension to notice what capabilities companies adopted to survive the crisis. The identification of resilience capabilities for companies is shown in Table 4.1. When considering the general features of analyzed studies, it was found that capabilities identified by researchers and the most prevailed are adaptability, agility, collaboration, decreased vulnerability, diversification, dynamic capabilities, flexibility, innovation, knowledge and learning abilities, and reconfiguring organizational resources.

There are three dominant capabilities found in the 105 selected articles: flexibility, innovation, and knowledge and learning abilities. They are followed by the capabilities of adaptability, agility, collaboration, diversification, and reconfiguration of organizational resources found together in 60% of the selected articles. Furthermore, the capabilities decreased vulnerability, and the dynamic capabilities represented around 10% of the total articles.

The organizations that have been analyzed in the selected studies include companies from various sectors such as manufacturing [55–60], financial market [14, 61–63], state enterprises [64, 65], sand service companies, [66–69]. By the firm's size, the sample covers small and medium size enterprises [24, 58, 70–73] and large corporations [68, 74]. As well as in several geographical areas among which are China [14, 55, 57, 59, 75, 76], Romania [24], Italy [61, 77–81], Turkey [69, 82–84], Iraq [70], Vietnam [64, 85–89], Croatia [45], United States of America [90–92], Spain [62, 66, 93–96], Jordan [58, 72, 97], Bangladesh [98, 99], Portugal [100, 101], Arab Emirates [68, 102], Israel [73, 103], Norway [104, 105], and Pakistan [60, 106–108].

Two case studies were found, one in Asia [39] and the other in Portugal [100]. The statistical model predominating is structural equation methods [45, 55, 60, 68, 98], but also researchers use others such as least squares [57, 90], linear structural relations [75], panel vector autoregression [59], and Pearson correlation [73]. Meanwhile, the use of qualitative methodologies is lower [93, 109–112], compared to the use of quantitative ones which is greater [14, 22, 24, 45, 55, 57, 68, 71, 77, 90, 98, 100, 113, 114].

As can be seen, the concept of resilience became an urgent term due to disruptive events [172]. Although adaptability, agility, and flexibility are typically classified as supporting traits of resilient businesses, they can help organizations recover more quickly from this predicament and absorb the impact of environmental shocks [14, 24, 41, 56, 75, 77].

Collaboration capability can enhance the resilience of organizations. Being collaborative is an enhanced resilience strategy in which at least two groups or individuals with different viewpoints investigate the others' activations to evaluate accuracy or validity. Implementing collaboration actions can be detected quickly enough to mitigate adverse consequences [119, 121, 125, 126].

The concept of decreasing vulnerability [43, 45, 46, 90, 173] is linked to the feeling of need, such as lack of financial resources, lack

Table 4.1 Capabilities acquired by organizations to be resilient

Capability	*Meaning*	*Articles related to the capability*	*Scope*
Adaptability	The ability of an organization to adapt to its surroundings and recover after a disruptive event is known as adaptability [41]	[14, 24, 39–41, 45, 55, 64, 102, 115–117]	[14] Studies approach and regression analysis based on the Chinese stock market [39] Qualitative study using case organization, PU Corp, a company in Asia [40] A literature survey to review the existing literature on supply chain resilience [41] A review of the literature on resilience, enterprise resilience, and extended enterprises [55] The structural equation model (SEM) was used to perform studies with Chinese employees in 31 companies across nine industries, including manufacturing, finance, education and training, and others [64] State capital enterprises in Vietnam using SEM [24] Micro and small enterprises in Romania. A questionnaire-based survey was used. An exploratory factor analysis was employed [70] Iraqi micro, small and medium enterprises use qualitative interviewing used as the approach, toking an abductive approach [77] Italian small family firms using Ordinary Least Squares regression [45] Empirical research was carried out on a convenience sample of 502 respondents from the Republic of Croatia, using Structural equation modeling [102] In Riyadh, Saudi Arabia, a study was conducted with 445 responses from male and female businesses [115] Related evidence is given in the contribution to three important supply chain competencies in the post-COVID-19 business environment from the standpoint of purchasing and supply management

(continued)

Table 4.1 (continued)

Capability	*Meaning*	*Articles related to the capability*	*Scope*
			[116] A conceptual model was created. Using survey data from 98 individuals of the Peruvian coffee supply chain, the model was tested using partial least square regression. Also performed was a fuzzy-set qualitative comparative analysis (fsQCA)
			[117] A conceptual framework is suggested to study the ability of a service firm to make adaptations to pandemic conditions
Agility	Agility refers to a company's capacity to respond quickly to changes in the environment [41]	[14, 23, 39–41, 56, 64, 74, 75, 77, 115, 116, 118]	[14] Ídem
			[39] Ídem
			[40] Ídem
			[41] Ídem
			[56] A bibliometric investigation of the robustness of industrial systems in the Industry 4.0 Era
			[64] Ídem
			[74] A case study in Russia boarding meetings with customers and interviews with subsidiary management
			[75] The study was conducted in China, with linear structural relations as the tool for data analysis, in companies that have adopted enterprise social media at work
			[77] Ídem
			[115] Ídem
			[116] Ídem
			[23] SEM was used to study a sample of 213 small retail businesses in the Emilia Romagna area of Italy
			[118] From an analysis of the location of households with the disease

Capability	*Meaning*	*Articles related to the capability*	*Scope*
Collaboration	Collaboration is a working practice whereby individuals work together for a common purpose to achieve business benefits. Collaboration is the ability to share information with business partners [41]	[39, 40, 71, 119–126]	[39] Ídem [40] Ídem [71] In small and medium-sized enterprises (SMEs), using fuzzy cognitive maps with managers and entrepreneurs who operated in the Lisbon metropolitan area [121] This paper identifies a third type of resilience, called meso-level resilience. Multiple supply networks collaborate on short to medium-term supply concerns, resulting in meso-level resilience [122] Based on a thorough literature analysis of peer-reviewed studies published in 2020, a framework for the impact of the COVID-19 epidemic on supply chains has been developed [123] The authors conducted focus groups with seven members of the World Fair Trade Organization Asia from six countries: Thailand, Bangladesh, Nepal, India, the Philippines, and Indonesia [124] Qualitative information from Bosnia and Herzegovina's SMEs [125] Using quantitative operational data obtained from JD.com in China [126] Face-to-face interviews from the qualitative phase were further analyzed through a questionnaire survey within Lagos and Abuja, Nigeria [119] Qualitative resilience assessment approaches are categorized as conceptual frameworks and semi-quantitative indices, and several quantitative resilience assessment approaches [120] In the fields of management and modeling and simulation, quantitative secondary resources such as scientific publications, relevant literature, and journals, as well as qualitative research methods, are used

(continued)

Table 4.1 (continued)

Capability	*Meaning*	*Articles related to the capability*	*Scope*
Decreased vulnerability	Vulnerability is defined as being at risk and the likelihood of having disruptions [41]	[45, 46, 90]	[45] In the Republic of Croatia, an online survey using SEM methods [46] A knowledge visualization index for pandemic vulnerability was created [45] Ídem [90] Using the data collected from people who had dined in a restaurant in the USA, a structural equation model was conducted with the Partial Least Squares method
Diversification	Diversification refers to a business strategy involving multiple product types, sale types, and brand categories [14]	[14, 57, 62, 63, 127–134]	[14] Ídem [57] Sampling 1434 Chinese manufacturing firms amidst the COVID-19 crisis, our two-stage least squares (2SLS) regression analyses [62] Thirteen portfolio strategies in the Spanish financial market (Ibex 35) during the COVID-19 pandemic by using three standard financial metrics [63] The data used were taken from the Compustat Bank Fundamentals Quarterly database using two estimating equations [127] In Caspian Basin, using annual data from the United Nations Conference on Trade and Development for each country from 2007 to 2018 method measure diversification index [128] Markowitz diversification techniques for cryptocurrency portfolios [129] Geographic diversification of the supply chains of Japanese Firms [130] The sample of this study consists of real estate firms listed in the Chinese A-share stock market that trade on the Shanghai Stock Exchange and the Shenzhen Stock Exchange

Capability	*Meaning*	*Articles related to the capability*	*Scope*
			[131] Using the Morgan Stanley Capital International daily stock indices data and the Carhart and the GARCH [132] The paper is an attempt to build a conceptual theory based on the combination of literary and phenomenological juxtaposition [133] Using wavelet coherence analysis in time–frequency space, the dependency between AI & Robotics equities and traditional and alternative assets is examined [134] This study used a combinatory methodology to examine how 124 Brazilian SMEs arranged their working capital and levels of dependent on clients and suppliers before and during the pandemic
Dynamic capabilities	An organization's and management's ability to integrate, build, and reconfigure internal and external skills in response to quickly changing circumstances [27]	[18, 58, 59, 98, 135, 136]	[18] The work was based on conversations with other participants of the Technological and Economic Dynamics Project at the International Institute of Applied Systems Analysis in Luxemburg, Austria [58] 43 semi-structured interviews with entrepreneurial resource providers, owners, and managers of many small and medium-sized firms across various industrial sectors in Jordan were used to obtain qualitative data [59] China's manufacturing industry uses the panel vector autoregression PVAR model [98] SMEs in Bangladesh using SEM [135] The theoretical framework is known as dynamic capabilities [136] An overview of the interconnections between the elements of the economic system that corporations use to chart their profit paths

(continued)

Table 4.1 (continued)

Capability	*Meaning*	*Articles related to the capability*	*Scope*
Flexibility	Flexibility is described as an organization's capacity to respond quickly and effectively to changing demands from its environment and stakeholders [41, 125, 137]	[14, 38–41, 70, 99, 116, 118, 125, 138–145]	[14] Ídem [38] Using a large-scale survey during the COVID-19 pandemic conducted by the Brazilian government to public or private sector and self-employed individuals, and control for industry-sector-interview-location [39] Ídem [40] Ídem [70] Ídem [99] The impact of COVID-19 on graduate employment in Bangladesh has a negative influence on family income and, subsequently, the economy of the country [41] Ídem [116] Ídem [118] Ídem [125] Ídem [138] Chinese A-share listed companies on the Shanghai and Shenzhen stock exchanges were analyzed with regression [139] Literature review [140] The study's methods included scientific literature analysis and synthesis, as well as a critical discussion based on the references presented [141] In Yogyakarta, Indonesia, a qualitative study design was adopted, which included semi-structured interviews with five creative industry-based enterprises. In SMEs, the data was examined using theme analysis with MaxQDA 2020 [142] Using the dynamic capability view to examine the relationship between firm innovation and a firm's response to supply chain disruptions

Capability	*Meaning*	*Articles related to the capability*	*Scope*
			[143] [144] explores how employees work directly with COVID-19 patients participating in job crafting amid a pandemic crisis [145] Propose policies that can lessen the negative effects of this pandemic on food assistance
Innovation	A new or enhanced product or process (or a combination thereof) that differs significantly from the unit's prior products or processes and has been made available to potential users (product) or put into use by the unit is referred to as innovation (process) [146]	[14, 16, 59, 68, 73, 91, 98, 100, 118, 123, 147–151]	[14] Ídem [16] Using financial and non-financial factors, the quantitative model was implemented in the Andean area [59] Ídem [68] Regression analysis of large corporations, SMEs, and households in the United Arab Emirates [91] Multiple regression analysis based on a sample of 61 R&D employees of UK and US technology-based firms [98] Ídem [100] The business sector in Portugal through seven case studies [73] Small businesses in the industry sectors in Israel that employ between 10 and 50 employees, using Pearson correlation coefficients [118] Ídem [123] Ídem [149] This study explores how companies reacted to top-down-initiated social innovation and entrepreneurship activities. It focuses on China, and it collects data from companies involved in the production of medical masks and the provision of solutions for nucleic acid tests [150] Discusses the potential value of digital technologies in enhancing global value change in MNEs and SMEs

(continued)

Table 4.1 (continued)

Capability	*Meaning*	*Articles related to the capability*	*Scope*
			[147] A mixed-methods approach is used, with quantitative data from the OPSI framework on the number of innovative ventures. Then, in a second phase, qualitative data from each project is examined in order to assess each initiative's open data innovation possibilities [148] Identify and discuss ten technologies playing a major role in the COVID-19 crisis [151] Qualitative method, interviews with Technological Research and Innovation Institutions, whether private or public
Knowledge and learning abilities	Facts, information, and abilities acquired via experience or study, as well as a theoretical or practical comprehension of a subject, are all examples of knowledge [152, 153]	[60, 61, 76, 78, 79, 85, 92, 105, 112–114, 114, 155–164]	[60] Data was collected from 610 randomly selected employees in the manufacturing firms of Pakistan using SEM [61] Using the forecast of Italian GDP growth for 2021 and 2022 published by the International Monetary Fund, including financial, political, and public health information available to the global economic analysts [76] An assessment of worldwide scientific co-production networks reveals Chinese organizations' growing importance and knowledge intermediation profile [78] In Italy, during the COVID-19 emergency, within the current institutional communication of politics [79] A point of view about growth and the capability to incorporate innovation, and quantity and quality of investment in education and knowledge, in Italy and their interrelation with the structure of the productive system [85] Research was conducted in the Vietnamese context via a questionnaire survey using SEM [92] During the COVID-19 outbreak, an online poll of 490 full-time employees from various industries in the United States was undertaken

Capability	*Meaning*	*Articles related to the capability*	*Scope*
	Enterprise Learning involves the people, process, culture, instructional content, and enabling technologies to deliver a holistic training strategy and maximize learning outcomes across the organization [154]		[105] A sample of 4854 knowledge-based entrepreneurial ventures was retrieved from a database of registered firms in Norway, analyzed by Tobit regression [112] The method is a qualitative case study of 22 employees from various geographically of an organization within one business sector, namely logistics [113] Data from a quantitative survey in the context of the venture capital-driven innovation ecosystem [114] A multivariable logistic regression model was used to conduct a cross-sectional survey of 140 adult citizens of Onitsha city in March 2020 [156] The method used is based on a comparative analysis of the deliberate and emergent knowledge strategies based on criteria like time perception, systems thinking, type of knowledge, type of changes, and complexity [157] A critical literature review method, finding five themes and related topics [159] Using content analysis, 1053 employees and 290 managers of knowledge work in Denmark responded [164] During the pandemic lockdown, an online cross-sectional survey was conducted among knowledge workers in Norway, and the results were evaluated using a range of approaches, including an independent sample t-test, a one-way Anova test, and linear regression analysis [155] Five basic repurposing principles are discussed, as well as the lessons they contain for managers in a variety of industries and organizations who must quickly innovate in the face of disasters [158] From a knowledge perspective, this analysis based on the classic four-quadrant "conscious–competence" framework- work examines the current state of the COVID-19 crisis. It draws on qualitative current media reporting limited to international, fact-checked pandemic coverage

(continued)

Table 4.1 (continued)

Capability	*Meaning*	*Articles related to the capability*	*Scope*
			[160] An integrated literature review based on the PRISMA methodology [161] A set of operational guidelines for healthcare organizations to launch effective countermeasures against such crises using effective knowledge management practices [162] A total of 19 papers collected published in Organization Science explore how organizations learn from crises [163] The study provides a paradigm for MSMEs to create an online knowledge ecosystem and a standalone text analytics tool, both of which are developed using advanced data analytics design science research approach
Reconfigure organizational resources	The firm's resources are the tangible and intangible assets that it can develop and efficiently govern. Employee talents, equipment, and the organization's aggregate skills are all examples of resources [15, 165]	[18, 19, 136, 155, 166–171]	[18] Ídem [19] Ídem [136] Ídem [155] Ídem [166] The longitudinal qualitative study deployed semi-structured interviews with nine owner-managers analytical procedures were used in small firms & small to medium-sized United Kingdom enterprises [167] Resources challenge equilibrium framework across system levels to facilitate service ecosystem well-being [168] The efficiency analysis approach is applied to a sample of Indonesian Islamic banks from 2014 to 2019 [169] Case study approach with a multi-criteria decision-making model in India [170] A theoretical sampling method was used in five companies in Italy that operate in diverse industries (three in automotive, one in printing, and one in rubber and plastic products manufacture) [171] Conceptual paper using the Ability-Motivation-Opportunity framework

of provisions, lack of experience, competition, risk, and others, adopting organizational capabilities could help to decrease vulnerability, acquiring resilience capabilities the sentiment of needing something can be handled in a better way.

Another way to deal with disruptive events is by adopting diversification capability; influenced by the economic trajectories of local economies. Organizations can adapt their vision, considering the shock event as an opportunity to diversify their products and services. Diversity is of great significance to social and economic stability and development, and some studies [14, 57, 62] have concluded that diversification helps enhance resilience. Considered that more diversified products and services become resilient [14, 57, 62, 63, 127, 128].

The strength of the dynamic capabilities of a business determines the degree of alignment of business resources, including its business model. To achieve this, organizations must be able to continuously detect opportunities, periodically transform aspects of the organization, and reposition themselves in a proactive way to deal with even newer threats and opportunities as they arise [27, 136].

One of the most critical issues in the literature review is the capability of innovation that helps to be more resilient [100, 147, 151]. Product innovations entail technological innovation and market innovation, and they are a major source of profit for businesses [174–176]. More flexibility to adjust to disruptive occurrences can be acquired through innovation [177].

Above all, people learn from a disruptive event, increasing firm knowledge. As knowledge grows, its accumulation produces more knowledge, which helps to improve processes or procedures, and applied knowledge, which derives from diverse products. The growing importance of knowledge as an economic resource has been reviewed from many angles, giving rise to slightly different meanings, each of which tends to emphasize different aspects, but learning from disruptive events [78, 92, 158, 162, 164] generates innovative ideas that help firms rethink on the capabilities they can build to be resilient.

Also, companies need to reorganize themselves to adapt to disruptive events. The reorganization has been proposed as a key dynamic capability. Organizational restructuring and organizational reconfiguration of resources are associated with positive performance, so in dynamic environments, reconfiguration turns positive [166–168, 170, 171]. The reallocation of resources can assist pay greater attention to what is vital in disruptive occurrences because the current structure of the firms is related to the past. Through these detected resilience capabilities (Table 4.1), firms embraced the crisis to deal with the effects of the pandemic event [14, 16, 35, 178].

4.4.1 Theoretical Implications

The extant literature provides some evidence on capabilities adopted by the enterprises to be resilient and deal with disruptive events. The theoretical mainstays are the institutional theory, the dynamic capabilities theory, and the black swan theory. Although these theories emphasize the positive aspects with which organizations can face adverse situations or maximize the use of their resources, it is recommended that more theories be included to have a holistic perspective.

Also, it should be emphasized that the resilience capabilities detected are not exclusive. A longitudinal study analyzing the events that put organizations at risk would help to understand what other capabilities have helped organizations to survive to have better handling of the situation. In addition, there are capabilities highly dependent on each other. Furthermore, it is necessary to find which of them are more appropriate depending on the company characteristics, such as size, sector, and context.

4.4.2 Practical Implications

Managers or people in positions of leadership in businesses, as well as other stakeholders, can use the study's findings to better deal with disruptive events and manage their recovery. Enterprises must be prepared to plan for short- and long-term scenarios, recognize the scope of the situation, implement capabilities, determine the actions to be taken in response to various scenarios that could be caused by disruptive events, adapt their organizations, and promote a resilient attitude.

Furthermore, organizations must examine the numerous conditions and markets in which they operate, as well as their geographical reach, specifically the country and economic entity to which they belong.

4.5 Conclusions

There are diverse ways of seeing resilience in the business world, but all of them agree on the company's survival and overcoming the circumstances of an unexpected event. Enterprises must develop and implement capabilities to recover and maintain their organizational viability. Organizational capabilities, as indicated by Teece in his work 2018 Business models, dynamic capabilities originate in part from learning, integrating resources, and using complementary assets from a theoretical standpoint. Many capabilities become routines, and some are only available to the top management team.

Enterprises are exposed to a broad risk and an unpredictable future characterized by both internal and external disruptive events due to several causes such as financial crises, world wars, pandemics, and others more common like scarcity of resources, lack of resources optimization, little investment in technology, market segments, low performance in innovation, lack of expertise, and high taxes. By developing resilience, organizations can decrease the degree of risk they are exposed to and increase their ability to adjust to uncertain events.

Finally, the research and capabilities used by enterprises to deal with the impact of SARS-CoV-2 in this literature review are as follows: adaptability, agility, collaboration, decreased vulnerability, diversification (products or services), dynamic capabilities, flexibility, innovation, knowledge and learning abilities, and the reconfiguration of organizational resources. Therefore, resilient organizations can cultivate these capabilities under challenging conditions to find subsistence opportunities.

Some of these capabilities are frequently identified as attributes (adaptability, agility, collaboration, flexibility), others as skills to be acquired (decreased vulnerability, reconfiguration of organizational resources), and others that involve more complex processes to be implemented (dynamic capabilities, innovation, diversification, knowledge and learning abilities).

It is also feasible to take a better approach to the problem and choose the capability that best meets our organizational needs by classifying the sorts of disruptive events. Furthermore, after the most vulnerable organizational areas have been recognized, measures must be made to relieve the strain.

In the literature exploration, we cannot speak of a profitable sector that has not been affected by the SARS-CoV-2 in extremity; all business sectors on a global scale were affected. Enterprises need to identify the internal characteristics and external influences which make them vulnerable to events.

To survive the economic depression caused by SARS-CoV-2, organizations studied here achieve desirable resilience through related opportunities with their products or services; they, also use internal collaboration to form decision-making teams to deal with the emergency. Therefore, some strong enterprises adopt strategic deviance, while weaker enterprises diversify. Also, some organizations use operational flexibility to deal with the disruption event, and some make changes in the reconfiguration of their resources.

Moreover, suppliers' payment conditions showed a direct relationship with enterprise resilience capability, with lower use of debt capital, as well as managers developed solutions for fulfilling and maintaining customer relationships arising from the inability to resume production in the short term.

On the other hand, enterprises should demonstrate, openness to product innovation and adaptation to respond to the disruptive event. This can be accomplished through investments in R+D, educational institution collaborations for the development of new products, and national innovation systems, among other things.

Organizations face several difficulties, and resilience capabilities are a critical tool for preparing for changes that may jeopardize their survival. Connecting systems, people, processes, and information, allows an enterprise to become more responsive to the dynamics of its environment.

Finally, the application of organizational resilience, requires the commitment of corporate governance, improving infrastructure, efficient use of technology, and resources available to support its implementation. Increasing resilience entails putting to use the resources and capabilities that businesses already have or can develop in order to deal with a disruptive event. Enterprises must design a plan to address the problem, determine the priorities, assess the financial impact, and reclassify the sources.

Future Work

Processes, systems, technology, and infrastructure should all be investigated further to make them more resilient. Analyze businesses in various domains and conduct cross-comparisons to improve the proposed framework.

Acknowledgements The author gratefully acknowledges Ph.D. María del Pilar Pastor Pérez for her support in this document.

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PART IV

Digital and Sustainable Transformations in Agriculture, Manufacturing, and Services

CHAPTER 5

Sustainability and Innovation in the Beekeeping Sector: A First Approach

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5.1 Introduction

Apiculture is a socially relevant activity, and its approach must be based on sustainability. The benefits derived from the consumption, commercialization, and use of its products (honey and wax, among others) have positive implications for climate change, food security, and poverty alleviation [1]. Under the principles of sustainable development, apiculture is defined as a group of activities aimed at breeding bees, producing derivatives that meet current consumption needs, and preserving resources for future

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S. Estrada (ed.), *Digital and Sustainable Transformations in a Post-COVID World*, https://doi.org/10.1007/978-3-031-16677-8_5

use. However, further work is necessary to improve reference frameworks geared toward the operationalization, evaluation, and measurement of the role of sustainability in the field [2]. In this regard, the Triple Bottom Line (TBL) perspective is a combination of economic, environmental, and social dimensions, known colloquially as the 3P's: Planet, People, and Profits [3–5]. TBL's interactive elements pursue an integrating equilibrium to approach the problem from a broad perspective [6].

The study of sustainability has evolved. Its most significant advances relate to the 17 Sustainable Development Goals (SDG), which integrate social, environmental, and economic matters and constitute the most recurrent and straightforward way of communicating the sustainability concept and its complex underlying relationships [4]. Currently, there is no consensus for measuring each of the pillars (economic, environmental, and social) and the topics that comprise them [7]. Thus, it is important to note that the economic pillar consists of concepts related to money flows and the market, such as income, expenses, taxes, subsidies, job creation, positive and negative externalities, innovation processes, and commercial exchange activities.

The environmental dimension refers to the rational use of natural resources, biodiversity conservation, promotion of renewable energy sources, protection against risks, and environmental care. For its part, the social dimension is linked to education, community, solidarity, security, health, well-being, equality, quality of life, culture, values, and personal development. Thus, the purpose of the present study consisted in identifying the convergences and interdependencies derived from the challenges faced by apiculture to achieve sustainable development through the construction of economic, environmental, and social pillars. Our goal was to make an initial diagnosis to propose feasible and systemic alternatives contributing to the attention of this problem and promote the generation of innovative and comprehensive solutions. Therefore, the following sections present apiculture's theoretical framework in two parts, the first related to the environment, and the second to the analysis of the economic and social dimensions of the problem. In addition, a third section deals with innovation in the sector and the use of digital tools to study apiculture.

5.1.1 Apiculture and the Environment

Like other species such as butterflies, hummingbirds, flies, and bats, bees play a leading role in transferring pollen between flowers for their reproduction. According to data from the United Nations [8], this phenomenon occurs in approximately 90% of flowering plants, and its impact is fundamental in biodiversity conservation and ecosystem services at a global level. Recently, global ecosystem services have been threatened by the loss of colonies and the decrease in bee populations, especially since 2010. As a result, conservation programs and public policies have been created that favor beekeeping worldwide.

The causes attributed to this incident are systemic [9]; that is, they are not due to a specific or individual component, but to the sum of factors that cause the stress problems both in bees and in their hives. Stress can be attributed to both biotic and abiotic factors: habitat, climate, genetics, pesticide use in agriculture, bad management practices in apiculture, poor food availability, malnutrition, and parasites and diseases. Examples of parasites and diseases include Varroa destructor, Acarapis woodi, American foulbrood, European foulbrood, and microsporidia (Nosema apis) [9–12]. To date, more than twenty-four types of viruses that affect honeybees have been identified, which, together with other pests and diseases, represent one of the greatest threats to colony survival [10, 12] and ecosystem preservation.

Different actions are performed to combat these problems, such as the case of Varroa destructor (mites); the attempt to mitigate its population has been approached using insecticides containing pyrethroids. However, adverse effects have followed this treatment both in the resistance of the mites to be eradicated as well as on bee populations, their feeding system, and the contamination of derived products [12]. Other investigations have indicated the presence of trace chemical pollutants due to pesticide use in products such as bee bread, pollen granules, wax, and royal jelly, although there are still no conclusive studies on the effects on humans [13, 14]. Moreover, it has been observed that fungicide contamination increases the propensity of bees to become infected with parasites such as Nosema ceranae [11]. Thus, one of the main drawbacks to researching the effects that chemicals cause on bee populations is the difficulty of measuring and quantifying the specific incidence of these products since, as previously mentioned, the loss of colonies is systemically influenced by other factors [12].

The adverse effects in bees derived from the use of pesticides occur at three levels: (1) Individual: Characterized by changes in the bees' behavior, life expectancy, and olfactory capacity; (2) Colony-level: Changes in the distribution of activities according to the animals' age and how they care for their young, mate, and lay eggs; and (3) Community-level: Related to the spread of diseases and pests to other hives and the accumulation of residues in the derived products [10]. For example, in a three-year study on the impacts of insecticides on bees conducted in Italy, [10] it was found that more than 60% of the examined pollen samples contained at least one pesticide; in some cases, the levels exceeded the permissible exposure limits for humans. Among the most frequently detected pesticides were chlorpyrifos in 30% of cases. This effect has important implications for the revaluation of pollen as a "superfood," and it provides a parameter to determine the illegal and inappropriate use of pesticides that undoubtedly affect long-term soil contamination, thus affecting the quality of crops.

The literature reports on sustainable actions to mitigate pests, such as using organic components. These are made up of acids and essential oils generated in the bee colonies themselves, whose properties reduce the risks of contaminating derived products and help the bees to resist pests. Despite this, viral infections from contact with mites remain [12], so it is imperative to know the ecological interactions between bees, parasites, and associated viruses [15].

There are sustainable mitigation solutions using probiotics to reduce the pathogen load of the Paenibacillus larvae [16]. This type of practice could be affordable and easy to implement for beekeepers, making it a compelling alternative against this disease and meeting the needs of beekeepers in developing countries. Likewise, another threat to the sustainable development of apiculture is malnutrition and the lack of food availability for bees, given periods of flowering shortage, during which bees feed on weeds [17]. Particular care should be taken in the introduction of managed bees such as honeybees that can affect wild pollinator species (food competition and disease transmission) and affect the reproduction of wild plants [18] and is a determinant for the maintenance of bee colonies.

An existing practice to counteract this phenomenon is the mobilization of hives. However, this is not practiced by traditional beekeepers.

A solution frequently used is to provide the bees with a sugar-based diet; unfortunately, it lacks the proteins and other necessary elements that pollen provides to guarantee a balanced diet. Other proposals to address malnutrition problems are related to the diversity of floral resources and crops. Examples include the cultivation of Fabaceae and the increase and conservation of the vegetation cover of semi-natural habitats [17]. In addition, constant monitoring provides information on the loss of honey-producing bee (melliferous) colonies, the type of bee most used globally, allowing for the implementation of necessary actions. However, not all countries show a commitment to implementing this measure. Such as in Latin America, a region where this indicator is not regularly monitored despite its high rate of lost colonies; in the region, this level could be above the global average, but there is a lack of information to confirm this [19].

It is important to note that the environmental implications of apiculture are ambivalent. Although they represent a means of conserving a tree and plant pollinating species, they also lead to the artificial and intensive introduction of bee species in wild and semi-agricultural environments, representing a potential risk for local wild species [20]. Concurrently, activities such as foraging competition affect the bees' collection of nectar and pollen [20]. In addition, diseases present in introduced bees are transmitted to wild bees and other wild pollinators through interconnection networks that allow the proliferation of viruses [9] and the loss of endemic species due to the hybridization of the species [21].

A case study by Valido et al. [22] found that high-density apiculture affects the communication channels that create networks to stimulate pollination, which has repercussions on the hierarchical structures of wild pollinators and a consequent reduction in nectar availability [18]. In this regard, Requier et al. [21] propose a comprehensive conservation system that includes both species of Apis mellifera based on the assumption that both wild and managed bees are endangered due to the loss of their habitat at a global level. Therefore, it is necessary to conduct genetic identification studies to delimit protection zones and differentiate them from agroforestry regions and natural zones where conservation hives (local subspecies) can be used under traditional production schemes to help solve this problem.

5.1.2 Economy, Society, and Apiculture

The concept of social innovation is still consolidating and in constant evolution, the collaborative approach can help to increase its scope in terms of sustainable development and social justice because it promotes the exchange of ideas and includes social stakeholders [23]. Crises and the pursuit of solutions to meet basic needs are two fundamental factors to develop social innovation in a context where governance converges with cooperation among social actors and economic players to deliver the desired social and democratic changes, where the local and social exchange is prioritized and effectively reduces social impact [24]. For such a purpose, non-governmental organizations are an ad hoc vehicle to address social needs via mechanisms that promote innovation and contribute to solving poverty and social impact problems [25].

Social innovation may be seen as a multidimensional concept that materializes different processes with the purpose to achieve an actual impact on society. Initially, social innovation focused mostly on organizational issues and was mainly centered on efficiency. This predominantly economic approach led to the observation that technological innovation can coexist with social innovation to promote economic development, and its relevance in the societal and political spheres has been pointed out, including, of course, its cultural elements [26]. Thus, although corporatist interests are the dominant force in the economy, all social actors must be considered since the impact of business actions affects them, which is also why social entrepreneurship becomes an alternative to materialize these interests [27].

Thus, apiculture can help promote social innovation, especially in developing countries, through social enterprises and cooperatives conducting technology management as well as social and economic practices. In this regard, it has been pointed out that scientific production is limited in apiculture's social and economic spheres, but its contributions from these perspectives are diverse and relevant. For instance, 75% of crops require pollination by insects such as bees [8]. This percentage exhibits the importance of this activity as a critical factor for food security. Likewise, it improves the well-being of the sector's workers, increases the participation of women in paid activities and empowers them, and provides them with greater equality in family decision-making. Additionally, it contributes to access to healthcare and generates positive changes in family and community relations since it promotes the formation of exchange networks between local and external actors [28–30].

The most evident social contribution of apiculture is the well-being of beekeepers. Consequently, small producers have been the most affected by the loss of colonies, which could be due to their not integrating hive migration practices into their work [31]. In developing countries such as Mexico, Tanzania, Ethiopia, and Iran, small producer apiculture is dominated by vastly experienced men over 30 years of age, whose knowledge is usually acquired through informal and traditional methods [32, 33]. For beekeepers, the educational level has been mostly irrelevant; however, education could undoubtedly result in a factor that, like technology, would add to optimized work [34] and added-value products derived from the inputs of apiculture.

Among the problems affecting the sector's activity and sustainable development are low productivity, scarce use of derived products at the national level, and limited exports [35]. Other barriers faced by beekeepers in developing countries are: (a) Lack of management skills; (b) Absence of quality standardization processes; (c) Low technification; (d) In-service training needs; (e) Pest and disease control; (f) Forest fires; (g) Bee migration, the difficulty of mobilizing hives, and climate change; (h) Pesticides and use of harmful chemicals; (i) Inefficient and poorly organized markets; (j) Low capital and limited subsidies [32, 34, 36]. In terms of social development, the main focus is on studying improvements, the implications of economic and social development programs for beneficiary families, and the analysis of beekeeping practices [37].

Apiculture has two main economic benefits. The first regards agriculture, since pollination contributes to the reproduction of 75% of crops, including approximately 87 types of food crops [8, 38]. The second regards the substantive activities of apiculture: bee raising and caretaking and the use of derived products such as pollen, honey, royal jelly, and wax, among others. Economically, the main threats are: (a) Undervaluation of beekeeping activities and little attention to the value chain; (b) Low perception of value by customers; (c) Uncompetitive consumer prices; (d) Limitations on income generation, and (e) Apiculture classified as a secondary activity despite its high potential [39].

In developing countries, many beekeeper families obtain a meager income, most likely due to the lack of training, protective equipment, and hive management. Apiculture cannot directly alleviate poverty; additional elements are necessary, such as an education that allows beekeepers to recognize, manage, and market the product to achieve tangible economic benefits [40]. It is essential to highlight that the traditional, inherited stance toward production and commercialization must evolve and become an entrepreneurial approach under a well-defined business model [41]. This novel approach would greatly help beekeepers to identify opportunities, maximize production, streamline processes, and increase their interest in bee conservation and business profitability [42, 43].

As previously mentioned, another threat to the sector is the use of pesticides, which significantly impact the apicultural and natural agricultural potential since they harm the distinct species of bees and other pollinators. The close relationship between apiculture and agriculture is an essential factor in the integration of activities for the development of organic apiculture due to the specific conditions required in the surrounding areas, which can represent severe limitations for beekeepers if not met [32]. Commercially, honey is the most important apicultural product in the world. In industry, it is used as a sweetener, a medicine, and for its antioxidant properties.

According to information from 2019, producer prices can vary from $1270.70 to $26,534.00 US dollars per ton, depending on the region. Although the median is $3728.40 US dollars per ton, the annual value [44]. Thus, the price differences are enormous and linked to technological use, honey production-quality processes, determination of floral origin, and the scarce use of economies of scale by small-scale beekeepers [39].

In 2019, the main honey producers worldwide were China, with an estimated production of 447,007 tons, followed by Turkey (109,330 tons), Canada (80,345 tons), Argentina (78,927 tons), Iran (75,463 tons), United States (71,1791 tons), Ukraine (69,937 tons), India (67,141 tons), Russia (63,526 tons), and Mexico (61,986 tons). However, the countries with the best yield (hg) are Ukraine (268,885 hg), Latvia (208,932 hg), Fiji (205,385 hg), Belarus (126,493 hg), Rwanda (11,845 hg), and Canada (1126 hg) [44]. In certain cases, low yields can be attributed to the low availability and quality of food due to intensive agriculture involving GMOs, agrochemicals, monocultures, and low temperatures [45–47]. In addition to honey, another apiculture derivative is propolis, a high-value product due to its antimicrobial and antioxidant properties with potential applications to preserve foods such as meat and fish and other uses in the cosmetics and health industries [48]. In conclusion, apicultural products other than honey should also be considered since they are additional sources of income. However, this requires parallel efforts to design and construct value chains to reach target markets.

5.1.3 Apiculture, Innovation, and Digital Tools

The concept of innovation has evolved toward a more comprehensive perspective, one in which novelty lies not only in processes, products, organizations, or marketing. Innovation can be observed in cultural, environmental, and social areas, where the aim is not always the market but its use per se [49]; it represents a reasonable means to adapt to the significant changes observed in the beekeeping sector. Furthermore, the depletion of natural resources derived from economic activity has given rise to proposals for sustainable development goals including both the beekeeping and the agricultural sector due to their close connection. Hence, sustainability actions undertaken for agricultural development represent a social well-being vehicle [50–54] and, in turn, a contribution to agricultural development.

In apiculture, the focus of innovation ranges from increasing hive productivity, minimizing sting risks, and honeycomb management, bee feeding, and beekeepers' well-being and quality of life. In other cases, various aspects of health, social structures, and the family environment are considered [55, 56]. Ultimately, there are potential development areas in the economy of apiculture that can be facilitated by digital components, and their repercussions should also be observed in the social sphere [57]. Although innovation in apiculture is increasingly being analyzed from different perspectives, technological innovation remains the predominant approach in the sector.

For example, its interrelation with science has facilitated the use of information and communication technologies (ICT) in this area and, therefore, technological innovation. It is focused on the measurement of factors such as colony loss (Colony Collapse Disorder), monitoring and follow-up, temperature, weight, and hive vibration conditions using technologies such as Low Power Wide Area (LPWAN), 3GPP protocols, Internet of things, and machine learning [58, 59]. In particular, colony monitoring seeking better yields and production efficiency is known as precision beekeeping [60].

From an economic perspective, ICTs provide solutions for connecting disassociated actors; an example of this is digital intermediaries, which constitute a replacement for local intermediaries and prepare for the emergence of new trade networks among different entities [61], which would improve consumer prices of apicultural derivatives and their diversity, enhance buying and selling conditions, and open new internationalization opportunities.

Regardless of the technological supply, traditional practices are often chosen over modern and formal practices in developing countries. This is attributed to distinct reasons, such as the low academic level of beekeepers, the value they give to tacit and traditional knowledge passed from generation to generation [62], the lack of dissemination and training on the use of technologies [63], and the weak relationship between local needs and conditions and cutting-edge technological solutions [34]. Thus, one of the significant innovation challenges of the sector is the strengthening of technological capacities and the development and integration of technologies that can converge with traditional practices [64]. Other pending problems are related to feasible technology transfer prices for small producers and the generation of philanthropic and governmental agendas [33, 34], whose vision predominates over an alternative path of innovation traditionally offered to external actors belonging to research institutes, academia, and the government [50].

An innovative approach involves technological processes, technology adoption [33], organizational change, business models [30, 36], sustainable development, social structures, and livelihoods [55]. Difficulties derived from the COVID-19 pandemic, climate change, and poverty are additional issues. Hence the emerging necessity to stimulate and promote diverse types of innovation. A possible path leads to open innovation as a substitute for the linear idea of R&D so that external and internal networks can coexist to promote the creation of value, favoring the growth of local competitive systems that can take advantage of the strengths of converging resources and capacities [65, 66]. Examples of open innovation in apiculture are observed in the socialization of local modifications to honeycombs. These actions are given feedback by different community members and lead to integrated government and philanthropic institution networks that allow the communication and flow of resources to address specific problems. Many others could be derived from cross-border collaboration through ICTs and social networks generated between urban and rural communities [57].

Another option is social innovation, whose objective is to resolve and positively impact social problems in a novel way through community participation. For example, Yap et al. [55] show how the problem of technology adoption can be addressed through participatory mechanisms, which include democratic processes and social restructurings such as the formation of groups and cooperatives that favor the exchange of knowledge and resources. Also, in certain regions, frugal innovation—which seeks to provide solutions through functional products at the lowest possible cost—constitutes yet another opportunity [33, 67]. In countries such as Ethiopia, new techniques and modifications made by beekeepers satisfy the minimum conditions for preserving a healthy habitat for bees, although they do not aim at maximizing yield. It is interesting that, through their observation skills, intuition, local materials, and tacit knowledge, these beekeepers have obtained favorable results in honeycomb construction using materials such as mud and manure [33].

5.2 Methods

Network analysis has proven useful to understand the dynamics of different areas of knowledge. It can be used to highlight the main related themes and other elements of interest (authors, countries, etc.) through search in databases such as Scopus and Web of Science (WoS) and the use of software tools such as VOSviewer, among others. Several researchers have used this approach to study honey, its pesticide contents, and the antioxidant properties of derived products [68–70]. Similarly, research based on patent documents is a valuable tool to understand the different technology sectors and disciplinary fields focusing on apiculture, as demonstrated by studies focused on nanotechnology, agricultural biotechnological, food-related, textile, and general and organic agricultural applications [71–74]. Given its economic importance and usefulness to generate technological forecasts, these tools anticipate market dynamics [75–77], and combined studies use both scientific production and patent documents to explain relevant factors to mitigate the mortality of species as important as *Apis mellifera* [78].

Thus, network analysis was conducted in addition to patent analysis to identify the most recent study topics associated with apiculture and the forefront of technological development in this sector. Firstly, a search was done in the Scopus database (accessed on August 17, 2021) [68] using the terms "beekeeping" and "apiculture" in the fields: Title, Abstract, and Keywords. From this search, 3688 documents were found (spanning 1909 to 2022). The bibliographic data was obtained to perform a network analysis with VOSviewer (version 1.6.17); this was conducted by downloading the first 2000 documents sorted by date. A co-occurrence analysis (author's keywords) was then performed for the interval from 2014 to 2022, using the full counting method and a minimum parameter of five occurrences per word. Additionally, it was normalized using the LinLog/modularity method, although the procedure can dispense with normalization or use other normalization methods such as association strength or fractionalization [79].

For the patent applications analysis (1953–2021), a search was performed on September 12, 2021, in the Lens database [80]. It was structured by the keywords "beekeeping" and "apiculture," but with the following fields: Title, Abstract, or Claim. For this purpose, the following filters were used: Document type: Patent application; Classifications: IPCR classification code; Query tools: Stemmed; Query language: English. The rest of the parameters were left as default (see Table 5.1 for the results and search criteria). The Lens database was selected due to its robustness and because it has remained in service over time, providing free document searches [81].

5.3 Results Analysis

A total of 4410 keywords (author) were detected, of which 203 met the minimum frequency threshold criterion and were used in the keyword map. Thus, twelve clusters were formed (for more details, see the tables obtained from the co-occurrence analysis in Annex 1). The three keywords with the most occurrences are listed by cluster below using the following nomenclature: (a) N—Node; (b) O—Number of occurrences; (c) L—Number of links; and (d) TSL—Total link strength. Thus, the

Table 5.1 Queries for data search

No.	*Database*	*Query*	*Results*
1	Scopus	(TITLE-ABS-KEY (beekeeping) OR TITLE-ABS-KEY (apiculture))	3688
2	Lens	(title:(beekeeping) OR abstract:(beekeeping) OR claim:(beekeeping)) OR (title:(apiculture) OR abstract:(apiculture) OR claim:(apiculture))	727

Source Prepared by the authors based on Scopus [82] and Lens [80]

results for clusters one through four were: **Cluster 1** (red)—N: apiculture, O: 119, L: 88 TSL: 185; N: honey, O: 118, L: 82, TSL: 193; N: beeswax, O: 23, L: 23, TSL: 39. **Cluster 2** (green)—N: monitoring, O: 21, L: 35, TSL: 65; N: colony losses, O: 16, L: 23, TSL: 49; N: beekeepers, O: 15, L: 17, TSL: 20. **Cluster 3** (blue)—N: apis mellifera, O: 257, L: 144 TSL: 512; N: honeybee, O: 59, L: 58, TSL: 97; N: nosema ceranae, O: 29, L: 34, TSL: 69. **Cluster 4** (yellow)—N: biodiversity, O: 24, L: 33, TSL: 52; N: honey production, O: 21, L: 23, TSL: 30; N: conservation, O: 16, L: 26, TSL: 35.

From 5 to 12, results were: **Cluster 5** (lilac)—N: honey bee, O: 124, L: 101, TSL: 254; N: honey bees, O: 33, L: 42, TSL: 63; N: varroa, O: 15, L: 19, TSL: 33. **Cluster 6** (light blue)—N: pollen, O: 30, L: 31, TSL: 56; N: nectar, O: 16, L: 13, TSL: 25; N: mite, O: 12, L: 19, TSL: 28. **Cluster 7** (orange)—N: precision beekeeping, O: 31, L: 17, TSL: 60; N: agriculture., O:26, L: 27, TSL: 52; N: precision apiculture, O: 17, L: 10, TSL: 32. **Cluster 8** (brown)—N: varroa destructor, O: 81, L: 52, TSL: 153; N: environment, O: 12, L: 15, TSL: 25 y N: honeybee health, O: 12; L: 18, TSL: 23. **Cluster 9** (pink)—N: beekeeping, O: 293, L: 150, TSL: 465; N: honeybees, O: 54, L: 54, TSL: 93; N: pollination, O: 44, L: 43, TSL: 103. **Cluster 10** (light pink)—N: paenibacillus larvae, O: 18, L: 16, TSL: 36; N: bee, O: 17, L: 20, TSL: 29 y N: American foulbrood, O: 15, L: 15, TSL: 32. **Cluster 11** (light green)—N: meliponiculture, O: 22, L: 18, TS: 38; N: apis cerana, O: 21, L: 26, TSL: 45 y N: stingless bees, O: 19, L: 18, TSL: 29. **Cluster 12** (sky blue)—N: beekeeper, O: 9, L: 7, TSL: 11; N: classification, O: 5, L: 4, TSL: 7, and N: data mining, O: 5, L: 5, TSL: 9.

The size of the larger nodes reveals the importance of the topic within the beekeeping sector. However, regardless of size, emerging topics appear that will undoubtedly play a fundamental role in this production area. An example is the precision beekeeping node, linked to terms such as bee colony monitoring, wireless sensor networks, Internet of things, swarming, deep learning, machine learning, and data mining, clearly reflecting an interest in modernizing and digitizing beekeeping monitoring tools, especially in developed economies, as discussed in the theoretical and conceptual framework. Additionally, a second node highlights the importance of economic, social, and environmental development: sustainability. Sustainability shows a low number of occurrences, but it has links to fundamental elements such as bee products, beekeepers, and bees, as well as elements present in Cluster 2: acaricide, apiary management, beekeepers, behavior, brood, citizen science, colony, colony losses, colony strength, disease, diversity, feeding, landscape, monitoring, morphology, mortality, nutrition, organic beekeeping, pest, survey, treatment, varroa

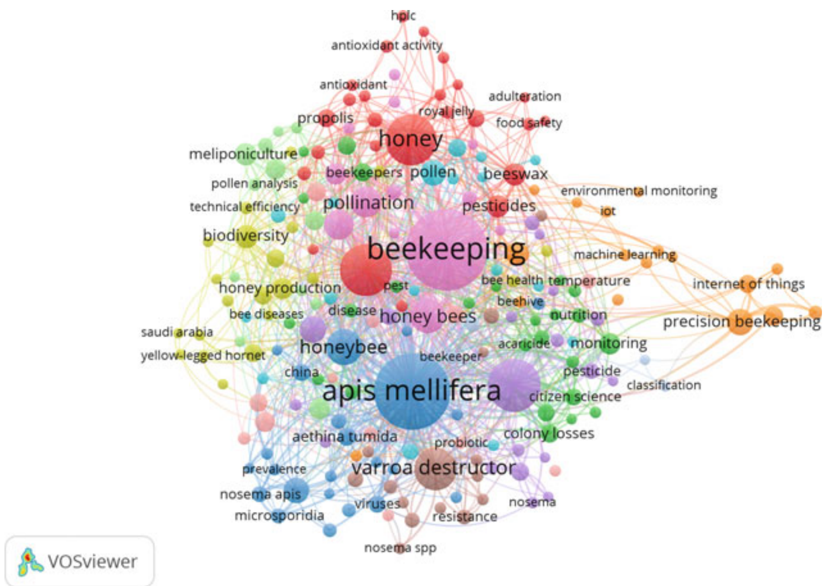

Fig. 5.1 Network Visualization (*Source* Prepared by the authors based on Scopus [2021] and VOSviewer [2021])

Table 5.2 Top ten jurisdictions and applicants

No.	*Jurisdiction*	*Documents*	*#*	*Top applicants*	*Patent document*	*Country of residence*
1	China	254	1	Breat SL	26	Spain
2	Republic of Korea	116	2	Bee Res Inst Caas	9	China
3	WIPO	89	3	Anderson Cedar	8	Australia
4	Japan	41	4	Anderson Stuart	7	Australia
5	United States	37	5	Jeong Hyuk	7	Republic of Korea
6	Spain	30	6	Healthy Bees LLC	5	United States
7	European Patents	25	7	Henan Inst Science & Tech	5	China
8	Russia	24	8	Batista Gonçalves Carla Maria	4	Portugal
9	France	16	9	Bazhong Yerui Miyuan Beekeeping Ind Co LTD	4	China
10	Mexico	14	10	Beewise Tech LTD	4	Israel

Source Prepared by the authors based on the results of Lens (2021)

control, and varroa mite. This scenario shows that sustainability is heavily oriented toward environmental problems; therefore, it is necessary to generate studies considering economic and social perspectives (Fig. 5.1).

A total of 727 patent applications were found to meet the previously described search filters. A Top Ten analysis of the most relevant results by indicator was performed based on this information. China tops the list of applications for the top ten jurisdictions, followed by South Korea, World Intellectual Property Organization (WIPO) PCT (Patent Cooperation Treaty) applications, Japan, and the United States. Not surprisingly, the most sizable number of applications is in China due to its position as the world's leading honey producer and its vigorous technological growth in multiple areas of knowledge. Asia is the region where 41.2% of honey is produced globally, followed by America (23%), where Mexico appears as a relevant producer in Latin America; in this ranking, Mexico occupies

Table 5.3 Patent applications by IPC classification

No.	*IPCR classification code*	*Document count*	*Description*
1	A01K47/06	181	"Other details of beehives, e.g., ventilating devices, entrances to hives, guards, partitions, or bee escapes…"
2	A01K47/00	152	"Beehives…"
3	A01K47/02	104	"Construction or arrangement of frames for honeycombs"
4	A01K47/04	93	"Artificial honeycombs"
5	A01K59/00	70	"Honey collection…"
6	A01K67/033	61	"Rearing or breeding invertebrates New breeds of invertebrates"
7	A01K51/00	53	"Appliances for treating beehives or parts thereof, e.g., for cleaning or disinfecting…"
8	A01K53/00	29	"Feeding or drinking appliances for bees…"
9	A01K49/00	28	"Rearing-boxes Queen transporting or introducing cages…"
10	A23K50/90	26	"Feeding stuffs specially adapted for particular animals, e.g., bees or silkworms"

Source Prepared by the authors based on LENS (2021)

the last position, this is an initial indicator of the interest of the country in developing and commercializing of these technologies. The most important applicants are companies, research institutes, and individuals. The presence of Australian and Israeli applicants in this list is worth noting, showing the interest of other actors from countries where honey production to generate inventions associated with apiculture is modest (see Table 5.2).

Based on the International Patent Classification (IPC), the ten main technology areas focus on modifications and improvement of the physical conditions of honeycombs, cleaning, and disinfection means to collect honey, bee feeding applications, elements for breeding or reproduction of invertebrates, and the transport or introduction of queen bees, among others (see Table 5.3). This highlights the interest of technology developers to address nutrition problems, pest and disease mitigation, colony loss, and honey production. The technological sectors associated with apiculture present a moderate number of patent applications, and in many cases, these are associated with basic production activities. However, beyond the ten main technological classes, other patents are associated with genetic engineering, which should be studied in greater detail to analyze its impact on the environment and society. Similarly, it will be necessary to monitor the development of other technologies related to the digitization of the sector and higher added-value products that use inputs such as honey. Regardless of the categories, some patent applications include food formulations with anti-mite activity; food and feeding methods for improving honey production and bee rearing; honeycomb automation, including the use of technology to monitor bee conditions (feed, pesticides, and climate control), and data analysis and management, including its delivery to the user.

5.4 Conclusions

The results of this study highlighted the challenges faced by apiculture in the three dimensions of sustainability. The literature review identified the main problems in the sector: hive loss, bee mortality, diseases, and pests, lack of management capacities, and low productivity. As shown by the patent analysis, some of these problems are being addressed using technological developments, for example, monitoring, cleaning and sanitation, habitat improvement, and honey production methods. However, the social and economic aspects cannot be addressed solely from this perspective. Therefore, it is essential to find comprehensive solutions to overcome the obstacles to technology transfer and adoption that arise when these are delivered to beekeepers and integrated into the apiculture value chains.

The strong dominance of developed countries was noteworthy, and many of them invest in developing technological solutions for the field. However, it is most unfortunate that developing countries, where 84.39% of the world's honey was produced in 2019, depend entirely on these economies to gain access to cutting-edge technological innovations to improve productivity. Consequently, the development of endogenous technologies to improve the beekeeping sector in developing countries and the generation of proposals to address local problems is a paramount necessity. Although the literature review shows that the technological capabilities of beekeepers in developing countries are still based on traditional techniques and given that education has failed to be a significant factor, it is necessary to close the technological and skills gaps and allow the sector's workers a chance to implement the techniques and technology that best suit their needs and context. The challenge is to find a combination that takes advantage of traditional knowledge and makes technology available to producers.

As shown by the network map, very few terms were associated with social and economic aspects; this research void needs to be addressed in greater depth. These results show the need to develop environment-friendly scientific and technological solutions while approaching this phenomenon under a socio-economic development angle that includes the study and the generation of proposals to promote social innovation and the well-being of beekeepers and their families. The challenges faced by this sector due to climate change and agricultural intensification require policies and programs to promote sustainability, under a comprehensive approach, to generate the skills that producers need to meet the demands of their local consumers and the global market.

Acknowledgements The authors want to thank Secretariat for Research and Graduate Studies of the National Polytechnic Institute for the institutional scholarship, and BEIFI for their support and funding for the development of this chapter, through research projects number 2021383 and 20220729.

Annex I

Cluster 1				*Cluster 2*				*Cluster 3*			
Items	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*
Adulteration	5	6	5	Acaricide	18	23	8	Acarapis woodi	10	11	5
Analysis	10	13	6	Apiary manage-ment	11	13	5	Aethina tumida	15	32	16
Antibiotics	9	11	6	Beekeepers	17	20	15	Apis mellifera	144	512	257
Antioxidant	5	7	7	Behavior	9	9	6	Argentina	10	13	5
Antioxidant activity	4	5	8	Brood	9	11	5	Bioinformatics	9	12	6
Apiculture	88	185	119	Citizen science	17	43	13	China	21	27	13
Apis mellifera l	15	17	9	Colony	7	7	5	Colony collapse disorder	12	18	8
Apitherapy	6	7	8	Colony losses	23	49	16	Control	13	15	6
Bee pollen	13	18	13	Colony strength	19	23	9	Diagnosis	10	12	5
Bee products	21	26	11	Disease	17	27	9	Honey bee viruses	6	9	5
Beeswax	23	39	23	Diversity	9	9	5	Honeybee	58	97	59
Botanical origin	7	9	6	Feeding	10	11	6	Microsporidia	14	29	11
Contamination	12	16	5	Landscape	11	13	8	Nosema apis	19	38	12

(continued)

(continued)

Cluster 1				*Cluster 2*				*Cluster 3*			
Items	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*
Food safety	10	12	8	Monitoring	35	65	21	Nosema ceranae	34	69	29
Fumagillin	5	7	5	Morphology	10	15	6	Nosemosis	10	16	9
Health	7	9	6	Mortality	17	37	13	Parasite	14	18	6
Honey	82	193	118	Nutrition	15	24	10	Phylogeny	14	17	7
HPLC	4	5	6	Organic beekeeping	10	11	5	Prevalence	14	17	6
Organic honey	5	7	5	Overwinterin	12	14	5	Probiotics	8	8	5
Pesticides	34	56	23	Pest	11	14	8	Real-time PCR	11	13	6
Physicochemical properties	6	10	5	Survey	13	29	8	RT-PCR	13	15	9
Propolis	18	27	16	Sustainability	9	15	15	Small hive beetle	12	25	11
Quality	5	12	7	Treatment	14	19	6	Viruses	25	35	13
Royal jelly	13	16	8	Varroa control	11	13	6				

(continued)

Cluster 1				*Cluster 2*				*Cluster 3*			
Items	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*
Turkey	14	20	9	Varroa mite	19	22	11				
Cluster 4				*Cluster 5*				*Cluster 6*			
Items	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*
Adoption	5	8	5	Acaricides	11	12	5	Apiaries	14	15	6
Apis mellifera jemenitica	7	8	5	Biomarkers	7	8	5	Apiary	13	14	5
Bee diseases	10	11	5	Colony collapse	13	15	7	Climate	12	14	5
Bee health	17	22	8	Colony loss	11	13	5	Distribution	15	17	5
Biodiversity	33	52	24	Gene expression	15	18	8	Efficiency	8	12	5
Conservation	26	35	16	Honey bee	101	254	124	Foraging	9	10	6
Development	12	13	6	Honeybees	42	63	33	GIS	7	10	6
Food security	7	7	5	Imidacloprid	12	15	5	Melliferous flora	8	8	5
Honey production	23	30	21	Immunity	14	20	8	Mite	19	28	12
Impact	7	8	6	Insecticide	8	11	6	Nectar	13	25	16

(continued)

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Cluster 4				*Cluster 5*				*Cluster 6*			
Items	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*
Invasive alien species	7	10	5	Neonicotinoid	11	19	9	Pests	14	22	8
Invasive species	20	29	16	Neonicotinoids	15	17	13	Pollen	31	56	30
Land use	14	20	7	Nosema	11	17	6	Production	8	11	5
Mexico	7	8	6	Parasites	16	21	6	Productivity	5	7	5
Morphometry	10	13	5	Pesticide	18	32	12	Queen bee	9	12	5
Pollinators	18	28	15	Pollinator	6	13	9	Reproduction	13	16	7
Rural development	11	18	7	Urban beekeeping	9	12	10	Stingless bee	12	15	10
Saudi Arabia	8	9	5	Varroa	19	33	15				
Technical efficiency	6	10	8	Virus	10	14	5				
Vespidae	5	8	5								
Yellow-legged hornet	10	15	7								

Cluster 7				*Cluster 8*				*Cluster 9*			
Items	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*
Agriculture	27	52	26	Australia	5	8	6	Beekeeping	150	465	293
Apis mellifera l	12	12	6	Breeding	7	9	7	Bees	32	63	40
Bee colony monitoring	4	18	9	Deformed wing virus	15	22	11	Climate change	14	19	11
Beehive	8	10	6	Environment	15	25	12	Economics	10	14	10
Beehives	6	6	5	Genetic Diversity	9	11	9	Ecosystem services	19	34	21
Deep learning	6	6	6	Honey bee health	18	23	12	Ethiopia	4	6	6
Environmental monitoring	6	7	5	Hygienic behavior	10	11	6	Geographical information systems	2	5	5
Internet of things	12	26	15	Management practices	9	13	6	Honey bees	54	93	54
Internet of things (IoT)	10	12	6	Mites	7	8	5	Land-use change	8	11	6
IoT	7	9	6	Mitochondrial dna	8	10	6	Livelihoods	4	6	7
Machine learning	11	14	7	Natural selection	12	17	6	Pollination	43	103	44
Pesticide residues	8	9	5	Nosema spp	12	17	6	Pollination services	5	7	5
Precision agriculture	10	12	5	Resistance	17	23	10	Remote sensing	6	6	5

(continued)

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Cluster 7				*Cluster 8*				*Cluster 9*			
Items	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*
Precision apiculture	10	32	17	Varroa destructor	52	153	81				
Precision beekeeping	17	60	31	Varroosis	14	18	7				
Swarming	10	13	6								
Wireless sensor networks	6	10	6								
Cluster 10				*Cluster 11*				*Cluster 12*			
Items	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*
American foulbrood	15	32	15	Apidae	11	18	7	Beekeeper	7	11	8
Bee	20	29	17	Apis cerana	26	45	21	Classification	4	7	5
Galleria mellonella	2	2	6	Apis dorsata	5	6	5	Data mining	5	9	5
Larvae	7	7	5	Brazil	9	11	5	Honey yield	10	18	11
Melissococcus plutonius	11	15	8	Hymenoptera	6	7	5				

(continued)

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Cluster 10				*Cluster 11*				*Cluster 12*			
Items	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*	*Items*	*Links*	*Total link strength*	*Occurrences*
Migratory beekeeping	9	12	13	Meliponiculture	18	38	22				
Paenibacillus larvae	16	36	18	Meliponini	11	19	10				
Pathogen	14	19	8	Melissopalynology	14	29	17				
Pathogens	13	16	8	MtDNA	7	7	7				
Probiotic	12	14	7	Pollen analysis	11	13	8				
Temperature	15	19	10	Stingless bees	18	29	19				
Transcriptome	8	8	7	Subspecies	11	12	5				

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CHAPTER 6

From "Smart Company" to "Smart Business": Implementation of Industry 4.0 Strategy Carried Out by GKN Mexico

Adriana Martínez Martínez

6.1 Introduction

Nowadays, we live in a new techno-economical paradigm denominated in Industry 4.0, Fourth Industrial Revolution, or Digitalization Era. This paradigm is transforming the industrial and labor world and other areas, such as education, health, and daily life. Concerning its influence in the industrial area, this paradigm has been adopted by multinational enterprises (MNEs) to increase quality, reduce costs, generate innovation, and be more competitive. One of the challenges for companies is to digitize their processes to increase their efficiency and respond as soon as possible to their clients [1].

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S. Estrada (ed.), *Digital and Sustainable Transformations in a Post-COVID World*, https://doi.org/10.1007/978-3-031-16677-8_6

Industry 4.0 seeks to increase the competitiveness of the company through the efficiency of resources, productivity, innovation, and customer services [2] since it implies a new logic and quality of the production process, making the existence of smart processes and products possible through the interconnection of machines, systems thus allowing real-time information to be obtained and which supports decision-making.

We can affirm that this new paradigm is in its gestation stage, but its effects strongly impact the definition of corporate strategies carried out in many industries; the automotive industry being one of the most affected by these changes. We can say that this industry is currently reinventing itself. There are few studies about the feasibility and effectiveness of I4.0 integration into existing manufacturing management systems [3]. Through this case study, we want to contribute to its comprehension.

Given the aforementioned, the purpose of this contribution is to analyze the implementation of the so-called strategy "Industry 4.0" carried out by the global company GKN Automotive and to identify the main challenges that this firm has faced and the way they have been solved; we analyzed the case of Mexico's manufacturing plants. Three periods were identified: (a) From 2016 to September 2018, when the company started with the implementation of this strategy and its goal was to transform the company, by 2024, into a "smart firm"; (b) From October 2018 to April 2019 when Melrose PLC acquired the company in April of 2018, and in the last quarter, for approximately 6–8 months the Industry 4.0 strategy was suspended to focus efforts on improving production. During this period, the central question was: How can industry 4.0 improve the indicators and make the company more profitable for investors? In 2019 the goal was to design a local industry 4.0 strategy considering the strengths of the Mexican plants. The ongoing strategy is based on five concepts: smart vision, smart automation, smart flow, smart quality and safety, and smart connectivity; and (c) from March 2020 to today, to assess the impact the pandemic had on the strategy.

To conduct this analysis, we carried out field research in their plants located in the municipalities of Celaya and Villagran (Guanajuato, Mexico). It was undertaken through a qualitative approach, and the information presented was gathered via in-depth interviews with key actors (members of the Industry 4.0 area, and upper managers, including the Plant Director) from April 2018 to March 2021.

The chapter is divided into four sections in addition to this introduction. The first of them briefly discusses what Industry 4.0 is and its scope. The methodological design is addressed in the second section. The results and their analysis are discussed in the third part. Finally, the conclusions are presented, where a recount of findings is done, and the following lines of investigation are indicated.

6.2 Industry 4.0: Definition and Scope

The term Industry 4.0 was introduced in 2011 in the Hannover Messe Fair by the German government. It was concerned with the future of the German economy and digitalization of manufacturing was highlighted as an opportunity; this is when the talk of the smart factory began. The initiative of I4.0 by the German government was focused on protecting the competitiveness of manufacturing industries [4].

Industry 4.0 focuses on establishing intelligent communication systems, including machine-machine communication and human–machine interaction. Salkin et al. [5] point out that the transformation toward Industry 4.0 is based on eight technologies: adaptive robotics, data analytics, artificial intelligence (Big Data and Analysis), simulation, embedded systems, Industrial Internet, the cloud, additive manufacturing, and the virtualization of technologies (virtual reality and augmented reality). Additionally, it represents a radical change in the business environment through emerging concepts like mass customization, serviceability, and digitalization of equipment, products, and processes [6].

As mentioned, Industry 4.0 could influence the industrial area mainly to increase quality, reduce costs, and generate innovation, which equates to a higher degree of competitiveness. Moreover, integrating Industry 4.0 technologies into shop floor production enables firms to manufacture customized goods and high-quality products with increasing resources [4, 7].

Industry 4.0, also known as the Fourth Industrial Revolution, represents a significant transformation of production through the unification of digital technologies and the Internet with conventional industry which allow devices to communicate and interact with others, collect and evaluate data in real-time to optimize costs and quality, to have robots with great autonomy and flexibility, and advanced manufacturing techniques [8]. It is the increasing convergence of digital, physical, and biological assets. The term means the technological integration of cyber-physical systems in production and logistics [7]. According to [4] (2021, p. 6), "I4.0 refers to the establishment of the digital environment by the massive deployment of sensors along with the application of I4.0 technologies, namely, big data techniques, additive manufacturing, machine learning techniques, robotics and the industrial internet of things for enabling connectivity between customers and suppliers across complete value chains".

The attributes related to Industry 4.0 are digitization, connectivity, interoperability, adaptability, scalability, efficiency, predictive capacity, and reconfigurability, and are related to cyber-physical systems and the Internet of things [6]. According to [6] (2019), the applications of Cyber-Physical Systems (CPS) are the pillars for the implementation of Industry 4.0; these comprise two fundamental concepts for its understanding and operation: interoperability and awareness. The scope of Industry 4.0 has to do with different areas:

a. Manufacturing: facilitating the generation and analysis of digital data that support the development of intelligent products, processes, and value chains, considering the use of interconnected intelligent systems and the Internet of things. Its focus lies in the creation of products and smart processes. Through cyber-physical systems, equipment and systems share information, and in the immediate future, they will be capable of generating actions and controlling themselves autonomously [9].
b. Business models: it "[…] is a description of the value that a company offers to one or several customer segments, as well as the architecture of the enterprise and its network of partners, to create, promote and distribute this capital of value and relationship in order to generate sustainable revenue streams" [10, p. 5].
c. Employment: It refers to the need for a new job profile that must take into account three types of skills: metacognitive skills (environmental intelligence, creativity, adaptability, continuous learning, and multidisciplinary), hard skills (design, programming, dispatch of cyber-physical systems, maintenance of cyber-physical systems, data management, transfer and use of knowledge, and quality control), and soft skills (communication, emotional intelligence, human–human and human–machine collaboration, identification,

and troubleshooting, security); but also to the need to establish work environments that promote learning and interaction between machines/robots and humans [11]. According to the World Economic Forum [12], new jobs such as robot coordinator, digital product manager, digital business developer, data protector, network integrator, digital communications planner, and social media manager will be created soon.

d. Daily life: Many technological devices on the market collect data through sensors and provide information to users. Among these, we have smartwatches, domestic robots, and household appliances. Wearable technology, for example, can detect and prevent falls, fitness tracking, make and receive calls, monitor, and transmit biological data for healthcare purposes, among others.

6.3 Methodological Design

The information presented is the result of the qualitative and interpretative analysis of a case study of a Tier 1 auto parts firm located in the municipalities of Celaya and Villagran, Guanajuato. We chose this industry because, despite the following information, it is still an important sector for Mexico: In 2021, vehicle production was 3,028,481 units. Thus, production decreased by 0.38% (11,697 vehicles) compared to 2020, in which 3,040,178 automobiles were manufactured. The importance of the automotive industry in Mexico can be seen through the following data: in 2021 the sector was the first foreign exchange generator, with a surplus balance of 85 billion dollars, and the country was the 4th largest exporter of vehicles worldwide light, the 7th producer of vehicles in the world, and the 5th exporter of auto parts. It contributes 32% of manufacturing exports and represents 18.3% of manufacturing GDP and 3.5% of total GDP [13].

Furthermore, there were two reasons to choose GKN: (1) the first is that it belongs to the automotive sector which, as we mentioned, is very important to the Mexican and local economy; and (2) it was one of the first companies at the local level to declare that it would establish an Industry 4.0 strategy.

For this analysis, we carried out field work research in the following periods: from April to May 2018, May 2020, and March 2021. The information presented was gathered through 11 in-depth interviews (Table 6.1) applied to key informants, all of them members of the 4.0 Industry

Table 6.1 In-depth interviews

Position/Period	*April–May 2018*	*May 2020*	*March 2021*
Global leader of Industry 4.0	X		
IT engineer (member of the I4.0 team)	X	X	
Brazilian manufacturing engineer (Rotational program)	X		
IT manager	X		
Mexican mechatronics engineer (Rotational program)	X	X	
Manufacturing manager	X	X	
Director of the Firm	X		X
TOTAL	**7**	**3**	**1**

implementation: global manager of Industry 4.0, engineers (IT, Mechatronics, industrial engineering), IT Manager, Director of the Plant. We also visited and took tours around the plants.

Each interview lasted anywhere from 40 to 80 minutes and depended on the interest and will of the informant. We asked questions about the conception of Industry 4.0, the strategy of implementation, its elements, the required job profile, the projects, the main challenges, and how they were faced, among others. All the interviews were recorded, then transcribed and finally coded and analyzed using Atlas.ti software. In the next section, we present and discuss the results.

6.4 Case Study: GKN Automotive

GKN Automotive is a world-leading supplier of automotive driveline technology and systems used across the automotive industry, from the smallest ultra-low-cost car to the most sophisticated premium vehicles demanding the most complex driving dynamics. GKN was established in 1759 in Dowlais, Wales. The company designs, manufactures, and services the aviation, automotive, and machine manufacturing industries. It has four divisions: GKN Aerospace, GKN Automotive, GKN Powder Metallurgy, and GKN Wheels & Structures. It provides technology based on highly engineered products for manufacturers of light vehicles, agricultural construction equipment, and aircraft engines. GKN is a world leader in CVJ systems, AWD systems, E-drive, and Trans Axle solutions and systems.

Its automotive division is the leader in transmission technology and engineering systems. It has 54 plants, five global technology centers, and ten technology centers of excellence. Located in 21 countries, it generates more than 29 thousand jobs and has more than 1400 patents. In 2018 it sold 4.9 billion euros. As mentioned, it is a Tier 1 company; its clients are the Original Equipment Manufacturer (OEM), among these are Toyota, Audi, Nissan, Tata, Subaru, Acura, GM, Chrysler, DMBW, KIA, and Honda.

Its presence in Mexico dates to 1979; it was the first auto parts company established in Guanajuato. In its beginnings, it belonged to Velcon (a Mexican company belonging to the Mexican Automotive Group DESC), and its technological partner was GKN. It started with the production of CV joints and in 1995 it won the National Quality Award. In February 2005, it was fully acquired by GKN. In Celaya it has two plants and a Technology Center opened in 1997. In Villagran it also has two plants [14]. According to the Director of GKN Mexico, it is one of the most competitive manufacturing plants. Some important features of the four plants are shown in Table 6.2.

Table 6.2 Important characteristics of the four plants

Feature/Plant	*Machining*	*Precision Forge*	*Assembly facility*	*Pro-shaft*
Year of Establishment	1979	2000	2006	2015
Products	Constant velocity joint (CVC)	Wide variety of extrusions (2 lines)	Constant velocity joint (CVC)	Constant velocity joint (CVC)
Capacity	7.5 millions of fixed joints 7.5 millions of sliding joints 7.5 millions of tulips	15 millions per year	7.5 millions	n.a
Location	Celaya	Celaya	Villagran	Villagran
Size	153,400 m^2	28,300 m^2	80,000 m^2	10,000 m^2
Employees	1108	100	500	250

Source Martínez [15], 2020, p. 171
n.a. Not available

Its main clients in Mexico are General Motors, Ford, Chrysler, Nissan, Renault, VW, Toyota, Honda, Mazda, Audi, and BRP. It is a leader in all-wheel drive (AWD) transmission technology. In 2012, it invested 110 million dollars in its Celaya plant, generating 250 direct jobs [16]. In 2014, Ford Motor Company granted it the Q1 certification, which means that it was designated a preferred supplier by recognizing excellence in product quality, service, and delivery. Furthermore, General Motors awarded it the Supplier Quality Award for Excellence (SQEA), in which compliance in product delivery, service, and quality are evaluated. In 2015 it employed 2075 people with an annual production of 1 million Prop-Shafts. In November of that same year, a new manufacturing plant was opened in the municipality of Villagran to produce high-quality Prop-Shafts for its range of Premium clients [17]. According to the Industry 4.0 leader, it produces 10 to 11 million pieces per year.

In April 2018, Melrose PLC acquired the UK publicly listed FTSE100 company, for 8 billion euros. According to its Webpage the project of this firm is: "Melrose buys good manufacturing businesses with strong fundamentals whose performance can be improved. Melrose finances its acquisitions using a low level of leverage, improves the businesses by a mixture of investment and changed management focus, sells them, and returns the proceeds to shareholders" [18].

6.4.1 GKN's Industry 4.0 Strategy

The trend toward digitization in the firm was already present before the concept of Industry 4.0 (I4.0) was introduced. Since its clients require information in real-time, GKN had already made progress on the issue of product traceability, from which they know how it was manufactured, that is, what operations were carried out.

According to GKN, the reasons that are driving the implementation of Industry 4.0 in the automotive sector are (1) mass customization (2) the search for greater safety since the number of car accidents is very high and this has led some countries, such as the United States, to tighten safety standards, and therefore demand that cars be safer, and (3) care for the environment.

Furthermore, in mid-2016, the company perceived the advantage of digitizing the production process and decided to undertake the Global Plan for Industry 4.0 to implement Industry 4.0 components that will lead it to become an intelligent company in 2024. According to the global leader of I4.0 strategy, they seek to focus on human talent where people focus on efficient decision-making and that all routine activities, which do not generate added value, are automated.

The implementation of Industry 4.0 was thought to be a global strategy to carry out from 2016 to 2024. The company conducted 28 pilot projects worldwide, focusing on information management systems and others on industrial or collaborative robots' applications. The aim was to build a Smart Plant based on *Human talent and People focusing on making a decision*.

The plants with the most technology and resources were chosen to implement the Industry 4.0 strategy; among these are the three plants in Mexico (Precision Forge and Machining located in Celaya, and Pro-Shaft located in Villagran), the other plants that participated in the project were located in Spain, Germany, Italy, India, Japan, China, Brazil, and the United States. When Melrose acquired the company, the Industry 4.0 implementation strategy is changed. The most important change is that there is no longer a group dedicated exclusively to it; they are divided into 3: Smart automation, connectivity, and manufacturing execution systems.

We identified three periods in the implementation of the Industry 4.0 strategy: (a) From mid-2016 to September 2018, when the company started with the implementation of this strategy and its goal was to transform the company into a "smart firm" by 2024; (b) From October 2018 to April 2019 (in April of 2018 Melrose PLC acquired the company) where in the last quarter, for approximately 6 to 8 months the Industry 4.0 strategy was suspended to focus efforts on improving production. During this period, the central question was: How can industry 4.0 improve the indicators and make the company more profitable for investors? In 2019 the goal was to design a local industry 4.0 strategy considering the strengths of the Mexican plants. The ongoing strategy is based on five concepts: smart vision, smart automation, smart flow, smart quality and safety, and smart connectivity; and (c) From March 2020 to the present, to assess the impact on the strategy during and after the COVID-19 pandemic. Below is a brief explanation of each of these periods.

6.4.1.1 First Period: From Mid-2016 to September 2018

In mid-2016, they started with 28 pilot projects around the world; some of their plants focused on information management systems and others on applications of industrial or collaborative robots. The plants with the most technology and resources were chosen to implement the Industry 4.0 strategy; among these are the three plants in Mexico (Precision Forge and Machining located in Celaya, and Prop-Shaft located in Villagran), the other plants that participated in the project were located in Spain, Germany, Italy, India, Japan, China, Brazil, and the United States.

During this period, two phases were carried out: (a) Phase 0, started in 2017, known as "Define and plan the strategy" in which the vision was defined, and an inventory of the Information Technology (IT) infrastructure was carried out. Among the information that the company mapped was to establish what data is important for each process and from which machines it could be extracted. Likewise, what was lacking in IT infrastructure was established to implement the strategy. (b) Phase 1, started in 2018, called "Sense and response" focused on productivity and quality. The focus was on cybersecurity. The company was concerned about the following topics: digitization, engineering systems, smart automation, and traceability.

6.4.1.2 Second Period: From October 2018 to April 2019

At the end of 2018, the company was acquired by the Melrose financial group, and for approximately 6 to 8 months, the industry 4.0 strategy was suspended to focus efforts on improving production. During this period, the central question was: How can industry 4.0 improve the indicators and make the company more profitable for investors? The global strategy of this group is to do more with less and link the different areas, production, supply chain, and projects with finance. Workers have been trained to understand that every project launched must have a return on investment of fewer than two years. To understand how each activity affects the company's profits, they were analyzed to determine what could be automated and what materials could be saved; that is, a Lean strategy was adopted through batch traceability, where moving from the physical to the digital was sought.

At the beginning of 2019, the Industry 4.0 Team presented the advancements of the Industry 4.0 Strategy to the global director of manufacturing who asked for an analysis of the strengths of the plants in Mexico and from this petition, the local Industry 4.0 strategy was designed.

The strategy was focused on creating business intelligence, creating a smart company that allows it to carry out different activities in a simple way and in real-time. Furthermore, the commitment is that all the projects carried out have a return on investment of fewer than two years to be approved globally and go through a series of filters depending on the investment amount.

6.4.1.3 Third Period: From March 2020 to the Present

In 2020, the company ceased its operations for three months which represented a significant economic loss since it had to pay salaries, compensation, and keep some equipment running which could not stop because it could break down. The state government supported putting pressure on the federal government to consider the automotive industry essential and be allowed to operate. Responding to product quality and safety standards, they continued with projects considered key on systems, automation, integration of devices to different machines to know what was happening in real-time, and traceability systems.

A formal Industry 4.0 team was established in February 2020. It comprises 4 engineers, two who had already been working on the past strategy and two who were incorporated from the New Talent program carried out by the company. One of the members of the team is a woman. She was part of a university team that won a robotics award in China with their design for a wall-climbing robot.

To design the new Industry 4.0 strategy, the firm hired a consultant to define, jointly, the different stages that should follow. The strategy considers three axes:

1. Carry out profitable projects that allow them to reinvest in acquiring new technology.
2. Traceability: involves Big Data and refers to the strategic generation of information, such as process trends, machine conditions, and so on. The use of this information should result in a safer product.
3. Be more productive with people through automation projects and robots.

The CEO of the company made the following comment in this regard:

"If Industry 4.0 does not improve the operation of my business and does not make my business grow, then I am making the wrong decisions. I must start seeing improvements in productivity, risk reduction in manufacturing. How am I going to see it? Well, maximizing the use of my assets and improving the labor productivity, improving a segment of the supply chain, transportation costs, logistics, improving or ensuring a stable production plan. Also, it is important to seek the raw material at the best price, manage the guarantee, reduce recalls, begin to mitigate geographic risks" (19, 2021).

From 2021 to 2023, they will be focused on the following issues: flow of materials, connectivity, and creating a business intelligence model. According to the industry leader 4.0: "…by 2023 we will already have real-time systems with digitization and prediction and traceability of what is happening online, that is our plan" (Personal communication, May 20, 2020). An initiative that is being promoted globally is for all GKN plants (around 54 located in 21 countries) to implement an automation project.

The Assembly plant in Villagran has made the greatest progress in the implementation of the 3 axes. This plant has the interface with the client and in 30 lines they can monitor the production process in real-time which allows them to know how the products were produced, line stoppages (in this area they have almost reached traceability level 3 in product safety) which is what is related to Big Data; however, it is not the most automated. The product it assembles is Half Shafts and this is done manually, 4 people are involved in the assembly of Half Shafts; in the future they could have a robot in the stations, but in addition to the high cost, technological progress still needs to be made since it is necessary to determine the exact point at which it must assemble and at the same time monitor a series of controls, so it cannot grow so much in automation; while the Celaya machining plant with the productivity axis has the greatest progress (between 50 and 60% progress), it has many automated cells, as well as robotic systems.

The current state of Industry 4.0 can be seen reflected in the following comment:

> […] also with the Internet of Things (IoT) technology and well, the part that I told you about at the beginning that is the connectivity part, having a network infrastructure connected to the machines to be able to make decisions in real-time, have traceability of the process and the product, communication of the machines, how I am today, I lack maintenance, or you know that I am processing a piece, sometimes we have in the same process three identical machines that do the same thing, then that communication of knowing what machine is available to carry out the process, all that communication between machines is also being generated

> and therefore Big Data, which is a key concept of Industry 4.0 where all the data is analyzed. (Leader of Team 4.0, personal communication, May 20, 2020)

Currently, the strategy is focused on fostering a Business Intelligence Model, the main benefits of it are: (1) Smart decisions: real-time decisions based on reliable data; (2) Leading, trending company: increase competitive advantages and improve customer experience; (3) Future prediction business scenarios: prediction systems integration with reliable data; and (4) Strategical control: communication, planning, and risk reduction at all levels.

It has five pillars:

1. Smart vision: intelligent vision systems. Its main benefits are quality inspection in real-time, risk detection on the shopfloor, reduction of complaints, and low-cost innovation.
2. Smart automation: policy for the use of robots in those operations that put the operator's safety at risk, where the time of the machine is very fast, or where there is excessive use of personnel. The main benefits are (a) Process improvement, (b) Cost reduction and savings, (c) Ergonomics and performance, and (d) Technology investment.
3. Smart flow: smart vehicles, augmented reality on reliability and inventory. The main benefits are (a) Material flow improvement, (b) traceability, and (c) Cost avoidance.
4. Smart quality and safety: the creation of production quality. The main benefits are (a) digital quality control (paperless quality), (b) COVID-19 risk detection, (c) process monitoring system, and (d) Security Zone Issues.
5. Smart connectivity: with all the information generated, the best decisions must be made in real-time. The main benefits are (1) Traceability, (2) Shopfloor connection: real-time data for KPIs, material planning, (3) Smart *Andon* (it means: "the line stop indication board", [20, p. 21], and (4) Future application: shopfloor and machine predictions, analytics, support areas improvement, paperless.

6.4.2 Collaboration and Human Talent: Two Fundamental Pillars in the Industry 4.0 Strategy

To develop their Industry 4.0 projects, they have teamed up with the Autonomous University of Querétaro, and the Technological Institute of Celaya. Furthermore, GKN and these universities have jointly developed Smart Vision, Smart Quality, and Smart Safety projects that have allowed them to identify assembly defects and quality issues. Behind all this, they have worked on training the operators, and only those who have completed the courses can change the parameters since they are asked to put their fingerprint to do so, and if they do not have the required training, they cannot perform them.

GKN recognizes that there is no profile to fully cover the technologies derived from Industry 4.0. Therefore, since the implementation of this strategy began, it has been given the task of forming multidisciplinary teams. In the first stage it was informal and since February 2020 it has been formalized.

Given that the implementation of the Industry 4.0 strategy is complex and requires diverse knowledge, the company, at a global level, decided to create a multidisciplinary international work team of experts in different areas: specialists in machines, maintenance, Information Technologies as well as in various fields of knowledge, manufacturing processes, computer systems, and electronic engineering. This was replicated locally. The local team members are from the areas of computer systems and mechatronics engineering. According to the project leader, this allows the knowledge of the physical world (processes) to interact with that of the virtual world (digitalization of information). The average age of the engineers working on this team is 26 years old and have a strong propensity toward technology. Here is a comment about it:

> […] what we did in Mexico to be able to move towards the Industry 4.0 strategy was to hire an expert in systems programming, the person is a computer systems engineer, and we complemented him with a person with a specialty in mechatronics who spent time working on issues of reconstruction or construction of machinery and equipment. So, the linking of these two profiles gave us a multidisciplinary team of people who can talk about what the physical world is like but who can also talk about what the virtual world is like and the digitization of information. Today, either we have people who are very skilled at systems but do not know

> the processes, or we have people who are very skilled at processes, but they cannot understand how systems work. (Global Head of Industry 4.0; personal communication, May 30, 2018)

For this reason, from 2016 to 2018, the strategy, both local and global, was to form a multidisciplinary team with experts in manufacturing processes, information and communication technologies, and programming, because the Industry 4.0 strategy requires teamwork from multiple areas with different perspectives and skills. Collaboration with external actors, such as suppliers, customers, and universities is also needed. The local team was made up of four members: the world leader, a programming expert, a mechatronics expert, and an expert from another plant. This expert was participating in the Global Rotation Program. The idea was to share best practices around the world. As we mentioned, one of the important characteristics of the team was the age of the engineers with an average of 26.

The global manager pointed out that the implementation of industry 4.0 leads to the formation of learning communities where skills such as teamwork, collaboration, and tolerance are fundamental since it is very unlikely that there is an expert in all areas of the knowledge that is involved since the integral solution of problems is sought:

> We are looking for engineers of the future, people capable of understanding what is today and what is going to be, who will help us transform what we have not done, who will allow us to learn different ways that even we have not imagined. (21, 2017)

The required skills to be successful in the so-called Industry 4.0 are those in which robots cannot compete with humans: leadership, decision-making, risk management, problem-solving, and creativity. In addition, creativity and innovation were pointed out by the interviewed engineers as two of the main activities that the company encourages to carry out in their daily practices:

> To try to investigate, to try to do things differently, to try to propose, and I think that has opened the doors for us to think differently and to be able to try to innovate, to create better things based on what we already have. I consider it is the fundamental point that the leaders are giving us here and I believe it has worked well. (Personal communication, Rotational team engineer, April 23, 2018)

In 2019 there was a change in the structure of the team in charge of the 4.0 strategy. The responsibility of this was given to the engineer who participated in the rotational program, it was continued by the systems engineer, and an interesting change was the incorporation of two engineers who had participated in the New Talents program carried out by the company. Their background was in the areas of robotics, programming, and automation. It is in February 2020 when the existence of this team is formalized, and the Industry 4.0 area is created.

Regarding the basic technical requirements that the company must meet to achieve the Industry 4.0 strategy, we can point out the need to have personnel trained in data analysis, focused on probability and statistics, who are capable of reading and interpreting the information, and make predictions. For GKN, soft skills take on relevant importance: tolerance, leadership, creativity, adaptation, teamwork, communication, detection, and problem-solving, among others.

In this sense, developing both the technical and soft skills required represents a double challenge for companies but which can, nonetheless, be faced through two strategies: (1) attracting human talent with a specific profile, and (2) retraining current workers through ad-hoc training programs [22]. The second strategy is essential when thinking about the future of work.

An important feature of work organization is the existence of self-managed teams: there is a team leader, and each member has a role. The selection of leaders is carried out in a process based on competencies. The company, as we mentioned, is more interested in soft skills, the main one being teamwork, as well as the ability to learn, work under pressure, and respect systems. The latter is essential since operators must carry out many activities in quality, traceability, and logistics systems, and when they skip a step, it can cause serious problems. Technical skills are taught over time; the leader supervises this training.

Because of the confinement caused by the COVID-19 pandemic, in the months of April and May 2020, the company had to lay off more than 300 workers. When activities resumed, GKN had the need to develop an accelerated training program to train new workers in the operation of robots, the use of automatic devices, or the use of software.

6.5 Conclusions

The purpose of this chapter was to analyze the so-called strategy "Industry 4.0" carried out by the global company GKN Automotive and identify the main challenges this firm has faced in their plant located in Guanajuato, Mexico, and how these have been solved.

Regarding the implementation of the Industry 4.0 strategy, the first vision was to become a Smart Company in a period of 8 years and for this it developed a roadmap with 5 phases, of which only 2 were carried out. The strategy was interrupted due to the acquisition of the company by Melrose financial group. When the strategy is resumed, the vision is to become a Smart Business, based on the lean strategy "do more with less." This has represented a great turn in the implementation of Industry 4.0, as they seek, with their own resources, to focus on profitable projects.

The main challenges faced by the company are:

1. Technological infrastructure: The company is working on strengthening its cybersecurity protocols; this is essential, because their machines share information, and it is important to prevent cyber-attacks. Another challenge is to ensure that analog machines (which are the oldest it has) can communicate with the digital machines, and in this way, they can share information; in this regard the company has had to work on reconverting older machinery.
2. Industry 4.0 job profiles: we can say that there is no engineer 4.0 in the labor market, consequently, the company has formed multidisciplinary teams and attracted new talents. Furthermore, the second important point to keep in mind is that current and older workers need to be retrained to obtain these new required skills, and the company has designed manuals and training programs when a new system is introduced. For GKN the most important skills are soft skills, especially teamwork.
3. Profitable projects: According to the current plant manager, trying to implement the Industry 4.0 strategy without reflecting on its meaning led to failed projects, such as the introduction of *cobots* (collaboration robots).

Finally, the concept of Industry 4.0 has been recently introduced. There is still much debate about its meaning and scope. We assume it as a productive model that can be implemented in some areas of companies to boost productivity through digitization. However, it is important to reflect on the relevance of its implementation and the possible advantages derived from it. Questions such as: a) Is the Industry 4.0 strategy feasible for all companies? b) Is it feasible for all sectors?, and, c) Does its implementation depend on the type of countries in which the company is located: emerging or developed? Therefore, it is necessary to continue carrying out case studies in different sectors and countries to understand more about this new production model.

Acknowledgements This research is part of the project IN309819 Industry 4.0, global value chain and new business models: 3 case studies of the automotive industry in Guanajuato, supported by UNAM-PAPIIT Program.

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CHAPTER 7

An Evaluation of Cashless Transactions During Pre- & Post-Demonetization Era in India

Dhanraj Sharma, Ruchita Verma, and Heavendeep Singh

7.1 Introduction

Demonetization is when the notes or the legal tender currency are stripped from the market. This act passes in the country by the Centre government whenever there is a change in the nation's currency. The current circulating money is withdrawn and replaced by the new notes

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and coins by the Central Bank of India. The main focus of the demonetization is to curb black money [1] in Nigeria. Pakistan, Myanmar, Soviet Union, Ghana, Congo, Britain, and North Korea also implemented demonetization in their country. The First Currency Ban in India was in January 1946; the currency of Rs. 1000 and 10,000 was withdrawn from circulation. The currency banned was again introduced by the government in 1954, and the new introduction of currency of 5000 demonetizations. The second time currency was banned was in 1978 when Prime Minister Morarji Desai demonetized currency of Rupees 1000, Rupees 5000, and Rupees 10,000. The third time currency was banned was on 8 November 2016. The notes or legal tender currency of 500 and 1000 were stripped of circulation. In 1978 and 2016, the currency with high demonetization was banned to curb the black money from the economy [2]. In 1978, the PM announced the demonetization on the radio; similarly, in 2016, the PM announced the demonetization on the News station. Both times, the concept of demonetization was kept confidential.

During the recent demonetization in India, there was a shortage of currency supply in the country. People were looking for an alternative option for payment in day-to-day activities and business. So this study primarily focuses on the impact of demonetization on cashless transactions in India after demonetization, as the more the cashless transaction, the lower the chance of black money in the economy.

The government adopts demonetization to put a check on black money [3]. According to [4], demonetization is expected to affect the economy in the Short period and medium-term as well. Hence, it is essential to study the impact. Chelladurai and Sornaganesh [5] studied the effect of demonetization from the theoretical point of view on different aspects like the Stock market, society, NBFC, SME, and FMCG sector. The study concluded that a good move government would lead to a reduction in black money. So our study is focused on the aspect of cashless transactions. The study analyzes the different types of cashless transactions during the pre- & post-demonetization to study the impact of demonetization as the more cashless transaction, the more transparency, and lower the black money flow.

Figure 7.1 shows graphical presentations of transactions of a different instrument. The number of transactions shows thousand on the left side, and the Amount of the transaction is shown in millions. We can see in RTGS and NEFT charts spikes in the different events, but mobile banking transactions in Amount and number show trends.

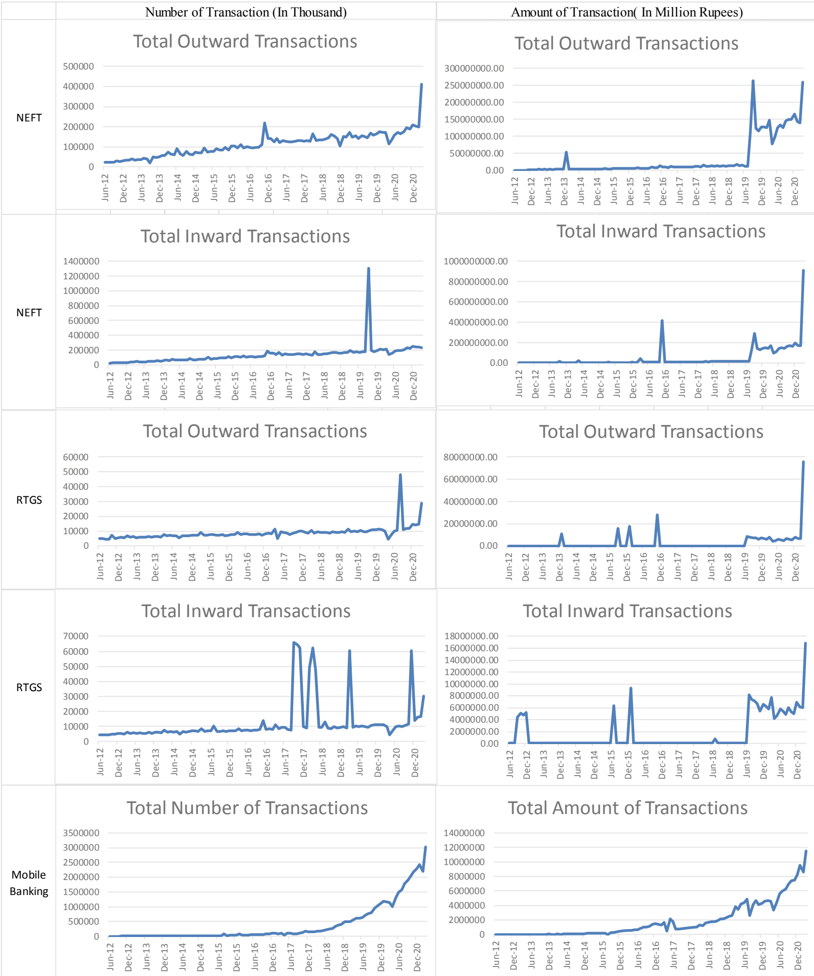

Fig. 7.1 Trends of cashless transactions during the study period (*Source* Researcher's compilation)

7.2 Review of Literature

There was various empirical research has been undertaken on the cashless economy in India as well as abroad. The main focus of the studies was on numerous issues like fraud, security, new methods of e-payments, etc. As we know, the question of the black economy is an issue hotly debated in India as it has been the main target of political actions. In his study, Sharma [6] estimates the size of the black economy in India for more than 40 years from 1970 to 2013 using the currency demand approach. This study revealed that the Indian economy is estimated to have a substantial black economy. In 2013, it was calculated at US$957 billion or 52% of Indian GDP; in early 1990, it was decreased due to fiscal reforms.

Some survey studies were conducted related to the perception of a cashless economy, such as Sharma [7], where a study in Jodhpur associated the potential of the currency-free economy in India. It has been estimated to what extent households incurred non-cash/ monetary expenditure. It also identified bottlenecks that impeded the ability of families to adopt the non-cash payment methods like security, internet connection, loss of card, hacker activity, and lack of technology are worries of customers towards switching to a cashless economy. Krishnan et al. [8] explore how digital cash adoption played a role in determining their resilience to the shock and how the different segments of the cash-dependent population in India coped with the crisis by considering the 505 respondents from two urban cities and two rural cities. They found that those segments lacking digital cash adoption were less affected than those aware of the banking access. Seranmadevi and Kumar [9] measure the effect of demonetization on the Indian economy using Structure Equation Modelling (SEM) based on 629 respondents by analyzing the impact of demonetization on customer satisfaction. They found a significant impact on the entire Indian economy, and demonetization also significantly influenced customer satisfaction.

As there are many benefits of a cashless economy, some studies focus on the benefits part of a Cashless economy. Pathania [10] cites some of the benefits of cashless transactions for nations, such as increasing GDP through the use of cards and reducing social costs, increased financial inclusion due to acceptance of electronic payments, decreased underground economy, lessened cash payments which allow electronic commerce to grow and facilitated trusted online transactions. He states that at 1.7% of GDP, India commits a much higher treasury cost than most developed economies. Rashmi [11] studied the cashless transaction and revealed that the liquidity-free economy has helped curb black money and counterfeit money, reduce cash theft, and also help to improve the growth of the Indian economy. Rao and Kanchana [12] detect the large cash withdrawals from inactive accounts and examine the log or trends found in the previous year's transactions.

The proposed work enhances the effectiveness of the tax evasion technique provided for suspicious accounts by using hashing method. The result indicated the possibility of being suspicious as they were involved in a sudden large amount of transactions. The impact of the introduction of cash-free payments on developing countries' economic growth and development was examined by Kumari and Khanna [13]. In their paper, they found that adopting the liquidity-free economy policy can strengthen the development of financial stability in the country. Many things have already been done to raise awareness of the cashless economy. A large proportion of the population is awaiting the introduction of the cashless economy. The initiative of a cashless economy will have considerable benefits for the developing economy, and the cash-free system will help combat corruption and money laundering.

Every government policy has some positive and negative sides, but the burden of the negative side is often felt only by ordinary people. Singh et al. [14] analyzed the effect of the demonetization policy implemented by the government of India by using the sentiment analysis approach from the ordinary person's perspective. The outcome demonstrates that a large proportion of Indians were satisfied with the policy of demonetization during the first few days after introducing the procedure; the ordinary person had to undergo many difficulties, which is why the sentiments of the normal person were more towards the opposing side. Eventually, as the new banknotes were released, the overall sentiments of the people became positive. Lastly, to sum up the results, in border terms, most of the Indians supported the demonetization policy implemented by the central government of India, excluding nine states those face a minor obstacle. Nagdev et al. [15] analyzed the immediate impact of demonetization on the Indian economy along with the barriers moving towards a cashless economy.

The result suggested that the demonetization hurt traditional banking, leading to cashless economic transactions. Kumar et al. [16] surveyed some villages adopted under the MGMG scheme (Mera Gaon Mera Gaurav) of the Palawan district of Haryana to document the difficulties faced by the farmers due to demonetization and farmer's opinions have been taken about the existing facilities for making digital payments. The responses collected from 54 respondents showed that the farmers faced numerous difficulties during the demonetization phase as the majority of farmers have bank accounts and are using them for getting loans, receiving the subsidy, and other direct benefits. Hence, farmers expressed both positive and negative sides to digital payment.

As the stock market is one of the indicators of the growing economy, some researchers also focus on the impact of demonetization on India's stock market. Anoop et al. [17] examine the impact of demonetization on the Indian Stock Market using the GARCH model, Augment Dickey–Fuller Test considering 200 days prior and post-event data by farming necessary dummy variables. The results showed the significant negative impact of demonetization on the Nifty50 Index and other sectors Indices like the Nifty Auto Index, Nifty Private Bank Index, etc., but due to demonetization, Nifty Realty Index was the most affected sector. Al-ahdal et al. [18] evaluate the impact of demonetization on the Indian companies' financial performance pre- and post-period of demonetization using quarterly results (March–December 2017). The 2892 companies listed on the Bombay Stock Exchange (BSE), National Stock Exchange (NSE), and Calcutta Stock Exchange (CSE) were considered as the sample size for the study.

The result revealed a statistically significant difference at a 5% significance level between financial performance before and after the demonetization period. Irrespective of their ages, it also found that the demonetization process affected either positive or negative impact on the financial performance of all the firms. Jawed et al. [19] used an event study to examine the impact of demonetization on all the listed stocks spanning over 20 industry sectors from November 2016 to January 2017. The result suggested that Group Affiliated companies witnessed the highest negative abnormal returns while PSUs got the least wrath, but the banking sector was the worst hit in the early days of demonetization. At the same time, other sectors like Pharmaceutical, Wholesale Trading, and Paper witnessed a windfall gain in the long run. So, they concluded that demonetization showed mixed effects during the early days of its implementation.

Most studies show that a cashless economy impacts the economy either positively or negatively. In the short run but will positively impact the economy's long run. So this paper is mainly focused on the impact of demonetization on the cashless economy. As if there is an increase in the cashless transaction after demonetization, that will result in a positive future for the economy due to many benefits in the long run.

7.3 Research Methodology

The present research is descriptive as it describes the description of cashless transactions during the pre- and post-demonetization periods.

7.3.1 Sample Profile

In this paper, we use the data of cashless transactions. We select samples by using the purposive sampling of non-probability sampling technique. Samples are divided into Private banking, Public banking, and Total banking transactions. We choose RTGS, NEFT, and Mobile banking as a sample of cashless transactions. We also consider the inflow and outflow of transactions in the case of RTGS and NEFT. We are not considering the inflows and outflows for mobile banking as the data are unavailable.

7.3.2 Study Period and Sources of Data

In the study, we collected from the official website of RBI for the period June 2012 to March 2021 for all the banks (Private and Public Bank), then we made three groups of banks: (1) Private Bank, (2) Public Bank, and (3) Total Bank. The data is further divided into two parts pre- & post-demonetization. The pre-period is 53 months, that is, June 2012 to October 2016 and the post-period is 53 months from November 2016 to March 2021. We consider November 2016 months post-demonetization as an announcement was made on 8 November 2016, and post days of the month are more.

7.3.3 Hypotheses of the Study

The study's null hypothesis is that there is no significant difference between cashless transactions during Pre- & Post-demonetization period. Further, the hypothesis is tested for the variables such as NEFT, RTGS, and Mobile Banking transactions shown in Table 7.1.

Table 7.1 Variables and hypotheses of the study

Variable	*Alternative hypothesis*
National Electronic Fund Transfer Outward	NEFTOPreD ≠ NEFTOPosD
National Electronic Fund Transfer Inward	NEFTIPreD ≠ NEFTIPosD
Real-Time Gross Settlement Outward	RTGSOPreD ≠ RTGSOPosD
Real-Time Gross Settlement Inward	RTGSIPreD ≠ RTGSIPosD
Mobile Banking	MBPreD ≠ MBPosD

Note For abbreviations, refer to Annexture I

These hypotheses will be analyzed using the parametric and non-parametric tests from private, public, and total banks based on the value and number of the transaction as well.

7.3.4 Analysis and Interpretation

For analysis purposes, we use descriptive statistics and test the normality of data for all the variables using the Shapiro–Wilk test. After checking the normality of the data, we are using the non-parametric Wilcoxon Signed Ranks Test for all data as non-normal distributed pairs are more in data during Pre- & post-demonetization for all pairs NEFT, RTGS, and Mobile Banking.

Table 7.2 shows the result of the Shapiro–Wilk test. The test shows the result for the normality of the data. As we can see, this table shows results for all banks' private, public, and total bank data. The result shows signs in most cases as the value of or significance is less than 0.01 in any case, which means the data is not normally distributed. We only find two pairs pre- and post-time for NEFTOPreD and NEFTOPosD pair and RTGSO-PreD and RTGSOPosD pair for private bank data as normally distributed as it is not rejecting the null hypothesis. Because the number of pairs that are non-normal distributed is more, we will use a non-parametric test over a parametric test, so we are using Wilcoxon Signed Ranks Test.

Table 7.3 shows descriptive stats of Private Banks, Public Banks, and Total Banks. The first column shows the period type, the second column shows the mean, the third column shows the months, the Fourth column shows the standard deviation and the last column shows the median for each period transaction (Amount or Number of the transaction). The table is divided into two-part the upper part considers the transaction

Table 7.2 Tests of normality

Variable	*Private sector banks*			*Public sector banks*			*Total banks*		
	Statistic	*df*	*Sig.*	*Statistic*	*df*	*Sig.*	*Statistic*	*df*	*Sig.*
Transactions (in numbers)									
NEFTOPreD	0.956	53	0.050*	0.945	53	0.017*	0.939	53	0.009
NEFTOPosD	0.972	53	0.249*	0.479	53	0.000	0.644	53	0.000
NEFTIPreD	0.849	53	0.000	0.938	53	0.008	0.946	53	0.019*
NEFTIPosD	0.929	53	0.004	0.979	53	0.468*	0.268	53	0.000
RTGSOPreD	0.984	53	0.700*	0.968	53	0.160*	0.969	53	0.187*
RTGSOPosD	0.946	53	0.019*	0.286	53	0.000	0.443	53	0.000
RTGSIPreD	0.835	53	0.000	0.968	53	0.161*	0.961	53	0.083*
RTGSIPosD	0.957	53	0.054*	0.513	53	0.000	0.563	53	0.000
MBPreD	0.752	53	0.000	0.784	53	0.000	0.775	53	0.000
MBPosD	0.845	53	0.000	0.820	53	0.000	0.836	53	0.000
Transactions (in amount)									
NEFTOPreD	0.477	53	0.000	0.282	53	0.000	0.348	53	0.000
NEFTOPosD	0.731	53	0.000	0.705	53	0.000	0.730	53	0.000
NEFTIPreD	0.367	53	0.000	0.971	53	0.230*	0.520	53	0.000
NEFTIPosD	0.558	53	0.000	0.406	53	0.000	0.548	53	0.000
RTGSOPreD	0.123	53	0.000	0.193	53	0.000	0.252	53	0.000
RTGSOPosD	0.514	53	0.000	0.238	53	0.000	0.375	53	0.000
RTGSIPreD	0.124	53	0.000	0.122	53	0.000	0.389	53	0.000
RTGSIPosD	0.724	53	0.000	0.507	53	0.000	0.715	53	0.000
MBPreD	0.800	53	0.000	0.570	53	0.000	0.714	53	0.000
MBPosD	0.899	53	0.000	0.860	53	0.000	0.881	53	0.000

Note *The normal distribution at 1% level of significance
Source Researcher's compilation

in volume data, and the lower part of the table considers the transaction in the Amount. We have high value means for all the Amounts of transactions. And also during the post-period. Column N shows the number of months taken for post- and pre-period. In this study, we divided the whole period into two equal periods of 53 months and November 2016, taken as post-period as most days were in post-period.

Column Mean showing in private banks, transactions related to number shows a high percentage during the post-period compared to the pre-period. In NEFT, outward transactions increased by 224.78%; on average, in NEFT, inward transactions increased by 195.94%. In RTGS, outward transactions increased by 100.43%, in RTGS, inward transactions increased by 91.3%, and in MB number of transactions increased by 2610.95%.

In private banks, transactions related to Amount show a higher percentage during the post-period than before. On average, in NEFT, the outward transaction increases by 1593.26%; on average, in NEFT, the inward transaction increases by 1256.42%, in RTGS, the outward transaction increases by 879.61%, in RTGS inward transaction increases by 1116.48%, and in MB number of transactions 1521.23%. Compared with the number of transactions to the Amount of transactions, the number of transactions increases less, but the Amount of transactions increases at a high percentage in all instruments except mobile banking. That means there was a higher transaction value during the post-period for these instruments.

In Public banks, transactions related to numbers show a higher percentage during the post-period than before. In NEFT, the outward transaction increases by 61.2%, on average; in NEFT, the inward transaction increases by 119.8%. In RTGS, the outward transaction increases by 234.18%, in RTGS, the inward transaction increases by 37.89%, and in MB number of transactions by 3765.59%.

In Public banks, transactions related to Amount show a high percentage during the post-period compared to the pre-period. In NEFT, outward transactions increased by 836.34%; on average, in NEFT, inward transactions increased by 1409.9%. In RTGS, the outward transaction increases by 368.12%, in RTGS, inward transactions increase 185.42%, and in MB number of transactions is 1691.57%. Compared with the number of transactions to the Amount of transactions, the number of transactions increases less but the Amount of transactions increases at a high percentage in all instruments except mobile banking. That means

Table 7.3 Descriptive statistics

		Private banks			*Public banks*		
	N	*Mean*	*Std. Dev.*	*50th-Median*	*Mean*	*Std. Dev.*	*50th-Median*
Transactions (in numbers)							
NEFTOPreD	53	29,891,633.0	121,841,448	28,388,547	35,443,566	15,992,808.4	35,277,145
NEFTOPosD	53	97,081,490.0	28,457,904.7	98,584,167	57,136,624.8	28,835,689.9	47,691,799
NEFTIPreD	53	20,282,495.1	9,028,448.3	19,078,433	51,000,240	23,237,070.4	48,556,094
NEFTIPosD	53	60,023,743.0	20,112,156.4	57,787,427	112,097,020	20,627,561.3	10,778,137
RTGSOPreD	53	2,713,765.4	551,062.6	2,771,751	3,648,485.4	546,235.1	4,114,092
RTGSOPosD	53	5,274,920.4	1,332,938.9	5,180,508	12,192,654	18,073,827.8	4,554,257
RTGSIPreD	53	2,805,230.8	719,267.3	2,812,278	4,027,564.9	544,535.0	3,724,143
RTGSIPosD	53	5,530,629.0	1,442,314.2	5,427,319	5,553,498.9	5,595,225.1	4,389,097
MBPreD	53	12,650,715.2	15,353,480.4	4,902,224	10,815,572.7	9,133,520.2	6,664,268
MBPosD	53	342,954,706	308,470,821	25,021,831	418,085,975	451,592,949	24,937,577
Transactions (in amount)							
NEFTOPreD	53	2,048,405.4	2,464,854.6	1,534,715.8	2,507,507.3	4,576,464.4	1,804,971.4
NEFTOPosD	53	34,684,731.5	37,956,544.5	8,122,644.3	23,478,683.2	28,174,141	5,064,215.7
NEFTIPreD	53	3,001,262.6	5,872,516.6	1,670,147.4	2,475,744.4	1,246,709.4	2,264,582.2
NEFTIPosD	53	40,709,845.6	62,576,837.1	7,955,674.5	37,381,184.1	72,407,043.6	6,977,865.2
RTGSOPreD	53	225,518.6	1,464,867.0	22,636.8	196,299.6	1,280,496.0	20,792.8
RTGSOPosD	53	2,209,205.2	4,071,578.8	58,436.5	918,913.6	1,670,356.7	26,201.6
RTGSIPreD	53	142,545.1	868,907.1	21,696.1	650,943.3	3,214,079.1	19,759.4
RTGSIPosD	53	1,734,028.6	2,175,612.3	56,720.1	1,857,925.2	6,780,017.1	24,892.2
MBPreD	53	121,141,362	145,328,663	34,740,901.2	82,018,670.1	156,956,616	8,476,576.2
MBPosD	53	1,963,979,435	1,327,594,773	1,637,419,170	146,942,130	1,257,938,546	802,996,452.1

(continued)

Table 7.3 (continued)

	Total banks			
	N	*Mean*	*Std. Dev.*	*50th-Median*
Transactions (in numbers)				
NEFTOPreD	53	64,902,336.4	27,589,738.2	63,606,680
NEFTOPosD	53	156,255,681	43,733,514.2	147,464,467
NEFTIPreD	53	71,282,735.1	29,662,655.1	67,634,527
NEFTIPosD	53	195,290,813	158,605,300	166,534,216
RTGSOPreD	53	6,453,716.3	1,182,774.4	6,941,547
RTGSOPosD	53	17,851,453.3	18,081,705.9	9,614,786
RTGSIPreD	53	6,741,330.4	1,038,873.7	6,523,997
RTGSIPosD	53	10,757,681.3	6,133,090.9	9,840,175
MBPreD	53	23,466,287.9	23,656,823	11,183,210
MBPosD	53	759,751,627	759,335,095	499,594,095
Transactions (in amount)				
NEFTOPreD	53	4,555,912.7	6,994,748	3,368,007.9
NEFTOPosD	53	61,079,063.7	69,865,671.3	13,229,572
NEFTIPreD	53	5,477,007.1	6,411,137.05	4,272,634.6
NEFTIPosD	53	88,732,986.2	144,231,252	14,825,018
RTGSOPreD	53	704,181.1	1,949,666.3	43,805.2
RTGSOPosD	53	2,668,085.7	3,583,089.8	83,696.0
RTGSIPreD	53	876,461.9	3,496,010	43,570.5
RTGSIPosD	53	4,429,228.7	11,040,934.8	81,330.0
MBPreD	53	203,160,033	293,393,105	43,577,936
MBPosD	53	341,231,216	257,184,087	2,511,991,155.0

there was a higher transaction value during the post-period for these instruments.

In private and public sector bank comparison, the number of transactions Increases more in the private banks for NEFT outward transactions, NEFT inward transactions and RTGS inward Transactions. For Mobile banking and RTGS outward transactions, there was more growth in percentage for Public Sector banks.

In private and public sector bank comparison, the Amount of transactions increases more percentage in the private banks for NEFT outward transactions and RTGS inward transactions. For Mobile Banking, NEFT inward transactions, and RTGS outward transactions, there was more growth in percentage for Public Sector banks. So numbers-wise, there are two variables in which public sector banks show high growth, and Amount wise, there are three variables in which public sector banks show high growth.

In Total banks, transactions related to number show a high percentage during the post-period compared to the pre-period. In NEFT, the outward transaction increases on average by 140.76%, while the inward transaction increases by 173.97%. In RTGS, the outward transaction increases 176.61%, in RTGS, the inward transaction increases 59.58%, and in MB number of transactions augments 3137.63%.

In Total banks, transactions related to Amount show a high percentage during the post-period compared to the pre-period. In NEFT, the outward transaction increases by 1240.65%. On average, in NEFT, the inward transaction increases by 1520.10%. In RTGS, the outward transaction increases by 278.89%. In RTGS, the inward transaction increases by 405.35%. In MB number of transactions is 1579.62%. Compared with the number of transactions to the Amount of transactions, the number of transactions increases less. Still, the Amount of transactions increases at a high percentage in all instruments except mobile banking. That means there was a higher transaction value during the post-period for these instruments.

The standard deviation and Median column show variation of value from the mean value, and the median shows the median value of the series. We have the highest value for both columns in total banks as it represents the total of both banks.

Table 7.4 shows the result for the Wilcoxon Signed Ranks Test. The table is divided into two-part transactions (in numbers) and transactions into Amounts. This table only shows the value of negative and positive ranks for all pairs in this study. We have 53 pairs table showing the positive and negative ranks for all variables and the mean rank and sum of the rank for positive and negative rank. We have many pairs with all positive ranks of 53 and no negative rank. That means there is a positive increase in the transaction during the post-period. We have the highest negative rank in RTGS outflow and inflow in Amount and the number of transactions in the case of public sector banks only. That means there were instant RTGS transactions decreased in the private bank during the post-period demonetization. However, that effect is not shown in the other cases. In these cases, the number of negative ranks is 14, 10, 16, and 17.

Table 7.4 shows the Test Statistics of the Wilcoxon test result as we have calculated the values for positive and negative ranks in Table 7.5. These are used in Table 7.6 to calculate the test statistics. Wilcoxon test reveals multiple results in the same direction, which means there is a significant increase in the number of transactions and the Amount of transactions in all variables for all types of banks. As we can see in table (Md = 57,787,427, n = 53) compare before (Md = 19,078,433, n = 53), $z = -0.6299$, $p = 0.000$. For the second pair in a private bank. Same we can see that from the table, all the values are significant, which means the government planning to ban old currency and increase the way of exchange online is successful. As found in many studies, transparent transactions increase the flow of white money in the economy and reduce the flow of black money.

7.3.5 Wilcoxon Signed Ranks Test b: Based on Negative Ranks

The results for the hypothesis are significant, so we reject the null hypothesis and accept the hypothesis for all and the transactions related to private banks, public banks, and total banks. The study finds that an increase in mobile banking transactions is highest during the post-period but the Amount of transaction increase lower percentage. The possible reason for an increase in these transactions introduces 4G in India during the low data cost, digitalization of India, more trust build of people and exciting offers given by banks during the post-period. Private sector transactions increased more than public sector banks in all cases during the post-period of Demonetization.

Table 7.4 Results of Wilcoxon signed ranks test

			Private sector banks			*Public sector banks*			*Total banks*		
			N	*Mean rank*	*Sum of ranks*	*N*	*mean rank*	*Sum of ranks*	*N*	*Mean rank*	*Sum of ranks*
Transactions (in numbers)											
Pair 1	NEFTOPreD	Negative Ranks	0	0	0	8	11.38	91.00	0	0.00	0.00
		Positive Ranks	53	27	1431	45	29.78	1340.00	53	27.00	1431.0
	NEFTOPosD	Ties	0			0			0		
		Total	53			53			53		
Pair 2	NEFTIPreD	Negative Ranks	2	2.0	4	1	1.00	1.00	0	0.00	0.00
		Positive Ranks	51	27.9	1427	52	27.50	1430.0	53	27.00	1431.0
	NEFTIPosD	Ties	0			0			0		
		Total	53			53			53		
Pair 3	RTGSOPreD	Negative Ranks	1	5.0	5	17	20.29	345.0	3	18.00	54.00
		Positive Ranks	52	27.4	1426	36	30.17	1086.0	50	27.54	1377.0
	RTGSOPosD	Ties	0			0			0		
		Total	53			53			53		
Pair 4	RTGSIPreD	Negative Ranks	2	9.5	19	10	15.30	153.0	1	9.00	9.00
		Positive Ranks	51	27.6	1412	43	29.72	1278.0	52	27.35	1422.0
	RTGSIPosD	Ties	0			0			0		
		Total	53			53			53		
Pair 5	MBPreD	Negative Ranks	1	1.0	1	0	0.00	0.0	1	3.00	3.00
		Positive Ranks	52	27.5	1430	53	27.00	1431.0	52	27.46	1428.0
	MBPosD	Ties	0			0			0		
		Total	53			53			53		
Transactions (in amount)											
Pair 6	NEFTOPreD	Negative Ranks	2	2.5	5	1	2.00	2.00	0	0.00	0.00
		Positive Ranks	51	27.9	1426	52	27.48	1429.00	53	27.00	1431.0

(continued)

Table 7.4 (continued)

			Private sector banks			*Public sector banks*			*Total banks*		
			N	*Mean rank*	*Sum of ranks*	*N*	*mean rank*	*Sum of ranks*	*N*	*Mean rank*	*Sum of ranks*
	NEFTOPosD	Ties	0			0			0		
		Total	53			53			53		
Pair 7	NEFTIPreD	Negative Ranks	3	22.00	66.00	1	1.00	1.00	2	20.50	41.00
		Positive Ranks	5	27.30	1365.00	52	27.50	1430.00	51	27.25	1390.0
	NEFTIPosD	Ties	0			0			0		
		Total	53			53			53		
Pair 8	RTGSOPreD	Negative Ranks	4	15.75	63.00	14	16.79	235.00	6	23.00	138.00
		Positive Ranks	49	27.92	1368.00	39	30.67	1196.00	47	27.51	1293.00
	RTGSOPosD	Ties	0			0			0		
		Total	53			53			53		
Pair 9	RTGSIPre	Negative Ranks	5	15.20	76.00	16	15.63	250.00	6	18.17	109.00
		Positive Ranks	48	28.23	1355.00	37	31.92	1181.00	47	28.13	1322.0
	RTGSIPosD	Ties	0			0			0		
		Total	53			53			53		
Pair 10	MBPreD	Negative Ranks	1	2.00	2.00	1	3.00	3.00	1	1.00	1.00
		Positive Ranks	52	27.48	1429.00	52	27.46	1428.00	52	27.50	1430.0
	MBPosD	Ties	0			0			0		
		Total	53			53			53		

Source Researcher's compilation

Table 7.5 Test statistics of Wilcoxon test

		Private sector banks		*Public sector banks*		*Total banks*	
		Z	*Asymp. sig. (2-tailed)*	*Z*	*Asymp. sig. (2-tailed)*	*Z*	*Asymp. sig. (2-tailed)*
Transactions (in numbers)							
Pair 1	NEFTOPreD NEFTOPosD	Used Pair sample t-test for this pair		−5.529[b]	0.000	−6.334[b]	0.000
Pair 2	NEFTIPreD NEFTIPosD	−6.299[b]	0.000	−6.325[b]	0.000	−6.334[b]	0.000
Pair 3	RTGSOPreD RTGSOPosD	Used Pair sample t-test for this pair		−3.280[b]	0.001	−5.856[b]	0.000
Pair 4	RTGSIPreD RTGSIPosD	−6.166[b]	0.000	−4.980[b]	0.000	−6.254[b]	0.000
Pair 5	MBPreD MBPosD	−6.325[b]	0.000	−6.334[b]	0.000	−6.308[b]	0.000
Transactions (in amount)							
Pair 6	NEFTOPreD NEFTOPosD	−6.290[b]	0.000	−6.316[b]	0.000	−6.334[b]	0.000
Pair 7	NEFTIPreD NEFTIPosD	−5.750[b]	0.000	−6.325[b]	0.000	−5.971[b]	0.000
Pair 8	RTGSOPreD RTGSOPosD	−5.776[b]	0.000	−4.254[b]	0.000	−5.112[b]	0.000
Pair 9	RTGSIPreD RTGSIPosD	−5.661[b]	0.000	−4.121[b]	0.000	−5.369[b]	0.000
Pair 10	MBPreD MBPosD	−6.316[b]	0.000	−6.308[b]	0.000	−6.325[b]	0.000

Source Researcher's compilation

Table 7.6 Summary of hypotheses testing

Variables	*Hypothesis formulated*	*Results*
National Electronic Fund Transfer Outward	NEFTOPreD $\neq$ NEFTOPosD	Significant (Accepted Alternative Hypothesis)
National Electronic Fund Transfer Inward	NEFTIPreD $\neq$ NEFTIPosD	Significant (Accepted Alternative Hypothesis)
Real-Time Gross Settlement Outward	RTGSOPreD $\neq$ RTGSOPosD	Significant (Accepted Alternative Hypothesis)
Real-Time Gross Settlement Inward	RTGSIPreD $\neq$ RTGSIPosD	Significant (Accepted Alternative Hypothesis)
Mobile Banking	MBPreD $\neq$ MBPosD	Significant (Accepted Alternative Hypothesis)

Source: Researcher's compilation

Annexure I List of Abbreviations

No.	*Short form*	*Full-form*
1	NEFTOPreD	National Electronic Fund Transfer Outward Pre-demonetization
2	NEFTOPosD	National Electronic Fund Transfer Outward Post-demonetization
3	NEFTIPreD	National Electronic Fund Transfer Inward Pre-demonetization
4	NEFTIPosD	National Electronic Fund Transfer Inward Post-demonetization
5	RTGSOPreD	Real-Time Gross Settlement Outward Pre-demonetization
6	RTGSOPosD	Real-Time Gross Settlement Outward Post-demonetization
7	RTGSIPreD	Real-Time Gross Settlement Inward Pre-demonetization
8	RTGSIPosD	Real-Time Gross Settlement Inward Post-demonetization
9	MBPreD	Mobile Banking Pre-demonetization
10	MBPosD	Mobile Banking Post-demonetization

7.4 Conclusion

This paper investigates cashless transactions pre- & post-demonetization in RTGS inward and outward, NEFT inward and outward, and mobile banking by using parametric. The study finds a significant increase in the number and value of cashless transactions post-period of demonetization in NEFT, RTGS, and Mobile banking. The study finds an increase in mobile banking transactions is highest during the post-period but the Amount of transaction increase lower percentage. The possible reason for an increase in these transactions introduces 4G in India during the low data cost, digitalization of India, more trust build of people, and exciting offers given by banks during the post-period. In other variables, we can see an increase in the Amount of transactions compared to the number of transactions, which means the per-transaction amount increases. The possible reason is an increase in more transactions by the upper class like a businessman and industrial entity, etc. As previously studied, Rashmi [11] said that the more cashless transaction, the less the chance of black money in the economy, so from the previous study, we can say that an increase in cashless transactions helps fight black money in the economy. Undoubtedly, many common people suffered a lot during the early period of demonetization. However, in the long run, with an increase in cashless transactions, the economy can grow better and fight against black money. Further study can be done on factors pushing the cashless transaction pre- and post-period of demonetization like technological factors: banking system, low-cost mobile internet, growth of mobile phone industry, and human behavior factors: safety, speedy, security, and easy record.

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CHAPTER 8

Analysis of Innovation Processes in the Circular Economy in Hotel Companies, Jalisco, México

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8.1 Introduction

Belda Heriz, [1] manifested ten years ago that about 2900 million of the urban population generated 0.64 kg of solid waste, according to the *Global Review of Solid Waste Management*, 2012. The same report estimates that, by that date (2012), there had been an increase of 3 billion urban residents, generating 1.2 kg per person per day (1.3 billion tons per year), an increase of more than 91%. By 2025, there are estimated to be 4300 million urban residents, generating around 1.42 kg of MSW per

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S. Estrada (ed.), *Digital and Sustainable Transformations in a Post-COVID World*, https://doi.org/10.1007/978-3-031-16677-8_8

person per day (2200 tons per year, slightly more than 6 million tons of waste every day). This is an increase of 70%.

The current fallacy lies, as was shown years later, since the beginning of the twenty-first century, the prices of raw materials have increased by 147% in real terms,

> for which, statistically, an annual investment of around $1 trillion in the natural resources generation and system conservation will be needed to meet the future demand. As the next problem on this line, we have the overexploitation and consumption of natural resources as well as the management of the waste. Based on the above it is estimated, according to an article published in the prestigious journal Nature 28 in 2013, that by extending the current socio-economic trends, by the year 2100 we will not reach the maximum peak of waste, but we will produce a whopping 11 million tonnes of urban waste per day, which would undoubtedly be a very costly economic and environmental burden. [1: 30]

The previous vision of the economy was short term, which consists of the use of predatory resources, of using and throwing away, and with the definite objective of obtaining many profits in a short time, with a capitalist approach, of linear production. Nowadays, the human consumption of natural resources isn't sustainable, if this situation continues at the same rate, we will finish all the natural resources.

The purpose of this investigation is to analyze the innovation process of the circular economy in hotel companies in Jalisco State, México. This investigation includes the hypothesis of the innovation process in the circular economy in the hotel companies is the way to attract guests by taking care of the environment and using renewable energies.

The paper is divided into seven sections, including the summary and introduction, the part of the literature review that explains the concepts of innovation from the perspective of some authors of the specialized literature and the Oslo Manual, as well as the emerging paradigms from the approach to the evolutions of propellers, especially the quintuple helix focused on eco-innovation, ecology, and sustainability, at the same time an explanation of the innovation processes of the circular economy is made. The methodological part explains that it is mixed research, a combination of qualitative and quantitative using interview and survey techniques. The results interpret the graphics and tables that were generated from the survey application. It also addresses the discussion of work as well as its conclusions.

8.2 Literature Review

8.2.1 Innovation Process

In the present century, the concept of innovation has changed drastically, since disruptive, social, business and educational innovation has been the core of many types of research. With that in mind, it is pertinent to address the issue as an evolutionary process; this section explains the following types of innovation (Table 8.1).

These ten types of innovation that refer [2] were born in agreement with the authors to strengthen companies in their development and consolidation, for instance, from the generation of the product to its destination which is for customers or final consumers, this process involves observing details that lead to the generation of the added value of the products offered, the connection with other companies or institutions to create value, the organization and alignment of human talent in the business and the sophisticated use of a superior working method in the enterprise.

The current demand for all companies is to generate innovation and this is the key to becoming able to land their way of manufacturing or producing a product or service. The ten types of innovation presented by [2] is the strength of all kinds of business in the globalization era, given this, the Organization for Economic Cooperation and Development [3] in the "Oslo Manual" identifies four types of innovation which are defined subsequently.

Table 8.1 Types of innovations

Keeley et al. [2]	*Oslo Manual OECD [3]*
1. Innovation in the business model	1. Product innovation
2. Innovation in strategic alliances	2. Process innovation
3. Innovation in the business structure	3. Marketing Innovation
4. Process innovation for business support,	4. Organizational innovation
5. Product innovation	
6. Innovation in the product system	
7. Innovation in service	
8. Innovation in the distribution channel	
9. Innovation in the product brand	
10. Innovation and customer engagement	

Source Own elaboration based on [2, 3]

1. Product innovation: the introduction of a good or service, which is new or significantly improved concerning its intended characteristics or uses. This includes significant improvements in technical specifications, components, materials, built-in software, friendly uses, or other functional features.
2. Process innovation: the implementation of a new or significantly improved production or supply method. This includes significant changes in techniques, equipment, and/or software.
3. Marketing Innovation: The implementation of a new marketing method that involves significant changes in product design or packaging, product placement, product promotion, or pricing.
4. Organizational innovation: the implementation of a new method of organization in business practices, workplace, or external relations. Also called innovation in management, basically, it perfects how the company is managed.
5. The interrelationship between types of innovation has been emerging in recent years for higher education institutions and enterprises as an economic paradigm due to changes in organizations and institutional structures that increasingly requires more explanation.

8.2.2 Emerging Economic Paradigms Using Triple, Quadruple, and Quintuple Helix

As a process of innovation in the circular economy at the international level, the linkage and collaboration between the actors of the triple helix university-industry-government is increasingly pressing for the economic development of a country and a state, the triple helix was born in the 90s by Henry Etzkowitz and his collaborators [4] precisely to strengthen this link as a strategy to generate collaborative projects, strategic projects and during these four decades has been made presence for the strengthening of the industries with the university and with the government, example we have cases Asian, European, North American and Latin American (Argentina, Mexico, Brazil and Chile), for example in Mexico many universities in the country are participating in innovation projects with National Council of Science and Technology (in Spanish Consejo Nacional de Ciencia y Tecnología) programs, other universities are participating with funds from other government institutions such as Pro Mexico, National Financial (NAFIN in Mexico), all this collaboration has been permeated together with companies whether industrial, trade or services. Currently, more and more collaborations are being developed with companies that are carrying out activities in digital form, taking care of the environment, and at the same time, considering technological development and sustainability.

Rickne et al. [5], recognize that there is new incorporation into knowledge spin-off or start-up creation that is replaced at the center of the university's spiral and other knowledge institutions that can be generated. This incorporation is called the "quadruple helix", it is a further extension of the involvement of heterogeneous agents [6, 7]. The main focus is to regulate the interaction, linkage, and cooperation of universities with the productive sector and government agencies through strategic projects and financial resources.

The quadruple helix is a space of social life for the actors involved, a place where you can interact, make decisions, of course, you can form a group of "people" members of the propellers (university, company, and government), to generate strategic projects and work in favor of micro, small and medium-sized enterprises and consequently the formation of human capital and the transfer of scientific, technological, and innovation knowledge.

Carayannis et al. [8], mention that there is another model that takes into consideration the environment, democracy, and social innovation, the model is called "the innovation model of the Quintuple Helix" is even more comprehensive than the rest, contextualizing the quadruple helix and adding, in addition, the helix and perspective of the "natural environments of society", it should be noticed that, for the present research, the ecosystem linked to the subsystems was taken by the same idea, where it supports the formation of win–win between Ecology and Innovation, which leads to the creation of synergies between the economy and society.

This quintuple helix goes beyond sustainability or sustainable development, it can mean and imply an eco-innovation and eco-entrepreneurship [9], with that in mind, they are included in the natural environment of society and the economy, social ecology, socio-ecological transition, and social responsibility.

Therefore, [8] carry out an analysis of the Quintuple Helix that has the potential to serve as an analytical framework for sustainable development and social ecology, by conceptually relating knowledge and innovation to the environment. Authors like [10] take up this whole process of innovation of the literature on the triple, quadruple, and quintuple helix which is relevant to the public policy of a nation, from various approaches and environments; economic, education, sociological, and ethics, that go hand in hand with sustainability.

Sustainable knowledge reflects the performance and quality of the natural environment. The Quadruple Helix also describes what sustainable development could mean and implies "eco-innovation" and "eco-entrepreneurship" in the current situation as our future in the environment.

Nowadays, the term "environment" is completely related to the theme itself, but there can exist different types of environments, going so much further, as the social and economic environment, which link with ecology. Then, the economy and politics go hand in hand in something we know as a society, and they need to be perfectly interlinked in order for the system to work correctly.

The twenty-first century is facing systematic changes, stemming from innovation in development model movements that were based on privatization and the hegemony of lucrative private enterprise, directly impacted by antisocial practices, they have returned to historical levels of inequality and poverty, in addition to the lack of adequate responses to the new social demands of the traditional enterprise, where the environmental sustainability of the business model is among the main objectives to be applied.

This model, in wanting to adhere to environmental sustainability, does not give the expected results, so currently, the need for change as a process of innovation is focusing on the social responsibility aspect, where several authors are transforming their discourses and practices by directing resources to the social and environmental problems of the world [11].

Within the previous global development paradigm, the social economy is emerging as a process of innovation, which is based on the benefits of the community and its social groups. It emerges as a third sector that performs macroeconomic and microeconomic functions that correct different imbalances and substantive economic and social problems. This sector increases the impact on economies, and contributes to a more balanced economic and social development, as world-renowned economists and intellectuals are defending, among them, the Nobel Prize winner Stiglitz, 2009, and Mintzberg, 2015, which argue that there would be a better balance in the economy, combining the three economic sectors, the public, the private capitalist, and the social economy [11].

Likewise, the community in search of improving its quality of life is emerging with the concept of social innovation as a process where authors like Etzkowitz [12] argue that growth in this type of economy and social innovation requires an active civil society, where "the Triple Helix anchored in a thriving civil society fosters the emergence of diverse sources of innovation", this social innovation is dimensioned through various eco-innovation approaches through the Triple, Quadruple and Fivefold Helix mentioned in the following sections.

8.2.3 Eco-Innovation

Vence and Pereira [13] settle that eco-innovation is any innovation aimed at reducing the environmental impact, in addition to technological change, covering as well organizational, social, and systematic innovations.

Eco-innovation is a facilitator of the circular economy, which is presented as an approach to maintaining and sharing value over time, from the perspective of eco-innovation a business model that needs to add ecological and social value and above all change the practices of the producer and the consumer, in search of reconfiguring how they interact in actions of distribution, repair, reduction, remanufacturing among others, based on eco-mobility systems, intelligent energy systems, short value chains.

The Eco-innovation observatory suggests the involvement of the restructuring of its economic, business, infrastructure, and government areas, it also enables the shift toward eco-innovation to be implemented in strategies aimed at reducing the environmental impact of resource use, the substitution of higher impact materials with lower resource productivity materials and strategies to increase services from a certain amount of products, such as delivery systems, pooling, and leasing [14].

As a result, the following types of eco-innovations to be implemented for a circular economy model are also proposed (Table 8.2).

Eco-innovation is the product of collaborative work between university-business-government, civil society, and society in general, that is to say, a multi-stakeholder and quintuple Helix effort. The European Commission has also been active in the field of environmental protection.

Table 8.2 Types of eco-innovation

Types	*Descriptions*
Product design with eco-innovation	The overall impact on the environment and material input is minimized throughout the product life cycle, allowing recovery options such as repair, maintenance, manufacturing, recycling, and cascading of components and materials
Eco-innovative processes	The use of materials, emissions, and hazardous substances are reduced, risks also and costs are saved in production processes. Advances in remanufacturing, such as replacement or repair of defective components, including product upgrading, product dismantling and recovery, materials and substances, functional recycling, zero waste production, zero emissions, and cleaner production
Eco-innovative organization	Methods and reorganization of management systems pressing to close losses and increase resource efficiency. New business models, for example, industrial symbiosis, new systems for collecting and recovering valuable resources from products to functional services (product-service systems)
Innovative eco marketing	Product and service design, placement, pricing promotion of reuse for the same purpose as bottles, appliances, and different purposes such as tires as boat fenders, eco-labeling, and green marks
Social eco-innovation	Behavior and lifestyle changes, user-driven innovation to share appliances, books, textiles, collaborative consumption floors, garden, tools, adequacy in plastic bag prohibition, smart consumption, responsible shopping
Eco-innovative systems	New systems are created with completely new functions that reduce the total impact on the environment, motivate a substantial dematerialization of the industrial society, implement smart cities, and permaculture actions

Source [14]

8.2.4 Ecology and Sustainability

"Ecology" refers to the interdisciplinary analysis of interactions between living organisms and their environment. Based on these patterns of interaction, the sum of living organisms and the non-living environment defines an "ecosystem", which is why we speak of eco-innovation and eco-entrepreneurship.

On the other hand, sustainability can be seen from two different approaches: the first, as the study of the relationship between society and its economy, for it to develop, and the other as the relationship between society and the environment, also trying to develop this area. It was the German biologist Ernst Haeckel (1834–1919) who coined the term Ecology in 1869 and defined it as "the study of the interdependence and interaction between living organisms (animals and plants) and their environment (inorganic beings)" [15].

This is where the definition "sustainable development" appears, which is a combination of the mentioned is, concluded as the optimization of the relationship of a society with its economy and at the same time with the environment in which it lives daily.

In this way, sustainable or sustainable development meets the needs of the present without compromising the capacity of future generations. Broader conceptualizations or definitions of democracy that do not limit the political system, but are interested in integrating the political system, society, and economy, in one setting or another, possible reflecting aspects of sustainable development.

Therefore, the democracy knowledge that unites the political system, society, the economy, and the environment allows the application of concepts of social ecology in a framework of sustainable development coming together with the sustainable development, It also analyzes the human activities of society between its "cultural world", including its customs and way of life, and its "material world", being everything that human kinds use and take from nature. The whole of studying social sciences and natural sciences has proved to be of great importance for social ecology.

8.2.5 Circular Economy

The changes of the circular economy are increasingly pressing for all citizens of the planet, 86% of society is concerned about the care of the environment and it is committed to a respectful production system that does not necessarily imply a greater financial outlay, where innovation processes can help reduce the costs of the transition to the circular economy and has been proved that "green" investments can become more profitable than traditional long-term investments. Keeping that in mind and in addition, this new economic model has the potential to create new jobs [16].

This model directs the change toward the circular economy and requires the commitment of all the actors involved in the model of the fifth or five-fold propeller that was explained in the previous sections.

Based on the above-mentioned, circular economy seeks the involvement of the university area through its research projects linked to companies. In addition to the exchange of data, coordination between administrations, the scientific, technological community, economic, and social actors, obtaining the favorable synergy for the fifth helix model.

The circular economy aims to recycle, and reuse using the necessary technologies and clean energy and has a focus on the green economy and sustainability, that is, an economy based on organic and inorganic natural resources. It was born from replacing the linear economy that was to use and throw. The aim should be not only to recycle and reuse, but also to change the production forms and consumption, that is to say, increasingly use biodegradable materials that do not pollute society, in addition, companies also get involved in not using raw materials that harm the environment, as it is known that in the industrial revolution world, we have not been able to give a balance to the sustainable economy, we remain trapped in the linear economy, which, although more and more countries separate organic and inorganic wastes. Mexican culture remains very indifferent to carrying out this action.

8.3 Methodology

In the methodological design, the specialized literature for the construction of a theoretical framework to frame the research was reviewed, and the type of research that was used was mixed, which sought to identify innovation processes in the circular economy in hotel companies in Jalisco, Mexico.

This research is exploratory in a way that it sought to describe the relationship between the circular economies as a process of innovation in hotel companies. The method used is deductive, due to how the topic was addressed since it moved from a global issue to a specific problem in the state of Jalisco. According to the information sources, this study was documentary research and field research, since data collection instruments were used, like expert interviews and a survey of hotel companies with a population of 15 of the most representative hotels inside Jalisco state, Mexico, and 3 expert interviews on the subject.

The interviews were with experts in Circular Economy (academics and researchers and tourism certification consultants) as a process of innovation in hotel companies in Jalisco.

On the other hand, it counts surveys of 15 hotel companies to determine the application of the circular economy. The sample was of convenience since they are the most representative in Jalisco in terms of providing more professional information.

8.4 Results

According to the results of the survey that was answered by 60% of the large hotel companies, followed by 20% medium, 13% small, and 7% micro, which provided information regarding innovation processes in the circular economy (Fig. 8.1).

These companies were asked 14 questions of which all the answers are reflected, although many of them are presented in graphic form and the rest in the corresponding description.

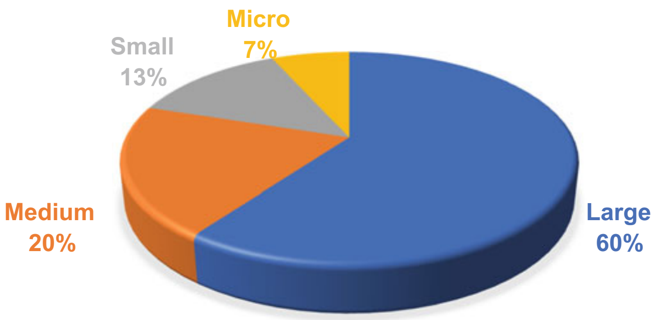


Fig. 8.1 Size of the company (*Source* Prepared by the authors)

The surveyed were first asked to point out the types of transportation being promoted in the hotel for the use of its guests for environmental care. The results showed that 100% of them use public transport, although 47% of them also indicated the use of a shared car, 13% use a bicycle and none of them use an individual vehicle or rental vehicle. According to the information presented, it is noteworthy to note that there is a higher percentage of environmental actions. In addition to that, the guest had information on some options such as moovit, waze, GDL routes, and others. Therefore, respondents pointed out others, such as Google maps.

On the other hand, respondents were asked for information regarding the types of products they use at the hotel to make this become sustainable, where they pointed out that 60% are biodegradable goods, 20% green goods and 40% of them said another type of product, although they did not specify what type (Figs. 8.2 and 8.3).

Added to the previous graph, the informants pointed out that in the department in which ecological friendly products are used: 100% in food and drinks, 87% in dry cleaners, and 27% in housekeepers, although in the laundry area, Human Resources is not as common to use sustainable products as reflected in the graph below (Fig. 8.4).

It was also requested that they indicate the products that are recycled, as well as the origin of the souvenirs. With that in mind, 100% of the respondents indicated that plastic, glass, paper, and cardboard are recycled, the only ones that are not reused are aluminum, and batteries, On the other hand, the typical souvenirs come from the local artisans, that is

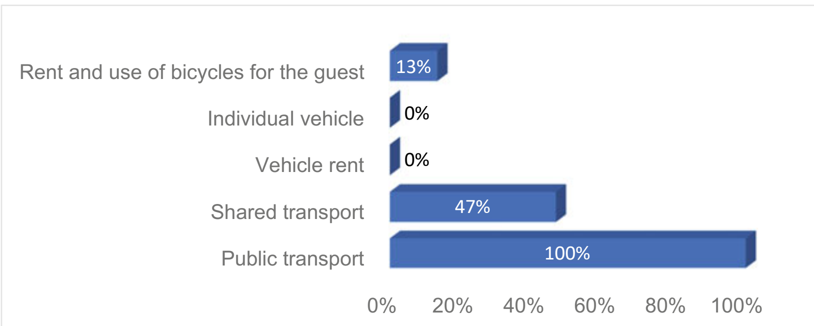


Fig. 8.2 Type of transport (*Source* Prepared by the authors)

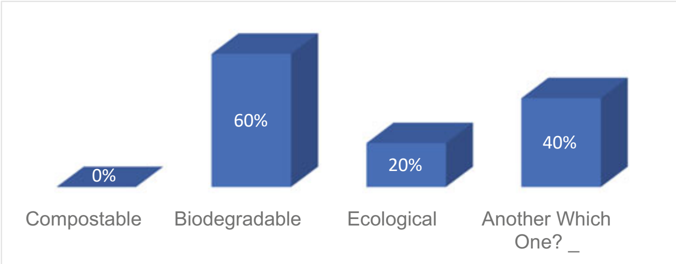
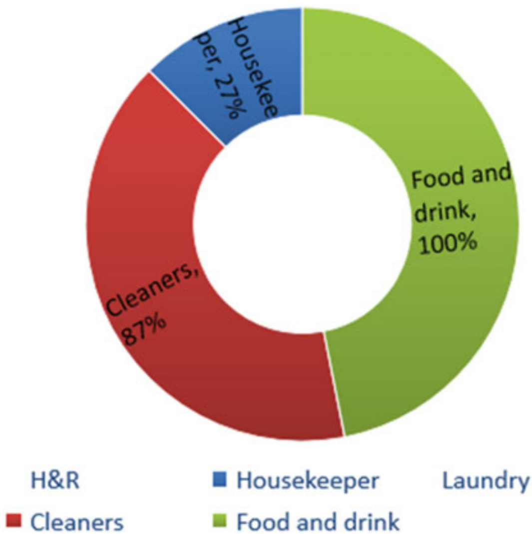


Fig. 8.3 Product used in the hotel (*Source* Prepared by the authors)

Fig. 8.4 Areas using sustainable products (*Source* Prepared by the authors)



to say, the hotel is decorated with products made in the community and not imported. The question was also whether whoever benefited economically from the products being recycled, responded that it was used in support of the community and for hotel employees.

In the area of water care, they were asked about the strategies used in the hotel, they replied that 100% was reused in sheets and towels of the guests, as well as rainwater recycling, Also the use of biodegradable products in showers in the establishment represented 60%, 20% in express showers (5 minutes) and finally, 13% use the solar heater. In water, recycling is used to irrigate green areas and wastewater for reuse (Fig. 8.5).

About the use of types of intelligent energies for environmental care, the informants commented that 80% were switched off and on with automatic light bulbs, and only 7% mentioned that they use solar panels; they also pointed out another but did not specify which. The renewable energy used is wind and solar primarily (Table 8.3).

They were asked if they had an environmental certification, they said that 67% had Earth Check and 33% mentioned Green Key, on the other hand, if they offer environmental training to sensitize employees, tourists, and the whole community, but it turns out that only 62% train their staff and 33%, guests (Figs. 8.6 and 8.7).

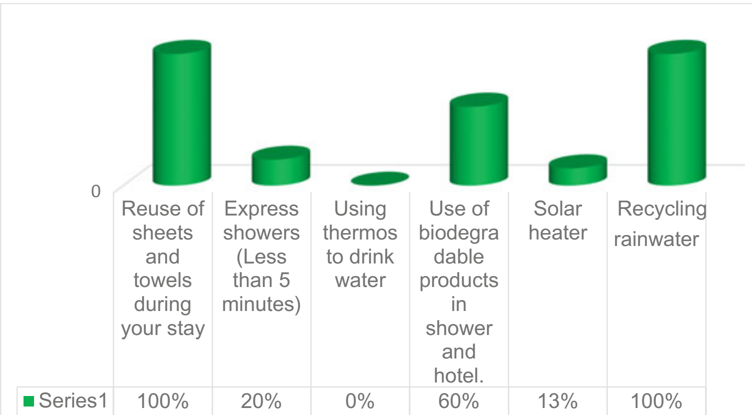


Fig. 8.5 Water care strategy (*Source* Prepared by the authors)

Table 8.3 Type of intelligent energy

Automatic switching on and off spotlights	80%
Use of solar panels	7%
Use of polarized sheets in windows	0%
Another. Which one?	67%

Source Prepared by the authors

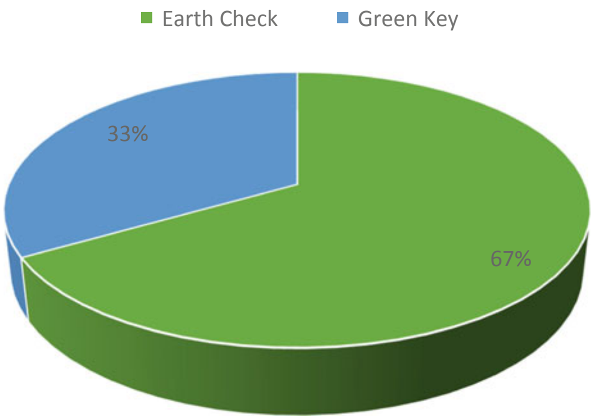
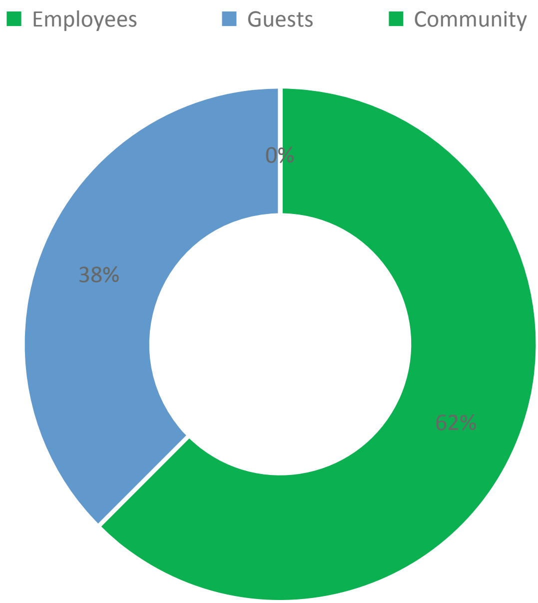


Fig. 8.6 Types of environmental certifications (*Source* Prepared by the authors)

Fig. 8.7 Training in Environmental issues (*Source* Prepared by the authors)



8.4.1 Interview in Depth

Regarding the results of the in-depth interview, there is a certifying evaluation area, where the goal is to achieve the sustainable development of the company and community. These accreditations follow a methodology of certification companies that gives them the guidelines to make changes and achieve the goal.

Guests and employees are invited to participate in training and environmental education. The certifications motivate hotels to implement environmentally friendly energies, with automatic switching on and off lights, air conditioning control, heating, and some even using solar panels, as well as low-power lights in public areas. In addition, shade trees are planted.

Reuse of sheets and towels during the stay of guests, showers, bathrooms, low consumption faucets, also rainwater recycling, accumulated condensation, and residual water from kitchen sinks.

Hotels and tourism companies are in the stage of sustainable development, which allows generating new theories as is currently the circular economy but is in the beginning of these processes.

8.5 Conclusions

Analyzing the processes of innovation in the circular economy in hotel companies in Jalisco, Mexico, we can confirm that it is a fundamental issue because of the level of consumption that humanity currently makes, which is not sustainable. This type of company is a model to measure the care of the environment, since the provision of services they perform, has an impact on the nature of different areas.

The objective that was proposed was the innovation processes in the circular economy of hotel companies in the state of Jalisco, which is a way to attract guests by taking care of the environment and using smart energy, having as a result that hotel companies have practices to take care of nature, with the use of biodegradable, organic goods, consume products.

Keeley et al. [2] established that innovation consists among other aspects of the vision of generating added cost of products; Derived from this it was found that both traditional hotel establishments offer elements of environmental care through the circular economy as a value-added product, to attract tourists.

The traditional hotels at 100% promote public transport or shared car, use environmentally friendly products such as biodegradable, ecological, and organic in different percentages and the whole apply recycling strategies.

Both the companies that belong to the platform and the traditional hotels seek to increase the impact of innovation, through the development and integration of technology and the scaling of disruptive business models, through collaborative work in four areas such as waste, energy, mobility, and water.

In this research, only 7% of traditional hotels use solar panels, which is a low statistic for the power generation category. In terms of certifications, the traditional hotel industry does have them, basically focused on the care of nature. Both traditional and platform-based hotel companies are at the beginning of the circular economy, but there is a lot of technology and innovation that can continue to be implemented to make these processes possible.

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CHAPTER 9

Embracing Digital Transformation in the Indian Travel and Tourism Industry

Smruti Rekha Sahoo

9.1 Introduction

Technology has played a revolutionary role in positioning our country as one of the top countries making the most advancement digitally in recent times. The Government of India is taking many initiatives to push the digital India scheme relentlessly. The digital transformation has widened India's possibility of innovation in every aspect and optimizing resources currently being pursued across sectors. Digital transformation is helping to simplify processes, making different services more effective and convenient for the end-users. Data and technology are coming together to accelerate change and address the criticality of harnessing data to optimize decision-making.

Gone are the days when one used to depend on a travel agent while planning a family vacation or work tour. Also, people used to stand in

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S. Estrada (ed.), *Digital and Sustainable Transformations in a Post-COVID World*, https://doi.org/10.1007/978-3-031-16677-8_9

long queues to book their railway or flight tickets. Mobile integration and online travel agencies have made this task easier and play a bigger role in customizing the user experience. Now, one can easily book a railway or an airline ticket online within seconds with just a click. The OTAs (Online Travel Aggregators) are playing a bigger role in providing customized services keeping the customer's different needs in mind.

In this era of digitalization, the rampant penetration of smartphones, easy access to the internet, and technology-driven tools and platforms have acted as catalysts for the speedy digitalization of the travel and tourism industry and have transformed the travel consumption pattern of the end-user. Companies associated with the hospitality industry are embracing technology to transform themselves into experience platforms while automating operations.

The prevailing scenario of COVID-19 has been a blessing in disguise where digitalization is at the forefront to make things contactless to prevent infection. Amid all our focus and efforts in staying safe, we missed the celebration, being with friends, spending time with extended family, and most importantly, traveling. Even though most countries have opened their boundaries to welcome tourists, it is not without limitations or restrictions. Taking valuable lessons from the pandemic, the travel and tourism industry needs to imbibe and take measures to ensure that they meet the evolving needs of the tourists. Fear of getting infected with COVID-19 and social distancing continue to haunt and remain barriers to return to normalcy.

9.1.1 Relevance of the Study

The era of traditional travel agencies and agents is almost over. Digitalization has never been so important, especially during these trying times of COVID-19, where the infection is spread through contact. The travel and tourism industry is one of the worst-hit sectors during this pandemic and in order to cope with the loss and survival, adapting to digital techniques and other latest technology is imperative. Thus, the study is significant, keeping the present scenario in mind to provide meaningful insights into the topic.

9.2 Review of Literature

Harting et al. [1] conducted an empirical study in Germany based on a theoretical foundation to discover how far digitalization has already changed the tourism industry and its potential benefits. The results showed that six main drivers, i.e., sales increase, classic booking, sharing economy, personalized offers, social media, and customer reviews, significantly impact the potential of digitization in the tourism industry. Panagiota [2] conducted a study to examine the impact of technology on the sector, and for this purpose, a mixed approach was used, with questionnaires and interviews with hotel guests and managers, respectively. The research findings revealed that booking systems, social media, and online reviews allowed better interaction between tourist businesses and consumers to facilitate marketing and greater exposure on behalf of the business. Purohit [3] studied the importance of digital marketing in the tourism industry and concluded that travel remained one of the most popular online interests and that digital technology has an increasingly profound impact on the tourism industry. A review was done by Kumar and Shekhar [4], where a link was established between the use of technology and the development of rural tourism. The study also provided a summary of how technology has evolved rural tourism. Zsarnoczk's [5] study concluded that the rapid development of ICT solutions brought immense changes in the tourism industry, and the traditional decision-making processes were gradually replaced with personalized offers, further increasing the importance of artificial intelligence. Hojeghan and Esfangareh [6] studied how the digital economy affects the tourism industry through internet and web technologies. Issues involved in improving the measurement of the digital economy were also outlined.

9.2.1 Objectives of the Study

The specific objectives of the study are:

- To study how digitalization has penetrated the Indian travel and tourism industry.
- To study the customers' perception of digitalization in the sector
- To study the customers' satisfaction level with the digitalization of the sector.

9.3 Research Methodology

This paper is an exploratory study based on both primary and secondary data. The secondary data has been collected from sources like research articles, journals, books, bulletins, periodicals, reports, and the internet. The primary data was collected by the online survey through detailed questionnaire and the respondents were selected randomly. The information gathered has been analyzed and interpreted to arrive at a fruitful conclusion.

9.4 Analysis and Discussion

Travel is essentially about connecting people and places. The use of digital tools, i.e., the internet and technology, has added value significantly to an entire travel experience. The COVID-19 virus has been a big blow to the travel and tourism industry, and the sector needs to take necessary steps for its survival and revival. Efforts must be made to find new ways to make travel contactless as far as practicable to regain the travelers' confidence and ensure that it is safe to travel again.

Moreover, tourism businesses need to keep up with the latest trends to gain a competitive advantage over rivals. It also helps in providing a better customer experience and promoting customer loyalty. Some of the measures that could be taken are:

9.4.1 Mobility Experiences

From digital check-in to using one's mobile phone as a room key, travelers, in many cases, expect a contactless digital experience that can be activated from customers' devices. Many reputed hotels are using retina and fingerprint scanning to unlock hotel rooms. Such measures improve customer experiences by eliminating the need to hold a key card or physical, both of which stand a chance of getting lost or stolen.

9.4.2 Bots and Robots

One of the most interesting digital trends in recent times is the increased use of artificial intelligence bots. Guests can use their Amazon Alexa, Google Home, or Apple's Siri to make common service requests. Chatbots can deliver replies to common and simple questions 24×7, resulting in better customer service and satisfaction.

9.4.3 Smart Kiosks

The way we acquainted ourselves with touchscreen, we again have to shift to touchless experiences. Existing touchscreen kiosks could be modified to be operated in a touchless manner.

9.4.4 Contactless Transactions

As we learn to live with COVID-19, it is important to change the payment options to digital mode to avoid contact while using it. Due to the pandemic, most people have learned to make payments digitally, thus, acting as a blessing in disguise. Some people have become conditioned to contactless experiences in a short period, choosing them more over physical transactions and interactions.

In order to know the impact of digitalization on travel enthusiasts, a study was conducted through an online survey where the respondents were selected randomly, belonging to different age groups, i.e., 21–40, 41–60, and above 60 years of age. The entire travel process was segregated into five major parts: Planning, Booking, Journey, Destination, and Experience. Several close-ended questions were asked on how digitalization has impacted their travel, and the responses were recorded. A total of 133 responses were received out of which 9 were found invalid. The total responses were received in the age group of 21–40, 41–60, and more than 61 in 72, 34, and 18, respectively. The figures are shown in the table, and the digitalization trend of travel patterns in different age groups is shown in Table 9.1.

From the above Table 9.1 and Fig. 9.1, it is clear that respondents in the age group of 21–40 use the digital way in their entire travel pattern. Travel planning is usually done using voice search, social media, or review sites that give more information about a particular destination. Similarly, booking is made online due to the user-friendly interface, discounts, and

Table 9.1 Digitalization trend in travel pattern

Age Group → Sequence	21–40 Total = 72	41–60 34	>60 18
Planning ↓	61	16	4
Booking	65	19	0
Journey	63	21	3
Destination	48	14	0
Sharing Experiences	59	18	1

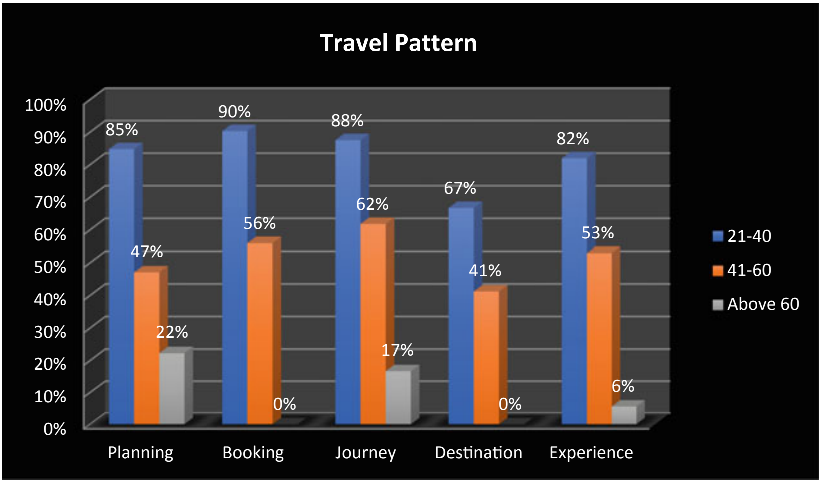

Fig. 9.1 Digitalization trend in travel pattern (*Source* Primary data)

attractive offers. People using E-tickets and digital boarding pass help save time instead of standing in long queues at the counters. However, when it comes to destination, people in the age group of 21–40 prefer to explore the destination rather than using digital media for ease. Sharing experiences on different portals through photos, blogs, and vlogs are very common in this age group, enabling others to know about that particular destination.

The respondents in the age group of 41–60 years provided mixed responses to the questions asked. Usually, they follow the traditional travel pattern since they are skeptical about the digital medium and more concerned about security issues. Respondents in the age group above 60 travel based on recommendations of their family and near and dear ones and also follow the traditional travel pattern.

9.4.5 Suggestions

Several factors contribute to the changing face of travel, namely, travel portals and websites, online discounts and promotional deals, 24×7 online assistance, and secure payment options. Organizations in the travel and tourism industry have no choice other than to invest in digital transformation. Technology has penetrated every area of tourism and needs to be given the highest priority. It is also important that digitalization is done keeping in mind the tourists' needs, preferences, and interests to provide them with a unique experience and gain customer loyalty. Managers and employees working in this field must be trained to take care of the varying needs of a customer.

9.5 Conclusion

There is no denying that digital transformation has already created a massive disruption in the tourism industry. In order to keep ahead, it is important to adapt to the latest trends to offer the best-personalized experience. Embracing technology will fuel the digital revolution in the tourism industry while automating operations. Making travel contactless will instill confidence in tourists' minds, assuring them that it is safe to travel and explore again. The damage due to COVID-19 cannot be undone; however, the valuable lessons learned should be taken forward, and efforts must be made toward creative digital business models that will reshape travel's future again. Coordinated efforts of government and industry will help transform Indian destinations into world-class attractions.

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CHAPTER 10

Challenges for the Digital Transformation of Ecuador's Tourism Industry: Perceptions of Leaders in Times of Covid-19

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10.1 Background

Digital technology has strongly impacted the tourism industry since the 1990s. This impact has meant changes in the information and communication process to evolve the tourist experience and create value for stakeholders [1]. New business models in tourism have been guided by trends such as e-commerce, digital marketing, virtual and augmented reality, or

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S. Estrada (ed.), *Digital and Sustainable Transformations in a Post-COVID World*, https://doi.org/10.1007/978-3-031-16677-8_10

new collaborative digital platforms [2]. These models demanded more and more skills and capacities from organizations to attend to the new requirements of tourists in a digital world [3]. Digital technology, which is increasingly changing through digital innovation, leads tourism in a revolutionized way. Thus, nowadays, tourism companies have the challenge to integrate the technological infrastructure, human talent, and qualities of their environment to reach their digital transformation (DT) [4].

Parallel to the technological change, the tourism industry has been facing challenges caused by the Covid-19. This unexpected situation caused the industry to leverage digital technology more strongly to survive and enhance its offer. Some tourism organizations have taken advantage of the potential of digital technology, promoting the destinations virtually and creating an expectation in tourists until the pandemic situation would be over [5]. This situation required greater adaptation, resilience, and new forms of management [6].

In this context, some Governments are becoming interested in the development of the digital environment of their country. Nonetheless, there are still some limitations that inhibit DT in the tourism industry. According to the World Economic Forum and World Tourism Organization [7, 8], several Latin American countries could present obstacles to adapt technologically their tourism industry to new situations because the region has presented low indexes of digital readiness [9]. For instance, Ecuador exhibits below-average rates of tourism competitiveness, especially in its technological infrastructure and digital skills, which could slow down its DT. Additionally, the Covid-19 crisis brought new challenges for the industry that would mean a driver to accelerate its transformation [10].

Beyond the current conjectural problems evidenced in the industry, tourism organizations face an intricate process. The DT is a complex phenomenon that encompasses various theoretical and practical approaches [11, 12]. Likewise, organizations tend to technological determinism [13]. This could impede the integration of human and technological factors needed for DT. So, despite the trajectory of digital technology in the tourism industry, organizations still face particular challenges of the digital age that lead them to generate common actions to respond to the tourism ecosystem [14].

The purpose of this study is twofold: (1) On the one hand, we will analyze, through the theoretical lenses of the organizing vision (OV), what is the perception of the DT in the leaders of the Ecuadorian tourism industry. The OV is a discursive construction, a common idea that legitimizes a technology or phenomenon [15], and its approach will allow us to know how the idea of DT is constructed in this context. (2) On the other hand, we aim to identify the challenges for the DT of the industry by following the neo-institutional isomorphism statements. This will make it possible to identify the challenges as forces that influence tourism organizations to gain legitimacy in society [16].

10.2 Theoretical Framework

10.2.1 The Organizing Vision

The OV is "a focal community idea for the application of information technologies in organizations" [17]. The interpretation, legitimation, and mobilization of an idea as good organizational practice, are the axis of OVs [15]. The OV allows evidence if a technological phenomenon is recognized by an organization and the meanings that emerge in a social group. These meanings can take place before, during, or after their implementation along with the organizational practices and changes that emerge in response to the phenomenon.

The OV is a constructivist notion. The social construction of technology proposes the interaction of social factors with technological ones as one, as a social-technological ensemble [18]. In this interaction, the OV is socially constructed by the discourses that emerge as buzzwords, terminologies that acquire various interpretations and meanings in the digital innovation environment [19]. In addition, decisions in organizations around technology are influenced by the VOs that legitimize practices through influences and perceptions of actors in a context [20].

Since DT is a technological phenomenon that has gained interest in today's digital economy, the study of the OV will allow us to know the notion that the selected tourist social group has regarding it.

10.2.2 Neo-Institutional Isomorphic Pressures

The neo-institutional theory is a theory focused on social construction. It points out that decisions in organizations could be guided by forces other than rational or economic ones to obtain legitimacy. DiMaggio and Powell [16], argue how organizations coexist with external and internal forces that tend to be homogeneous in the practices and structures of companies to gain legitimacy. This would lead organizations to adopt similar decisions and become more and more similar to their competitors in the same domain of activity, what they call institutional isomorphism. These forces can be:

- Coercive pressures: related to formal and informal conditions that exert pressure from the political, legal, or regulatory aspects. Governments or other related institutions impose or enforce regulations forming a common legal environment. Likewise, they impose penalties or sanctions that force organizations to acquire practices that tend to standardize the industry. Actions related to economic or structural issues managed by the government can also be considered [16].
- Mimetic pressures: organizational behavior tends to imitate the practices of their peers to gain legitimacy with the stakeholders. That is, they tend to imitate other companies, meet customer requirements and please new trends in society, balancing their values and beliefs. These forces are also related to decisions regarding the use of new technologies [21].
- Normative pressures: these refer to issues related to professionalization in industries such as the knowledge acquired by employees, specialization, standardization, training, and professional networks, which establishes and normalizes conditions and methodologies in organizational practice [22].

The isomorphic pressures have been used in some research in the tourism context [23]. In this study, the isomorphic pressures that emerge as challenges of DT will be identified. We consider challenges as weaknesses or barriers that inhibit or affect the development of DT [24].

10.2.3 The Digital Transformation in Tourism

DT is a continuous and complex process where technological, organizational factors and relationships with the environment are managed to take advantage of digital technology. It is a process that aims at the benefit and interests of the organization and its stakeholders, within a changing digital context [12, 25]. As mentioned above, digital technology has made some processes (i.e. reservation, communication between actors, multimedia management, information analysis) more efficient through new virtual scenarios in tourism [1]. Thus, tourism organizations are managing different areas to face the current digital trends focused on tourist well-being and new organizational objectives [4].

The organizational adaptation to digital technology gives way to DT. In tourism, the DT pursues the construction of smart cities to connect multiple destinations, actors, and communities around the world through dynamic digital platforms, connected artifacts, artificial intelligence, and big data. For this, digital skills and change management are needed to handle new requirements, new tourists, and a huge flow of information. This integration of human and technological factors allows to support decision-making in the organizations and exploit digital technology to personalize the tourism offer [26–28]. Efforts of DT have been evidenced in some tourist organizations such as hotels [29, 30], museums [31], or other destinations [32, 33]. In these cases, the tourist requirements, the employees' skills, and the process of digitalization have been managed. The DT in tourism has been also evidenced in sustainability projects [34, 35], and rural tourism [36].

Around the DT, some weaknesses have been identified in tourism organizations. The industry has evidenced the need to strengthen collaborative efforts to create new digital business models [37] and improve the technological infrastructure on a national scale [38]. Likewise, some factors that need to be reinforced are digital skills, digital and resilient leadership [39], and a digital strategy integrated into the new tourist demands [31].

At a global level, challenges have been identified in DT related to the budget issue [29], resistance to change, lack of vision in organizations and lack of collaboration between stakeholders [39], monopolization of tourism infrastructure [13], weak political intervention [40], disarticulation of public policy [41], digital gaps, Internet connectivity problems [42] and weak domestic and foreign database management [43]. Nonetheless, the challenges vary according to the context where the DT is developed. Every industry and its context could identify new challenges.

10.3 Methodology

Through a qualitative and interpretative methodological approach, we aim to understand the perceptions around the DT and its challenges in the Ecuadorian tourism industry. This industry encompasses the set of organizations that offer services throughout the tourist chain such as food and beverages, accommodation, tourist operation and intermediation, community tourism centers, entertainment, and tourist transport [44]. The research questions of the study are:

(a) What is the OV of the DT in the tourist industry of Ecuador?
(b) What are the isomorphic pressures that are presented as challenges for the DT of the Ecuadorian tourism industry?

Semi-structured interviews with a phenomenological design were carried out to understand the meanings from the perception of the participants [45]. Interviewees were contacted via email and their participation was voluntary via Zoom. Leaders of public and private associations and institutions immersed in the tourism industry were integrated such as representatives of the Ministry of Tourism, provincial tourism chambers, tourism departments of local municipalities that represent a joint vision of the tourism industry. Likewise, leaders who manage the professional career of tourism and leaders of tourism businesses related to accommodation and tourism operations were included. Fourteen interviews were conducted until a saturation point was reached [46]. At the request of some interviewees, their anonymity has been maintained in the study.

The interview was designed as an open conversation regarding practices of the industry in response to the digital age. Only at the end of each interview, the term of the DT was introduced, asking them if they believed that the industry is transforming digitally. This approach was followed to avoid ambiguous responses regarding DT, which is a relatively recent topic in the Ecuadorian tourism context and most leaders are not digital experts. To generate empathy toward the interviewees, the interview also addressed topics about the experience of leaders in the Covid-19 crisis. The digital age was explained to the interviewees as the new digital scenarios of mobile applications, social networks, digital marketing, big data, digital platforms, smart cities, and artificial intelligence, which are tendencies in tourism. Likewise, the conversation focused on identifying situations that could be representing difficulties for organizations in this digital age. The interviews were conducted from May to August 2021, with an average time of 50 minutes.

The interviews were recorded, transcribed, and coded through NVIVO 11. A structural coding was applied that allowed us to identify sentences and paragraphs as the unit of analysis. The phrases related to "how the industry responds to the digital age" and the leader's opinion regarding DT of the industry were coded to analyze their perceptions. The phrases related to coercive, mimetic, and normative pressures were coded to analyze the challenges of DT. The coded verbatim allowed us to conduct a thematic analysis through the identified items and recognize the topics that represent each category [47]. The codes assigned to each interviewee are shown in Table 10.1. Every idea expressed by each interviewee was considered of equal importance for the analysis. The analysis of the codified ideas has allowed us to understand how the topic of DT is perceived in the industry and the challenges that this phenomenon entails. This is shown in the following sections.

Table 10.1 Interview codes

Tourism organization	*Interviewee's position*	*Code*
Public	Director	E1
Public	Director	E2
Public	General Manager	E3
Public	Director	E4
Public	Director	E5
Private	President	E6
Private	General Manager	E7
Private	President	E8
Public	Tourism area leader	E9
Private	Director	E10
Public	Director	E11
Private	President	E12
Private	President	E13
Public	Tourism area leader	E14

Source The Authors (2021)

10.4 Results

10.4.1 Organizing Vision of Digital Transformation in the Tourism Industry of Ecuador

The leaders' perception gives us a representation of what DT is and how it is reached, who is the principal actor in DT of the industry, what the digital technologies in this process are, and what its scope in organizations is. Figure 10.1 indicates a mental map that summarizes the codified ideas. The original words expressed by the interviewees were used to build the OV of DT in the Ecuadorian tourism industry.

The leaders interviewed gave their perceptions of how the tourism industry is responding to the digital age and whether they believe it is digitally transforming. The speeches of the leaders repeatedly showed their approach to the digitalization of the industry, for example, "when we talk about digital transformation, that is, we mutate this physical world to carry out all its processes in the usual way to a digital way" [E5]. The leaders reinforce that the digital age is linked to the generation of data and how to manage it for decision-making: "this new technology is also associated with obtaining data that is tremendously important" [E6].

Digital technology is the tool to respond to this digital age. The application of various digital technologies is necessary for organizations. The most mentioned were the social networks and collaborative platforms: "There is a Facebook, an Instagram, so they are things that we have to integrate [...] It is an investment to have a web page and always be with technology" [E13].

Likewise, responding to the digital age is to generate comparative advantages at a global level: "We have to provide comparative advantages, we have to be at a global level because they have to know us at a global level, this is through digitalization, digital marketing, payment processes digital and others" [E1]. Organizations need to transform themselves to have a digital presence: "if you are not on Facebook, on Instagram, on Google, selling your product, selling your service, you are nothing" [E9].

The industry might be updated to new digital trends because "the digital ecosystem is ready" [E7]. "Jetti is an application that many of the Esmeraldean businesses have applied precisely because the young people of the new age, the millennials, and the centennials, use it" [E13]. The transformation is built to develop trust in a more demanding tourist, "the digital economy is equal to trust, no one can forget that. Why? Because all these elements such as the blockchain, currencies like bitcoin,

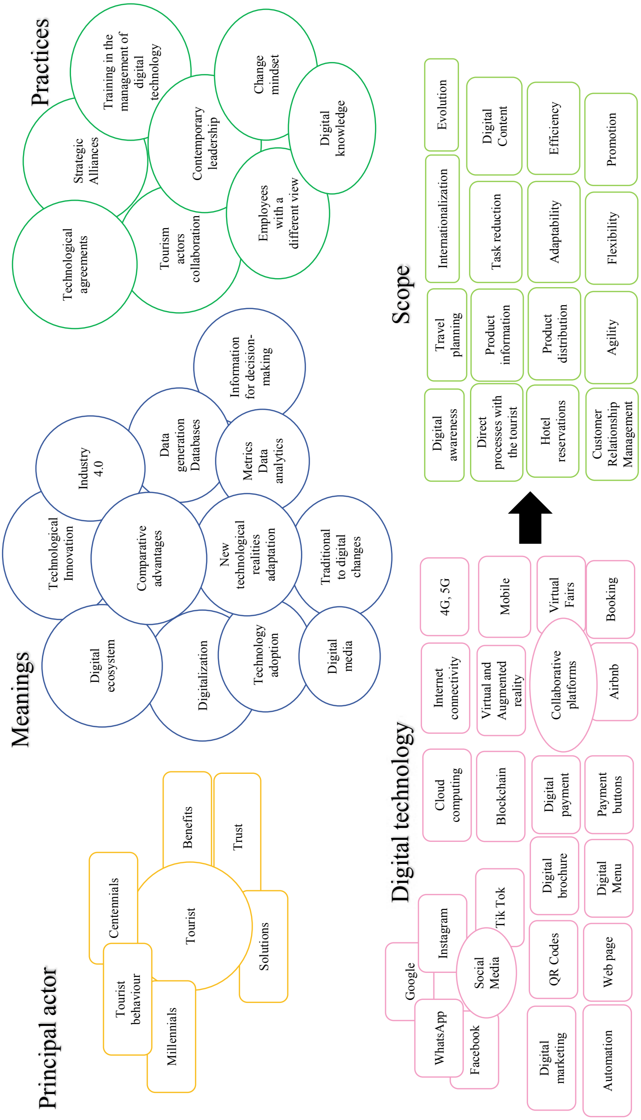

Fig. 10.1 The organizing vision of DT in the tourism industry of Ecuador (*Source* Authors, 2021)

and all of this are built on the development of trust" [...] "through technology, digitalization, providing solutions, benefits and making life easier for tourists" [E1]. In the same way, the transformation responds to a more informed tourist, "now every tourist in the world knows his destination through an application" [E14].

Organizations need to have more trained employees with digital knowledge, "within their groups of employees, companies must have people who have a different vision, totally ambiguous to reality. When I say ambiguous, they think differently, act differently, generate different things" [E7]. The digital age requires a more interrelated collaboration between industry players: "we must face these new challenges and the important training of the private company together with the academy" [E8].

Organizations are transformed to create a direct relationship with tourists, "now if we cannot show them an attraction directly and personally, we can from the technological side. It is no longer necessary to have a computer, a laptop, we already do it through a telephone" [E11], "the Ecuadorian tourist buys alternatively with various mechanisms, one of these is WhatsApp, transfers or payment links that he executes for a direct reservation" [E7]. The digital age makes organizations look for efficiency and improvements in their offer, "the technological part provides more information on products and tourist destinations, gives a greater comparison of the offer between products on the market, in addition, the reduction of time and costs with the purchase of certain elements" [E11].

The interviewed leaders argue that DT is a process of the digital ecosystem, part of the technological innovation of industry 4.0. A process that generates comparative advantages through digitalization and the adoption of technology, concerning digital media. Also, it allows adaptation to new technological realities, a change from the traditional to the digital, where the generation of data and the management of information are central actions that support decision-making in tourism organizations and provide benefits to new tourist.

10.4.2 Challenges for Digital Transformation in the Tourism Industry of Ecuador

Several verbatims were identified within each isomorphic pressure. The verbatim allowed a thematic analysis that highlights the main challenges of the industry for DT. This is shown in Fig. 10.2.

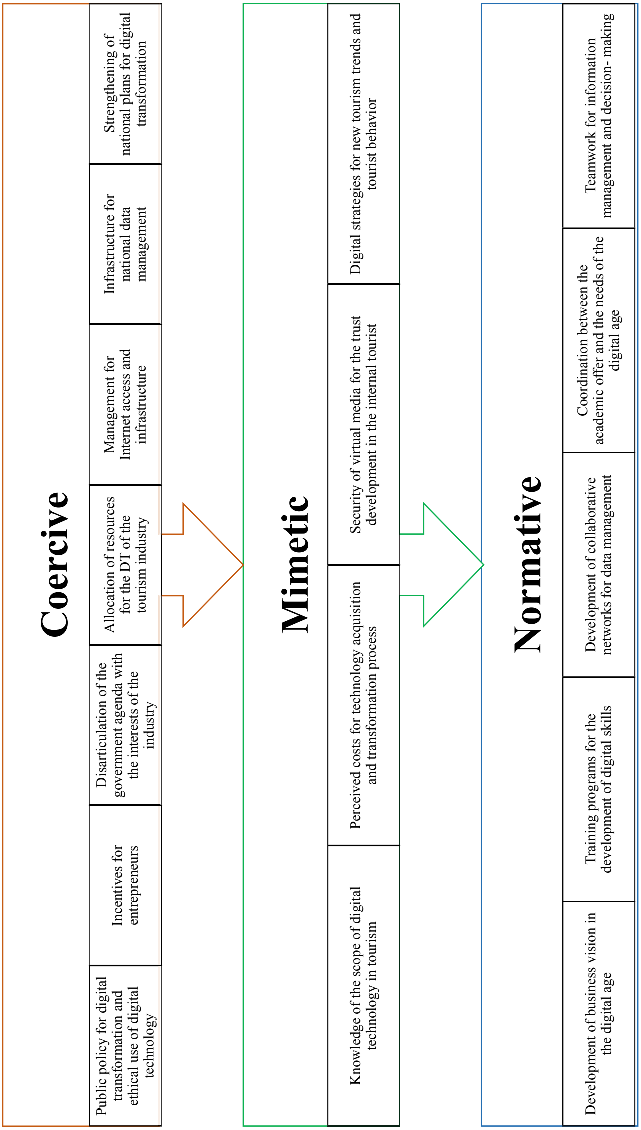

Fig. 10.2 Isomorphic challenges for DT in the tourism industry of Ecuador (*Source* Authors, 2021)

Leaders shared various insights, most of them focused on topics regarding normative and coercive pressures. The perceptions regarding the mimetic ones were the least mentioned by the leaders. For example, regarding coercive pressures, there were perceptions regarding Internet connectivity problems that some communities present, “the main barrier we have is that many communities do not have access to the Internet, they are really very far away” [E14]. There were also perceptions regarding poor data management at the national level. It was expressed that “the Ecuadorian State has been very selfish in that it does not understand tourism, it has been very selfish in handling this data that is not available to investors” [E6]. Another point identified was regarding the weaknesses in public policy for the ethical use of digital platforms: “it is one of the things that is affecting us. I invite you to see on Facebook, on Instagram, ghost operators…they don’t need to be regularized, they don’t pay taxes, they don’t pay employees, they don’t pay rent, they don’t pay fees to the municipality” [E12].

Regarding mimetic pressures, several leaders perceive a minimal benefit from technologies such as virtual fairs, since the relationship with the client is difficult: “This communication helps, but it is not effective. I have participated in virtual fairs where I have not been able to achieve anything productive” [E6]. Likewise, the Ecuadorian market still presents resistance due to the issue of security: “Ecuadorians have a certain fear of buying online, that the products do not reach us, that there is some fraud when we put our credit card on some web page” [E2].

Finally, regarding the normative pressures, a lack of vision on the part of the businessmen of the industry was pointed: “the problem really is to change the mentality in the subject of this transformation, in the innovation and digitalization of the tourist ecosystems” [E10]. Likewise, there is a need for digital preparation and development of digital skills: “we need that tourism entrepreneurs know about social media, data and big data management […] they can do SEO or SEM analysis, from the information that is based on the market” [E5].

10.5 Discussion

The DT is a process that is taking space in the organizations of the tourist industry of Ecuador. Based on the three axes of the OV [15], the interpretation of the DT is around a process of adaptation to the new realities and digital requirements that the industry face. The perceptions issued by the leaders and the activities related to the DT show that there is a legitimacy of the process as a necessary practice for tourism organizations. This need might be enhanced by the resilience that the tourism sector has had in the financial crisis caused by Covid-19. Regarding the mobilization, the challenges identified show that more actions are required so that the government, business forces, and the national tourism market are involved in support of the DT of tourism in Ecuador. However, there is a perception that actions must be coordinated in the short term.

According to what is highlighted in [39], the leaders participating in this study are aware that the transformation process requires the management of human talent and contemporary leadership. In addition, it requires a different vision, a change mentality, and digital knowledge to achieve the benefits of digital technology in tourism and promote collaboration between actors to develop alliances in the sector.

Some challenges identified in this study coincide with those identified in the literature. There are coercive challenges such as the need for an articulated public policy for DT and the allocation of financial resources [40, 41], the lack of infrastructure management for Internet connectivity [42], and weaknesses in national data management [43].

Normative challenges such as a lack of a budget in organizations [29], a weak vision at the business level [39], and the need for collaborative networks [37], were also evidenced. Finally, mimetic challenges stand out around the lack of evidence of the scope of digital technology for the benefit of companies based on its cost–benefit. This DT challenge has been identified at the level of various industries [48].

According to the results achieved in this study in a pandemic context, the Ecuadorian tourism industry presents the challenges reported by the Spanish tourism sector five years ago [49]. Mainly, normative challenges related to the lack of strategic vision and lack of human talent and knowledge of digital skills. Also, coercive challenges such as regulatory uncertainty and structural deficiencies with information and communication technologies; and, mimetic challenges such as the lack of knowledge of benefits and advantages of digitization in tourism entrepreneurs, and financing difficulties due to the cost of technologies.

10.5.1 Reflections

This study aimed to analyze the perceptions of leaders of the tourism industry regarding the DT and challenges of this technological phenomenon. For this, we based on constructivist theories such as organizing vision and neo-institutional isomorphism, respectively.

Based on the results, we can highlight that DT is recognized by leaders as a necessary response to the new requirements of the digital society and a process that forms comparative advantages. The main challenges point to the fact that the Ecuadorian tourism industry needs collaborative work between government institutions and companies. Likewise, the industry needs to manage the technological infrastructure to develop digital strategies and skills in the tourism sector.

This study has theoretical and practical implications. Regarding the theoretical, the constructivist approach in DT has been exposed. The organizing vision and isomorphic pressures highlight a technological phenomenon integrated into an organizational and contextual reality. Regarding practical implications, the challenges identified warn the actions that the tourism industry authorities should consider in an Ecuadorian context to respond adequately to digital requirements and face critical scenarios due to the pandemic.

This study was carried out in the context of the Covid-19 pandemic that keeps the tourism sector in a financial crisis. Representatives from all provinces of Ecuador or all tourist activities could not be covered. The topic of DT has been of interest to the leaders during the interviews, however, this interest could be attributed to the evident need to apply digital technology to develop new strategies and cover new requirements of the current context. Future studies are required to compare the perceptions and challenges around DT according to tourist activity.

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PART V

Digital and Sustainable Entrepreneurship and Business Models

CHAPTER 11

Innovation and Digital Transformation as a Competitive Strategy in University Entrepreneurship in Victoria de Durango, Dgo., Mexico

Mayela del Rayo Lechuga-Nevárez

11.1 Introduction

In a globalized world and constant change due to the accelerated advance of information and communication technologies, it is essential that enterprises must be created and projected to global scenarios, with the aim to improve their capabilities and returns resulting from the competitive advantages acquired in the process [1]. In this context, innovation and digital transformation in enterprises have become an imminent necessity for the sustainability of businesses in the face of the new normal caused by the Covid-19 pandemic [2].

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S. Estrada (ed.), *Digital and Sustainable Transformations in a Post-COVID World*, https://doi.org/10.1007/978-3-031-16677-8_11

Digital transformation makes use of technology and is aimed at improving the performance and objectives of companies; this makes it a strategy to generate a cultural change. Hence, some authors point out that transformation is the sum of innovation and change management [3].

Digital transformation is a cultural phenomenon that cannot be ignored by entrepreneurs; this transformation goes beyond the use of digital platforms and the use of technologies; it is about defining the business from a different point of view, and to achieve it requires innovation and changing the way entrepreneurs think and manage. Entrepreneurial initiatives constantly change depending on the strategies proposed to maintain their position in the market, improve it, and survive; in this way, the transformation is a factor that adds value to business [4].

The development of new technological solutions affects the operability of enterprises where entrepreneurs recognize the importance of incorporating them into their management, recognizing their importance, making them necessary to transform the way business operates. To the above can be added the thinking of [5] those who assert that businesses are obliged to continuously look for new ways to add value to their businesses and offer value to their customers through the use of digital media situation that invites the approach of a digital transformation [2].

With this, Innovation, Digital Transformation in University Entrepreneurship in the face of the new normal product of social distancing caused by the COVID-19 pandemic today has been a fundamental part of its permanence in such a competitive market. Faced with a business environment of changes, a cultural evolution, the latest events in recent months, and the impact on University Entrepreneurship, this research arises whose research objective is to analyze innovation and digital transformation in University Entrepreneurship in Victoria de Durango, Dgo., Mexico.

Digital transformation is the integral implementation of digital tools to different resources, processes, products, services, and assets to improve efficiency and generate more value for the customer [6]. The development of new technological solutions affects several areas where the leaders of organizations recognize the need and possibility of truly transforming the fundamentals of the way they do business through the continuous planning of specialized strategies. To the above can be added the thinking of Kotler and Armstrong [7], who affirm that commercial firms are obliged to continuously look for new ways to add value to their businesses and offer value to their customers using digital media situation that invites the approach of a digital transformation.

11.2 Literature Review

11.2.1 Innovation, Digital Transformation, and University Entrepreneurship

Entrepreneurship is a global process present in all countries, which has developed since the existence of man, who has explored and worked to always to provide a livelihood, and given its relevance, as well as that of the entrepreneur and companies in the economy. It is necessary to analyze entrepreneurship under a multidimensional lens [8]. In this sense, entrepreneurship is the ability that people have to create innovative ideas and make them tangible; it involves creating or transforming a product or service. In something more attractive and with greater competitive advantages; it also includes, in some cases, the planning and management of projects in order to achieve objectives [9].

For Shane and Venkataraman [10], entrepreneurship is a process of discovery, evaluation, and exploitation of opportunities that involve starting a new business offering a product or service to consumers. The entrepreneur, on the other hand, is the person who discovers, evaluates, and exploits this opportunity.

University Entrepreneurship is the discipline with the capacity for generation, transformation, and application of knowledge, for the renewal of resources and contexts, through the creation of entrepreneurial initiatives, it is a transformative element in a society demanding changes with a representation of a significant social and economic well-being in a context of organizational evolution [10]. For this, university entrepreneurship requires not only the individual characteristics of the person (personality, attitudes, and aptitudes) but also involves technical or specific skills such as knowledge, experience in a specific sector and instrumental or transversal skills such as leadership, ability to work in a team, negotiation skills, respect for diversity, ability to search for information, decision-making capacity, among others. Therefore, entrepreneurship implies proposing a clear objective, having an initiative [11].

In this line, university entrepreneurship is characterized by the capacity for innovation in its processes and activities, that is, breaking with the traditional way of doing things, proposing a product or services that provide added value, and breaks with the established routines [12]. Entrepreneurship and innovation represent substantial processes of economic activity, which are born from the need to meet a market requirement [13].

The entrepreneurial and innovation capacity of entrepreneurs allows us to bring the technological-digital mentality to the entrepreneurial world of the communities and society where the ventures are located. Digital transformation begins when entrepreneurs incorporate technologies and include it in the value chain allowing the affinity of the physical and the virtual [14].

Digital transformation is presented as the most important challenge for the competitiveness of countries and an opportunity for social and economic development for all entrepreneurial initiatives in Mexico. Digital transformation leads businesses and the community where they are located to a culture of innovation and permanent reinvention, growth, and development focused on the final consumer, a reduction of geographical and cultural barriers, an opening to the companies to the global digital ecosystem, becoming a competitive advantage in the face of social distancing caused by the COVID-19 pandemic [11].

Schumpeter's ideas [15] about entrepreneurship and innovation as part of the Digital transformations are adjusted in a context of disruptive ideas in the line of taking risks in conditions of uncertainty. This effort is aimed at the social, economic, and cultural transformation of society as a source of productivity and competitiveness where families benefit from the income generated from the jobs created and enterprises access the factors of production under reasonable conditions [16].

In the business field, small economic units stand out as the engine of the economy. The concept can be understood as micro, small, and medium enterprises that represent 70% of employment worldwide are preponderated most in economies with incomes low and medium–low [17]. As a result of population growth, it is estimated that developing economies will need to generate 600 million jobs by 2030 to provide job opportunities for the population and, in turn, indicates that the labor force will be oriented toward jobs in the service sector, which today represent 26% in low- and middle-income countries. and 75% in developed countries [18]. This allows us to infer that these organizations today represent a backbone in the dynamism of the economy, but at the same time, it shows the great challenges to responding to future requirements [19] even, called to transform and glimpse opportunities outside their national borders.

Digital transformation involves properly conceiving the new rules of the business world and having the ability to adapt to a market that is changing. Constantly providing innovative and original solutions in both products and services. In this cultural change in innovation, it is not about changing or automating a process; it is about putting people, customers, and consumers as a central part of the business, using all the resources, including technologies, to provide with better products and services. In this line, university entrepreneurs have had to adapt to these new models and challenges, where the new normal has tested the capacities of adaptation and anticipate the needs of the consumer that are constantly changing and permanent form [11].

Digital transformation is, therefore, the redefinition of an organization or a company through the use of technologies to improve how it organizes its operation and manages the tasks to be performed, produces, and distributes the products or services to customers or society in general. In the case of traditional companies, digital transformation focuses on the process in which some digital components are added to the usual products or services that modify the nature of those products and services by adding better performance to them through connectivity with other products or services or a certain degree of intelligence [15].

Digital transformation is based on information and instant connectivity beyond the frictions of space and borders. Limits unfold both toward the micro decoding information beyond the nano (genomics), and toward the most distant (think of exoplanets). Digital transformation impacts the economy like a Tornado [20] by enabling the consolidation of hyper-connected, near-real-time global processes and markets.

Digital transformation is the set of electronic tools which allow the continuous improvement of an established process, generating a benefit to the intervened area; it is also seen as an opportunity to identify new opportunities for improvement that facilitate the development of activities. All is to achieve a short-term or medium-term goal [21].

11.3 Materials and Methods

It began with the literature review to contextualize the research topic. In this case, the problem revolves around the objective of the research to analyze innovation and digital transformation in University Entrepreneurship in the face of the new normal in the city of Victoria de Durango, Dgo., Mexico. So, the information that was collected is related to the variables of Innovation, Digital Transformation, and University Entrepreneurship; this is shown in Table 11.1.

The research approach is quantitative. The study design is descriptive, explanatory, and; non-experimental, correlational, since there was no manipulation of variables. Cross-sectional scope, since the research was carried out in a single period, time, from January to March 2021 [22].

11.3.1 Sample

We worked on a population of 125 companies created by university entrepreneurs. To determine the sample, the finite population formula was used with a confidence level of 95% and an estimation error limit of 5%, obtaining a total of 95 companies. Non-probabilistic sampling was used for convenience, for the ease it offers to create samples according to the ease of access, and the availability of people to be part of the sample [22]. In this case due to the conditions of social distancing caused by the health contingency due to COVID-19.

Table 11.1 Variables and factors of the research variables

Variables	*Factors*
University Entrepreneurship	Search for opportunities Commitment Ethics Taking risk Setting goals Resilience Creativity Persistence Independence Entrepreneurial training
Innovation	Innovative culture Products and services Processes organization Marketing Efficiency and effectiveness
Digital Transformation	Digital culture Digital leadership Human relation_clients Business_online

Source Own elaboration based on the literature review (2021)

11.3.2 Survey Design

The instrument was designed based on each of the factors considered to analyze the variables of Innovation, Digital Transformation, and University Entrepreneurship. The questionnaire consisted of 110 questions under the Likert scale, 50 related to University Entrepreneurship, 30 to Innovation and, 30 to Digital Transformation. A form was created in *Google form* and applied virtually due to the sanitary conditions of social distancing resulting from the COVID-19 pandemic. The instrument was validated using the technique of expert judgment [23] made up of 6 experts in the field, two academics, two entrepreneurs, and two collaborators of government instances: the reliability of 0.960 of Cronbach's Alpha coefficient. SPSS V.25 was used for data analysis.

11.4 Results

In this part, the results are shown, checked, and corroborated with the theoretical visions and empirical evidence of studies carried out under different contexts. Regarding the sociodemographic characteristics of the entrepreneurs analyzed, 49% are women, while 51% are men. The average age is 34 years. Marital status indicates that 33% are single while 64% are married and 2% belong to another marital status. 100% are professionals, that is, they have a university degree. 13% have a postgraduate degree. As for the socioeconomic level, 93% belong to an average level.

The results are shown, checked, and corroborated with the theoretical visions and empirical evidence of studies carried out under different contexts. Regarding the sociodemographic characteristics of the entrepreneurs analyzed, 49% are women, while 51% are men. The average age is 34 years. Marital status indicates that 33% are single while 64% are married and 2% belong to another marital status. 100% are professionals, that is, they have a university degree. 13% have a postgraduate degree. As for the socioeconomic level, 93% belong to an average level.

The characteristics of the enterprises investigated, 97% are micro, that is, they have less than ten employees; as for the productive sector, it was found that 60.5% belong to the service sector, that is, they are companies that provide a service to the community, such as advisory and consulting firms in various areas, tourism companies, training companies; 9.9% to the industrial sector where the main activity is the production of goods through the transformation and, or extraction of raw materials, among which are butchers, dairies, food businesses and 29.6% to the commercial sector, mentioning that a venture can belong to more than one sector, 74% are full-time entrepreneurs, that is, fully dedicated to their business. 61% are consolidated ventures, and 71% were created with their income.

The results obtained from the descriptive statistics are shown, and the findings found are explained through the correlations of the variables and factors used in this research using the Pearson test. The descriptive statistics from the point of view of Hernández Sampiere and Mendoza [24], allow us to know the objects of study of the research. In this way, the variables University Entrepreneurship, Innovation, and Digital Transformation present those corresponding to mean, standard deviation, variance, range, minimums, and maximums with each factor used for their analysis.

Table 11.2 shows the descriptive results of the variable University Entrepreneurship with its analysis factors: Opportunities, commitment, Ethics, Taking risks, Set goals, Resilience, Creativity, Persistence, Independence, and Training in entrepreneurship; each of them is characteristics of entrepreneurs.

Table 11.3 shows the factors that were considered to analyze the Innovation variable: Innovative Culture, Innovation in products and services, Innovation in processes, Innovation the organization, Innovation in marketing, Innovation in Efficiency and effectiveness, such as part of the innovator process of entrepreneurship. Table 11.4 shows the factors to

Table 11.2 Descriptive statistics of the variable University Entrepreneurship

University Entrepreneurship	*N*	*Rank*	*Minimal*	*Maximum*	*Mean*	*Standard deviation*	*Variance*
Opportunities	95	2	3	5	4.58	0.428	0.183
Commitment	95	2	3	5	4.44	0.468	0.219
Ethics	95	2	3	5	4.74	0.344	0.119
Run_risk	95	2	3	5	4.01	0.510	0.260
Fix_goals	95	3	2	5	4.24	0.664	0.441
Resilience	95	2	3	5	4.50	0.453	0.205
Creativity	95	2	3	5	4.07	0.643	0.413
Persistence	95	2	3	5	3.88	0.496	0.246
Independence	95	2	3	5	4.06	0.470	0.221
Training_Em	95	4	1	5	3.53	0.966	0.932
N Valid (per list)	95						

Source Own elaboration based on survey data (2021)

Table 11.3 Descriptive statistics of the Innovation variable

Innovation	*N*	*Rank*	*Minimal*	*Maximum*	*Mean*	*Standard deviation*	*Variance*
Innov_Culture	5	2	3	5	4.00	0.404	0.163
Innovation_Products_Services	5	4	1	5	3.82	0.816	0.667
Innov_Processes	5	4	1	5	3.29	1.200	1.441
Innov_Organizationn	5	4	1	5	3.27	1.202	1.444
Innov_Marketing	5	4	1	5	3.39	1.199	1.439
Innov_Efficiency and Effectiveness	5	3	2	5	4.07	0.570	0.325
N valid (per list)	5						

Source Own elaboration based on survey data (2021)

Table 11.4 Descriptive statistics of the Digital Transformation variable

Digital Transformation	*N*	*Rank*	*Minimal*	*Maximum*	*Mean*	*Standard deviation*	*Variance*
Culture_Digital	95	4	1	5	3.44	1.169	1.367
Leadership_Digital	95	4	1	5	3.52	1.115	1.242
Resource_Human_Dig	95	4	1	5	4.32	0.897	0.805
Relation_Clients	95	4	1	5	3.25	1.220	1.489
Business_Online	95	4	1	5	3.25	1.270	1.614
N valid (per list)	95						

Source Own elaboration based on the survey data (2021)

study the Digital Transformation variable: Digital Culture, Digital Leadership, Human Resources with knowledge in the digital area, Customer Relations, and Online Business.

11.4.1 Correlations of Research Variables and Factors Used for Their Study

Table 11.5 shows the association of the factors used to analyze the variable of University Entrepreneurship. Observing an association, statistically significant (bilateral sig. less than 0.05), with the dependent variable University Entrepreneurship, which fulfills the assumption of linearity positive between each factor.

Table 11.5 Correlations of the variable University Entrepreneurship and the factors used for its study

		University Entrepreneurship	*Opportunities*	*Commitment*	*Ethics*	*Run_risk*	*Fix_goals*
University Entrepreneurship	Pearson (r)	1	0.653**	0.550**	0.643**	0.442**	0.716**
	Sig.bilateral		0.000	0.000	0.000	0.000	0.000
	N	95	95	95	95	95	95
Opportunities	Pearson (r)	0.653**	1	0.486**	0.411**	0.274**	0.577**
	Sig. bilateral	0.000		0.000	0.000	0.007	0.000
	N	95	5	95	95	95	95
Commitment	Pearson (r)	0.550**	0.486**	1	0.297**	0.090	0.389**
	Sig. bilateral	0.000	0.000		0.003	0.387	0.000
	N	95	95	95	95	95	95
Ethics	Pearson(r)	0.643**	0.411**	0.297**	1	0.337**	0.382**
	Sig. bilateral	0.000	0.000	0.003		0.001	0.000
	N	95	95	95	95	95	95
Run_risk	Pearson (r)	0.442**	0.274**	0.090	0.337**	1	0.301**
	Sig. bilateral	0.000	0.007	0.387	0.001		0.003
	N	95	95	95	95	95	95
Fix_goals	Pearson (r)	0.716**	0.577**	0.389**	0.382**	0.301**	1
	Sig. bilateral	0.000	0.000	0.000	0.000	0.003	
	N	95	95	95	95	95	95
Resilience	Pearson (r)	0.732**	0.441**	0.290**	0.568**	0.219*	0.458**
	Sig. bilateral	0.000	0.000	0.004	0.000	0.033	0.000
	N	95	95	95	95	95	95
Creativity	Pearson (r)	0.749**	0.390**	0.358**	0.425**	0.251*	0.458**
	Sig. bilateral	0.000	0.000	0.000	0.000	0.014	0.000
	N	95	95	95	95	95	95
Persistence	Pearson (r)	0.422**	0.041	0.079	0.362**	0.266**	0.115
	Sig. bilateral	0.000	0.690	0.447	0.000	0.009	0.266
	N	95	95	95	95	95	95
Independence	Pearson (r)	0.584**	0.433**	0.240*	0.291**	0.307**	0.350**
	Sig. bilateral	0.000	0.000	0.019	0.004	0.003	0.001
	N	95	95	95	95	95	95
Training_Em	Pearson (r)	0.549**	0.157	0.220*	0.189	−0.073	0.261*
	Sig. bilateral	0.000	0.130	0.032	0.066	0.481	0.011
	N	95	95	95	95	95	95

		Resilience	*Creativity*	*Persistence*	*Independence*	*Training_Em*
University Entrepreneurship	Pearson (r)	0.732**	0.749**	0.422**	0.584**	0.549**
	Sig.bilateral	0.000	0.000	0.000	0.000	0.000
	N	95	95	95	95	95
Opportunities	Pearson (r)	0.441**	0.390**	0.041	0.433**	0.157
	Sig. bilateral	0.00	0.000	0.690	0.000	0.130
	N	95	95	95	95	95
Commitment	Pearson (r)	0.290**	0.358**	0.079	0.240*	0.220*
	Sig. bilateral	0.004	0.000	0.447	0.019	0.032
	N	95	95	95	95	95
Ethics	Pearson(r)	0.568**	0.425**	0.362**	0.291**	0.189
	Sig. bilateral	0.000	0.000	0.000	0.004	0.066
	N	95	95	95	95	95
Run_risk	Pearson (r)	0.219*	0.251*	0.266**	0.307**	−0.073
	Sig. bilateral	0.033	0.014	0.009	0.003	0.481
	N	95	95	95	95	95
Fix_goals	Pearson (r)	0.458**	0.458**	0.115	0.350**	0.261*
	Sig. bilateral	0.000	0.000	0.266	0.001	0.011
	N	95	95	95	95	95
Resilience	Pearson (r)	1	0.574**	0.285**	0.429**	0.317**
	Sig. bilateral		0.000	0.005	0.000	0.002
	N	95	95	95	95	95

(continued)

Table 11.5 (continued)

		Resilience	*Creativity*	*Persistence*	*Independence*	*Training_Em*
Creativity	Pearson (r)	0.574**	1	0.181	0.369**	0.396**
	Sig. bilateral	0.000		0.079	0.000	0.000
	N	95	95	95	95	95
Persistence	Pearson (r)	0.285**	0.181	1	0.359**	0.087
	Sig. bilateral	0.005	0.079		0.000	0.401
	N	95	95	95	95	95
Independence	Pearson (r)	0.429**	0.369**	0.359**	1	0.054
	Sig. bilateral	0.000	0.000	0.000		0.600
	N	95	95	95	95	95
Training_Em	Pearson (r)	0.317**	0.396**	0.087	0.054	1
	Sig. bilateral	0.002	0.000	0.401	0.600	
	N	95	95	95	95	95

**The correlation is significant at level 0.01 (bilateral)
*The correlation is significant at level 0.05 (bilateral)

Table 11.6 indicates the factors used for the analysis and their association with the Innovation variable, observing a statistically significant association (bilateral sig. less than 0.05), with the dependent variable Innovation, which fulfills the assumption of positive linearity between each one of the factors.

Table 11.7 shows the association level of the factors used to analyze the Digital Transformation variable, observing a statistically significant association (sig. bilateral less than 0.05) with the dependent variable Digital Transformation, which fulfills the assumption of positive linearity between each of the factors.

Table 11.8 shows the level of correlation between the three variables studied, University Entrepreneurship, Innovation, and Digital Transformation. Observing a strong correlation between the dependent variable University Entrepreneurship and the independent variables Innovation and Digital Transformation, they are associated, statistically significant (bilateral sig. less than 0.05), with the dependent variable University Entrepreneurship, with which it is fulfilling the assumption of positive linearity between each of the variables.

11.5 Discussion

The results shown in the descriptive statistics for the variables of the subject of the study indicate that University Entrepreneurship is significantly represented by the factors of Ethics with an average of (4.74 ± 0.3), Opportunities with an average of (4.58 ± 0.4), Resilience with an average of (4.50 ± 0.5), observing that university entrepreneurs are always looking for opportunities to grow in their business, they have a high value of Ethics and an element also of utmost importance in these times such as Resilience, where their resilient capacity allowed them to overcome the set of obstacles generated by the new normal caused by the COVID-19 pandemic. Coincides what Mukiur [26] mentioned that university entrepreneurship requires not only the individual characteristics of the person (personality, attitudes, and aptitudes) but it also involves technical or specific competencies such as knowledge, experience in a specific sector, and instrumental or transversal competencies such as leadership, ability to work in a team, negotiation skills, respect for diversity, ability to search for information, decision-making capacity, among others.

For the Innovation variable, the most significant factors were Innov_ Efficiency and Effectiveness (Efficiency and Effectiveness) with an average

Table 11.6 Correlations of the innovation variable and the factors used for its study

		Innovation	*Innov_ Culture*	*Innov_Products_ Services*	*Innov_Pr ocesses*	*Innov_Organization*	*Innov_Marketing*	*Innov_ Efficiency and Effectiveness*
Innovation	Pearson (r)	1	0.766**	0.485**	0.834**	0.897**	0.884**	0.257*
	Sig. bilateral		0.000	0.000	0.000	0.000	0.000	0.012
	N	95	95	95	95	95	95	95
Innov_ Culture	Pearson (r)	0.766**	1	0.449**	0.581**	0.619**	0.530**	0.369**
	Sig. bilateral	0.000		0.000	0.000	0.000	0.000	0.000
	N	95	95	95	95	95	95	95
Innova cion_Pr oducts_Service s	Pearson (r)	0.485**	0.449**	1	0.239*	0.283**	0.216*	0.090
	Sig. bilateral	0.000	0.000		0.020	0.005	0.035	0.387
	N	95	95	95	95	95	95	95
Innov_Processes	Pearson (r)	0.834**	0.581**	0.239*	1	0.671**	0.696**	0.097
	Sig. bilateral	0.000	0.000	0.020		0.000	0.000	0.348
	N	95	95	95	95	95	95	95
Innov_ Organi zation	Pearson (r)	0.897**	0.619**	0.283**	0.671**	1	0.890**	0.041

		Innovation	*Innov_ Culture*	*Innov_Products_ Services*	*Innov_Pr ocesses*	*Innov_Organization*	*Innov_Marketing*	*Innov_ Efficiency and Effectiveness*
	Sig. bilateral	0.000	0.000	0.005	0.000		0.000	0.097
	N	95	95	95	95	95	95	95
	Pearson (*r*)	0.884**	0.530**	0.216*	0.696**	0.890**	1	0.055
	Sig. bilateal	0.000	0.000	0.035	0.000	0.000		0.095
	N	95	95	95	95	95	95	95
Innov_ Efficieny and Effectiveness	Pearson (*r*)	0.257*	0.369**	0.090	0.097	0.041	0.055	1
	Sig. bilateral	0.012	0.000	0.387	0.348	0.697	0.595	
	N	95	95	95	95	95	95	95

**The correlation is significant at level 0.01 (bilateral)
*The correlation is significant at level 0.05 (bilateral)
Source own elaboration based on survey data (2021)

Table 11.7 Correlations of the Variable Digital Transformation and the bold factors for its study

		Transfor mation_Digital	*Culture_ Digital*	*Resource_Human_Dig*	*Leadership_Digital*	*Relation_ Clients*	*Business_Online*
Transformation_Digital	Pearson (r)	1	0.915**	0.620**	0.906**	0.857**	0.840**
	Sig. bilateral		0.000	0.000	0.000	0.000	0.000
	N	95	95	95	95	95	95
Culture_Digital	Pearson (r)	0.915**	1	0.517**	0.875**	0.852**	0.731**
	Sig. bilateral	0.000		0.000	0.000	0.000	0.000
	N	95	95	95	95	95	95
Resource_Human_Dig	Pearson (r)	0.620**	0.517**	1	0.537**	0.494**	0.415**
	Sig. bilateral	0.000	0.000		0.000	0.000	0.000
	N	95	95	95	95	95	95
Leadership_Digital	Pearson (r)	0.906**	0.875**	0.537**	1	0.828**	0.696**
	Sig. bilateral	0.000	0.000	0.000		0.000	0.000
	N	95	95	95	95	95	95
Relation_ Clients	Pearson (r)	0.857**	0.852**	0.494**	0.828**	1	0.673**
	Sig. bilateral	0.000	0.000	0.000	0.000		0.000
	N	95	95	95	95	95	95

		Transfor mation_Digital	*Culture_ Digital*	*Resource_Human_Dig*	*Leadership_Digital*	*Relation_ Clients*	*Business_Online*
Business_O nline	Pearson (*r*)	0.840**	0.731**	0.415**	0.696**	0.673**	1
	Sig. bilateral	0.000	0.000	0.000	0.000	0.000	
	N	95	95	95	95	95	95

**The correlation is significant at level 0.01 (bilateral)
Source own elaboration based on the survey data (2021)

Table 11.8 Correlation of the variables University Entrepreneurship, Innovation, and Digital Transformation

		University Entrepreneurship	*Innovation*	*Transformation_Digital*
University Entrepreneurship	Pearson (*r*)	1	0.718**	0.645**
	Sig. bilateral		0.000	0.000
	N	95	95	95
Innovation	Pearson (*r*)	0.718**	1	0.893**
	Sig. bilateral	0.000		0.000
	N	95	95	95
Transformation_ Digital	Pearson (*r*)	0.645**	0.893**	1
	Sig. bilateral	0.000	0.000	
	N	95	95	95

**The correlation is significant at level 0.01 (bilateral)
Source own elaboration based on survey data (2021)

of (4.07 ± 0.6), Innov_Culture (Cultural innovation) with an average of (4.00 ± 0.4) e Innov_Products_Services (Innovation in products and services) with an average of (3.82 ± 0.8), in this case, it is observed that entrepreneurs with the incorporation of Innovation into their businesses sought to make their production processes efficient and effective and innovate in the development of products and services, and this has led to cultural evolution in them in terms of innovation, coinciding with the position of Kuratko [14], who mentions that university entrepreneurship is characterized by the capacity for innovation in its processes and activities, that is, breaking with the traditional way of doing things, proposes a product or services that provide added value, and that breaks with established routines and experiences a cultural change in entrepreneurs.

On the other hand, in the Variable Digital Transformation, the most significant factors for entrepreneurs were, Resource_Human_Dig (Human Resources) with an average of (4.32 ± 0.9), then Leadership_Digital (Digital leadership) with an average of (3.52 ± 1.1), and Culture_Digital (Digital Culture) with an average of (3.44 ± 1.2), showing the importance of employees and the entrepreneur himself being able to carry out the Process of Digital Transformation in entrepreneurship, the importance that digital leadership can have on the part of business owners and as a consequence a cultural transformation in the context of the entrepreneurship itself and the community in where they are located. Is consistent with what was explained by Guerra, Torres, Sumba, and Cuevas (2021), who assert that businesses are obliged to continuously look for new ways to add value to their businesses and offer value to their customers through the use of digital media situation that invites the approach of a digital transformation.

11.5.1 Correlations

The results of the correlations show the level of correlation between the three variables studied, University Entrepreneurship, Innovation and Digital Transformation. Observing a strong correlation between the dependent variable University Entrepreneurship and the independent variables Innovation and Digital Transformation, they are statistically significantly associated (bilateral sig. less than 0.05), with the dependent variable University Entrepreneurship, which fulfills the assumption of positive linearity between each of the variables, as well as each of its factors. This shows in the study the congruence between the actions of entrepreneurs in their businesses based on the cultural evolution brought about in a certain way by the events that have arisen in recent months, which made them innovate and digitally transform their ventures as a competitive strategy in the face of the demands of the new normal, with this impacting socially and economically. Entrepreneurship, innovation, and digital transformation represent substantial processes of economic activity, which are born from the need to meet a market requirement [5].

11.6 Conclusions

The results of the analysis of Innovation and Digital Transformation show an impact on University Entrepreneurship in the face of the new normal generated by social distancing due to the COVID-19 pandemic, where Innovation and Digital Transformation implemented by the entrepreneurs allowed them to remain in the market and establish competitive advantage with similar businesses.

The integration of technology in various areas of the ventures gave life and permanence to the businesses, allowing them to provide quality customer service in all senses, increase efficiency, effectiveness and productivity in the operation of their processes, improved customer satisfaction and employees as a fundamental part of the business. Innovation and Digital Transformation impact on all productive sectors, that is, they are not exclusive to certain sectors, giving them a new impetus and changing business models, as was the case with the university ventures analyzed.

In this same line, the study allowed to know that Innovation and Digital Transformation not only allowed entrepreneurs to provide a better service and sell produce a better product for their customers but also the identification and use of new business opportunities and this, in turn, will be some of the driving forces of digital transformation and business innovation in difficult times with a context in unfavorable conditions for the development of entrepreneurial initiatives, but with the vision and innovative and digital culture of entrepreneurs managed to make this health contingency an area of opportunity for remain and in some cases consolidate as a company.

On the other hand, some of the ventures analyzed showed digital maturity, that is, it was possible to identify a level of adoption and implementation of technologies within the company, and as a consequence a continuous improvement quantitatively and qualitatively in the operation of the business impacting on the results of the company, manifesting an awareness of the importance of Innovation and Digital Transformation, reflecting entrepreneurs a commitment in the establishment of business objectives, training for employees, interest in investing, and a digital leadership that allows them to continue in this arduous work to develop, consolidate, and sustain their entrepreneurship in the face of the demands of the new normal product of the COVID-19 pandemic.

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CHAPTER 12

ICTs, Media, and Social Networks Use Indicators in Micro, Small, and Medium-Sized Companies: An Overview in the Context of the COVID-19 Pandemic in Mexico

Luis Alfonzo Zea Jiménez

12.1 Introduction

Although the global crisis caused by the COVID-19 pandemic differs from other crises [1], it affected various sectors of society and, to varying degrees, economic activities. At the macro level, new models have adjusted generated to cope with financial instability [2]; at the micro-level, the firm's business models have adjusted to improve the chances of future success [3] and due to the permanence in households, habits, and

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S. Estrada (ed.), *Digital and Sustainable Transformations in a Post-COVID World*, https://doi.org/10.1007/978-3-031-16677-8_12

social behavior changed and the consumption of digital services [4]. For their part, government bodies implemented actions that, based on social distancing, generated positive and negative economic impacts [5]. The pandemic affected regions on all continents, widening the social inequality gap, leading to socio-economic reactivation, and forcing companies to seek survival (MSME[1]) [6].

The widespread use of social media worldwide influenced the perception and coping of the COVID-19 pandemic. Thus, social media became relevant regarding interaction with government information, as in the case of *Twitter* [7]. In contrast, a negative phenomenon of misinformation was also generated [8–11], which presents an opportunity for health authorities and government agencies to generate strategies to improve their mechanisms and procedures for informing society through these channels of interaction [12].

Analyses and studies on *microblogging* platforms have been critical in determining the spatial transmission mode in China's cities of the COVID-19 pandemic outbreak; thus, these tools may help generate effective procedures for prevention strategies in urban areas spaces [13]. Seeking data information through Internet platforms served:

(a) As a form of surveillance to monitor the spread and development of infectious diseases [14, 15]
(b) To measure public attention to health emergencies [16]
(c) To conduct impact studies on the spread of panic behaviors and disinformation flows in the Middle East, as well as on the acquisition of information on COVID-19 through digital social media [17–22]
(d) To study the use of indices to search for information on digital social media to predict the number of COVID-19 cases in potential high-risk infection areas [23].

The promotion, development, and use of ICT tools in almost all sectors of society led to mobile smart devices in all human activities.

[1] In this research, the term MSMEs includes micro, small, and medium-sized enterprises. Although, the aforementioned reference studies speak of small and medium-sized enterprises (SMEs).

Consequently, ICTs took a leading role in emergency and pandemic situations such as COVID-19. Due to confinement, work activities in companies were affected and demanded changes in organizational management's forms and processes as an adaptation to the new spaces for remote teleworking [24]. The crisis generated by the pandemic affected various sectors undergoing accelerated digital transformation through ICTs; therefore, reliable indicators will be necessary to understand the impact of the intensive use of digital platforms in organizations. Similarly, MSMEs require indicators that measure the use and impact of ICTs and more knowledge of their information resources to generate entrepreneurial projects that boost their organizational capacities in decision-making.

The epidemic has generated challenges and opportunities to accelerate the digital transformation that will impact the economy and society. Thus, ICT adoption has great potential to drive the digital economy as an innovation engine and inclusive growth [25]. Despite the growing trend in connectivity infrastructure coverage, gaps persist in access and use by businesses [26]. However, there is a growth in Internet use that favors the generation of technological entrepreneurship by creating applications on digital media platforms and social networks.

Due to confinements and health restrictions in the wake of the COVID-19 pandemic, traffic indicators for digital platforms for remote work increased, impacting the consumption of digital resources among firms. In the previous year, of OECD firms with more than ten employees, a quarter had e-commerce sales operations, a third of firms used cloud services, and more than half had a social media presence [27]. On the other hand, although digital technologies improve productivity and performance in small and medium-sized enterprises, studies show that there are still data gaps in understanding the effects of the pandemic on small and medium-sized enterprises. One of these gaps is the management of using digital technologies to face the effects of COVID-19 to ensure business continuity [28]. The digital transformation of organizations during confinement allowed them to move toward digital consolidation, which gives them a higher degree of maturity as they tend to be more flexible; this is observed in small companies with local reach as it allows them to explore options with new business models quickly [29].

SMEs need to implement strategies that encourage digital technologies, develop financing strategies to promote the creation of technology-based start-ups, and strengthen the actors in the digital technology ecosystem. Thus, 70% of OECD companies use the Internet for their supply chain; in Latin America, only 37% do so. One effect of the COVID-19 pandemic was that between March and April 2020, the presence of companies on the Internet increased by 800% on websites in Mexico and Colombia [30]. Therefore, it is essential to understand the indicators of ICT and social media use on the Internet to obtain valuable information to drive a productive digital transformation in MSMEs.

The boom using mobile media and social networks and new business models generated new data related to ICT adoption and the creation of technological ventures. There has been a 68% year-on-year growth in geolocation applications on mobile devices since 2013 [25]. This trend increased in 2020 due to the confinement by the COVID-19 pandemic [26]. There was also a growth in the adoption of social media and social networking platform applications for communication and remote teleworking communication in Mexico and Latin America [30].

A general guide in Latin America for the interpretation of statistical information and for the generation of ICT-based indicators, whose purpose is to understand the evolution and transition toward the information society, and a framed methodological tool has been developed to carry out analyses through measurements, called the Lisbon Manual [31]. This manual is a reference that measures diverse areas of ICT as government and public institutions, communication, and interaction in social practices. It also emphasizes the importance of understanding the impact and performance of business organizations. Consequently, the manual is interested in the use and effects of ICTs in organizations based on the services they offer and supports, the measurement of coverage capacities of infrastructure, and the dispersion of services in social and business sectors.

The Lisbon Manual[2] [31] presents guidelines and recommendations for instruments for measuring the information and knowledge-based society in Ibero-American countries. Chapter 4 provides a guide of indicators for measuring ICT access and use in companies, and Chapter 5 offers exclusive guidelines for the high-tech sector, which generates ICT inputs for other business sectors and society in general. Taking the manual

[2] RICYT is the Ibero-American and Inter-American Network of Science and Technology Indicators (RICYT), in which all the countries of the Americas participate, together with Spain and Portugal. It emerged from a proposal of the First Ibero-American Workshop on Science and Technology Indicators, held in Argentina at the end of 1994, http://www.ricyt.org/2010/07/que-es-la-ricyt/.

mentioned above as a reference, Mexico has data collection instruments through the surveys of the National Institute of Statistics and Geography (INEGI) and the Ministry of Economy (SE), which offer some indicators regarding the use of ICTs and entrepreneurship, according to company size. The Lisbon Manual[3] has been a reference for indicators implementation in countries [32]. These have shown the degree of development and availability of infrastructure, computer equipment, software development, telecommunications lines for business use, websites, e-commerce, and public access to websites on the Internet [31]. However, there is a need to obtain disaggregated information—across channels of communication and interaction of services and products based on digital platforms on social media applications and social networks to understand their effect on enterprises.

The development and degree of adoption of ICTs occur from the beginning of the first decade of the twenty-first century in Mexico; advances are obtained thanks to the implementation of public policies related to infrastructure and financing instruments for the development of consumers and producers in the ICT sector [33]; therefore, this generates opportunities for companies toward the development of content, software, and platform applications on the Internet.

The hypothesis is that MSMEs in Mexico lack indicators about ICTs to obtain information to evaluate the use of social media and social networks that serve in decision-making for technological enterprises to create opportunities with new products and services in the face of the Covid-19 pandemic. The objective is to evaluate ICTs, media, and social network indicators in Mexican SMEs and determine if they offer information for decision-making in technological entrepreneurship projects such as creating new products or services compared to the COVID-19

[3] The countries of Ibero-America consider a general guide for interpreting statistical information and generating indicators based on ICT, whose purpose is to know the evolution and transition toward the information society, called the Lisbon Manual [31]. This manual is a reference base that measures various areas such as government and public institutions and communication and interaction in social practices; it also emphasizes the importance of understanding the impact and performance of business organizations. In this way, it is interested in the use and effects of ICTs in organizations based on the services they offer and supports the measurement of coverage capacities in the implementation of infrastructure and the dispersion of services in social and business sectors.

pandemic. After the introduction section, which presents the purpose and importance of the article, is the methodology used in the research; subsequently, the results are presented, and finally, the discussion with the conclusions is developed.

12.2 Method

This research applies a qualitative approach based on electronic documentary research to explore data sources that allow decision-makers to have information on ICT digital media and social networks. This research is transversal, as it compares specific characteristics of the different instruments that allow knowing the use of ICT digital media and social networks for technological entrepreneurship projects. This documentary research applies the technique of searching, reviewing, selecting, compiling, and analyzing primary data sources based on surveys conducted by statistical analysis institutions in Mexico to interpret them and draw conclusions.

12.3 Results

12.3.1 Boosting Entrepreneurship Activities

Several financial support programs have been developed to promote the growth and sustainability of technological enterprises in MSMEs [34–36]. Thus, in 2013 the National Entrepreneur Institute (INADEM), a decentralized administrative body of the Secretary of Economy, was created to support business entrepreneurship. However, the conditions of the ecosystem for entrepreneurship in Latin America currently present a declining scenery. In Mexico, INADEM was closed in 2019, and the National Entrepreneur Fund underwent adjustments after the change of government in 2018 [37]. It reveals that support for MSMEs through these public policy instruments is essential, as it encourages growth through companies with new business ventures in the economy.

Microenterprises require financing for their entrepreneurial projects at various stages of growth. For this reason, it is essential to know what type of federal government institutional program supports these projects with financial resources. The National Survey on Productivity and Competitiveness of Micro, Small, and Medium-sized Enterprises (ENAPROCE) disaggregates data by firm size, providing operating characteristics based on the measurement of management skills and entrepreneurship, sources of financing, global production chains, technological and innovation capabilities, business environment and its regulation, as well as knowledge of government support [38]. The financial support programs for entrepreneurship of small and micro-sized companies are relevant to the foundation in the stages of development and maturation, which is through government programs at municipal, state, and federal levels. All these sources of support contribute to generating new projects to face crisis stages, such as the one generated by the COVID-19 pandemic.

Figure 12.1 shows the microenterprises that use various federal government instruments to support projects related to entrepreneurship and thereby manage to maintain expectations of growth and survival. The survey does not contain questions that show support for entrepreneurship from non-governmental sources of financing, nor is it comprehended whether they resort to intermediaries to acquire these resources.

MSMEs require access to the benefits of government support programs; however, not all companies did not achieve it, so it is essential to know why they did not request assistance. Government support programs are the only way many organizations can access funds amid the economic downturn from the COVID-19 lockdown.

Figure 12.2 shows that SMEs do not seek support because of the lack of information regarding entrepreneurship support programs. ENAPROCE 2018 does not have a specific question to determine sources of financing for private entrepreneurship projects. For MSMEs to survive, mature, and develop as profitable businesses in a complex economic environment, indicators are required that allow public policy decision-makers and company managers to adjust, plan strategically, and face crises such as the COVID-19 pandemic.

12.3.2 ICT and Internet Use in Business

The percentage of microenterprises that used computer equipment to develop business activities is 37.45% [38]. More than one-third of the total microenterprises use computer equipment for business activities. They require ICT resources to support their operations and organizational management; however, then is essential to understand constraints

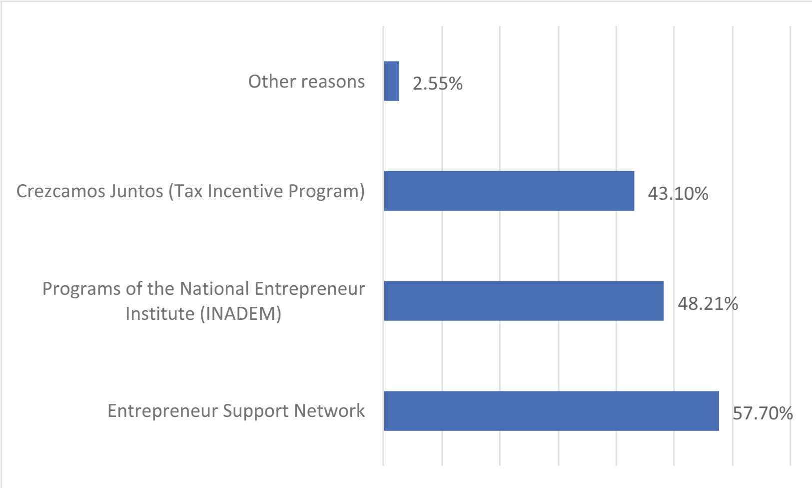

Fig. 12.1 The number of microenterprises[4] identifying one or more federal government programs for business promotion and support[5] (*Note* Adapted from the *Encuesta Nacional sobre Productividad y Competitividad de las Micro, Pequeñas y Medianas Empresas [ENAPROCE]* [38])

faced by enterprises because they are not using them. Therefore, ICTs indicators and social media platforms are necessary as an organizational management capacity to confront a changing environment. MSMEs require computer equipment, programs, business use, Internet collaboration, applications, electronic communications infrastructure, and training. In addition, a digital strategy should be harmonized with the strategic planning of an MSME, which is fundamental to strengthening the organizational management capacity under challenging environments.

Figure 12.3 shows that most microenterprises state that the main reason for not using computer equipment in developing their activities

[4] Note: For calculating the percentages of the ENAPROCE, the total sample size of the surveyed enterprises is 23,928, and 22,188 correspond to the MSEs.

[5] Note: The sum of the partial percentages does not correspond to 100% as they are percentages based on a multiple-choice question.

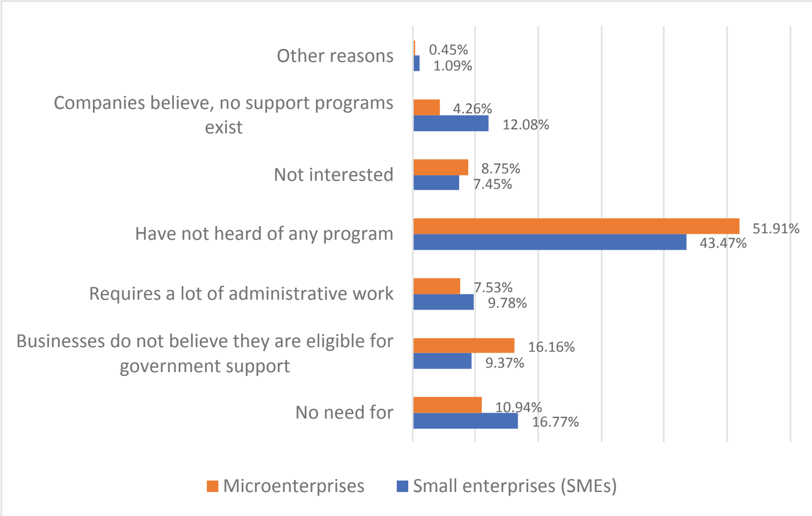

Fig. 12.2 Percentage of enterprises according to the main reason they did not apply for federal government programs (*Note* Adapted from the *Encuesta Nacional sobre Productividad y Competitividad de las Micro, Pequeñas y Medianas Empresas [ENAPROCE],* [38])

is the belief that they do not need it; a second reason is the acquisition of training resources. The following reasons relate to a lack of financial resources and interest because they do not know that it could be helpful to them. This information shows that the country's microenterprises do not use equipment due to insufficient training and unawareness of the advantages offered by investing in ICTs for strategic support in their business operations. One of the resources companies require for their communication activities is Internet service. Microenterprises that use this medium to carry out business operations account for 39.70% [38]. However, the figure shows a low value of ICT use.

Figure 12.4 shows the percentage of microenterprises according to why they do not use Internet services to develop business activities. The main reason is that they do not consider it useful for their organization; in the second place, they do not know how to use it. The exact reasons are given for not using computer equipment, requiring training to take advantage of the benefits of utilizing the Internet in their organizations.

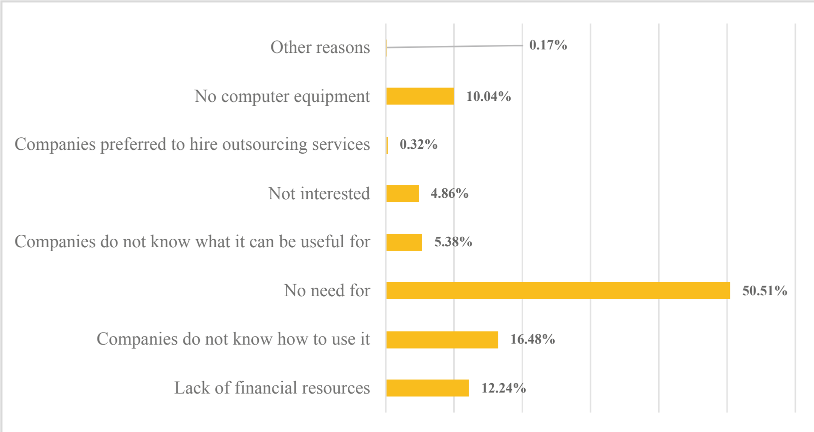

Fig. 12.3 Percentage of microenterprises according to the main reason they did not use computer equipment to develop their activities (*Note* Adapted from the *Encuesta Nacional sobre Productividad y Competitividad de las Micro, Pequeñas y Medianas Empresas [ENAPROCE]*, [38])

As a percentage of microenterprises, it is essential to know what is the primary use of these services in the business. Figure 12.5 shows that the main use in microenterprises is searching for information and administrative operations of electronic invoicing, followed by communication and contact tools for customer service, marketing, sales, and, lastly, orders to suppliers. The survey does not provide information about the use of digital media applications and social networks as a means of communication and interaction, nor as a linking channel in activities that support the organization's resource generation processes.

The use of computer equipment serves as a reference to see the degree of utilization of ICTs in SMEs to support their business activities. Figure 12.6 shows that SMEs have a higher percentage of computer equipment use than microenterprises. Therefore, it can be deduced that this type of enterprise has a greater capacity and knowledge to benefit from ICTs and use the Internet to support business processes. Understanding why MSMEs don't use computer equipment in their organizations is essential. Figure 12.7 shows that almost half of them say they

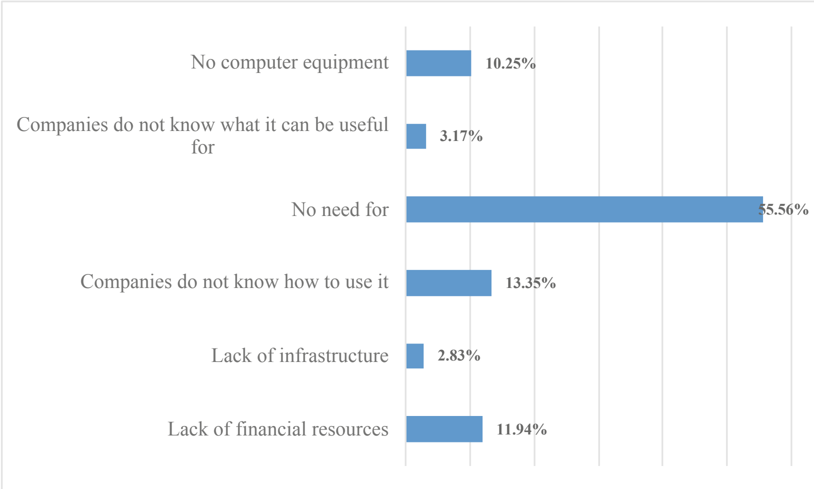

Fig. 12.4 Percentage of microenterprises according to the main reason they did not have the Internet to develop their activities (*Note* Adapted from *Encuesta Nacional sobre Productividad y Competitividad de las Micro, Pequeñas y Medianas Empresas [ENAPROCE]*, [38])

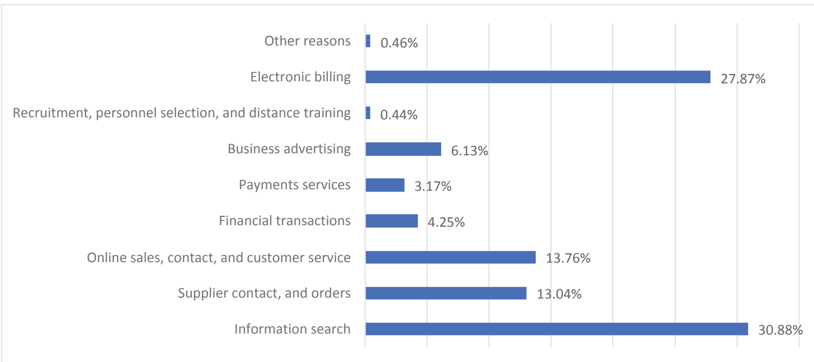

Fig. 12.5 Percentage of microenterprises according to the primary Internet use in the business (*Note* Adapted from *Encuesta Nacional sobre Productividad y Competitividad de las Micro, Pequeñas y Medianas Empresas [ENAPROCE]*, [38])

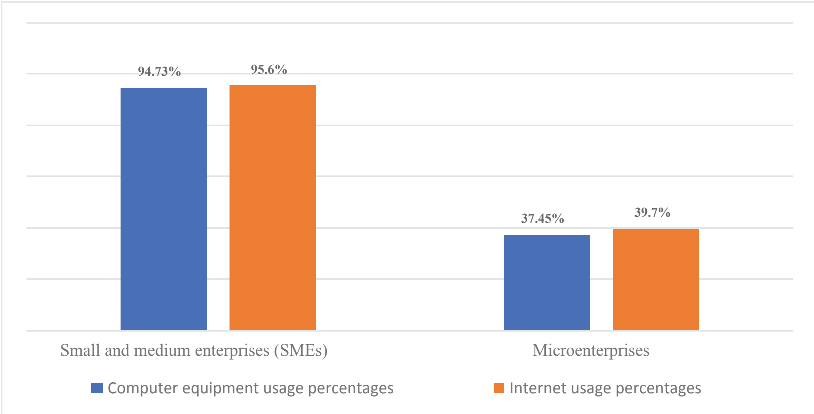

Fig. 12.6 Percentage of MSMEs that used their own, borrowed, or leased computer equipment and, in addition, used the Internet for business activities (*Note* Adapted from *Encuesta Nacional sobre Productividad y Competitividad de las Micro, Pequeñas y Medianas Empresas [ENAPROCE]*, [38])

do not need computer equipment, claim not to know how to use it, or require financial resources. The lack of knowledge about the benefits and training to take advantage of computer equipment indicates the need to improve the updating programs in the management of computer tools for companies.

Figure 12.8 shows that some MSMEs do not need Internet services, which contrasts when the service should carry out communication, interaction, and transaction activities for marketing processes, customer management, and service to suppliers in companies. However, since the COVID-19 pandemic, the communication services through the Internet have increased; therefore, the need for Internet services has changed, and disaggregated indicators are required to understand the use of social networks and management processes in companies.

Figure 12.9 shows the percentage of SMEs using the Internet according to their administrative activities for e-invoicing, online sales, and customer contact. In addition, microenterprises are using the Internet for online information searches. It is observed that the size of the enterprise influences the use of the Internet, inferring that SMEs have more knowledge, skills, and resources to make better use of the Internet in their

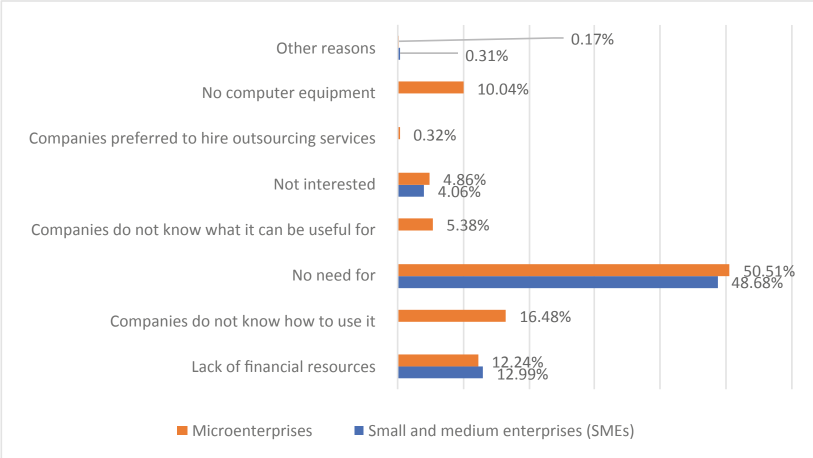

Fig. 12.7 Percentage of enterprises according to the main reason they did not use computer equipment to develop their activities (*Note* Adapted from *Encuesta Nacional sobre Productividad y Competitividad de las micro, pequeñas y medianas Empresas [ENAPROCE]*, [38])

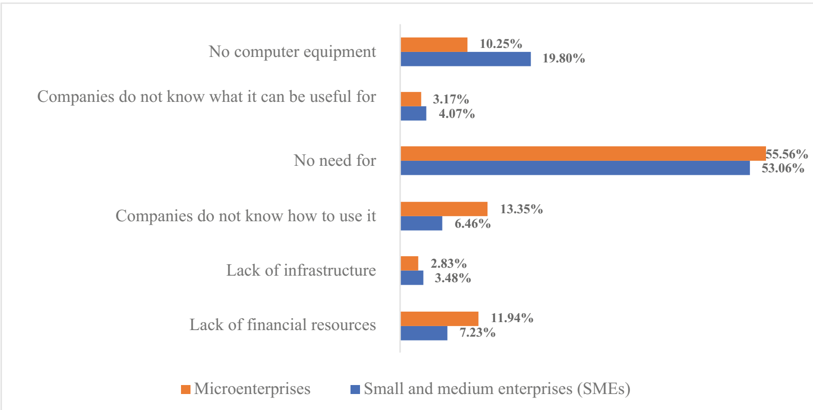

Fig. 12.8 Percentage of enterprises according to the main reason they did not use the Internet to develop their activities (*Note* Adapted from *Encuesta Nacional sobre Productividad y Competitividad de las Micro, Pequeñas y Medianas Empresas, [ENAPROCE]*, [38])

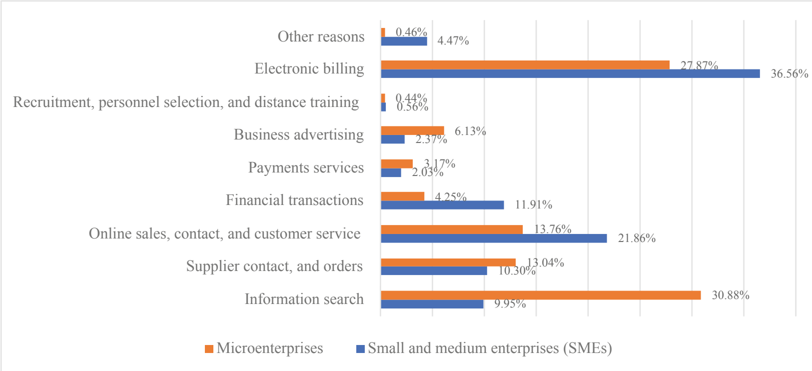

Fig. 12.9 Percentage of enterprises according to the main reason they used the Internet to develop their activities (*Note* Adapted from *Encuesta Nacional sobre Productividad y Competitividad de las Micro, Pequeñas y Medianas Empresas [ENAPROCE]*, [38])

business operations. The survey shows the primary use of the Internet, but there is no disaggregated information on business processes on which platform or type of service is used.

A subsector of ICT companies is related to activities of the software industry and innovation through computer programs in its different modalities; hence, an influential government public policy initiative was the Program for the Development of the Software Industry and Innovation (Prosoft[6]). This program had the following objectives:

- Formation of human capital with knowledge of ICT and innovation
- Generation of applied research in strategic sectors
- Generation of ICT infrastructure and innovation
- Generation of financing for companies in strategic sectors for the development and adoption of ICT and innovation.

[6] PROSOFT is the program of the Mexican Ministry of Economy for the Development of the Software Industry and Innovation. It is a public policy that promotes the ICT sector in Mexico and innovation in strategic sectors, http://prosoft.economia.gob.mx/acercade/.

Therefore, knowledge of its existence and participation in the Prosoft support program are relevant to assisting technological ventures that have already been consolidated for at least five years to promote actions that support their long-term growth. The general information is obtained from the Survey on Research and Technological Development (ESIDET), with the last update in 2017.

Figure 12.10 [39] shows information about their knowledge of the Prosoft program, which relates to the ICT sector by company size. It is observed that the companies with more knowledge about the Prosoft program are in the segment of small companies, which are the ones that show more interest in this type of support program for the ICT sector.

Intending to determine the effect of the COVID-19 pandemic on businesses, INEGI applied a new instrument in 2020 called the Survey on the Economic Impact Generated by COVID-19 on Businesses (ECOVID-IE). Then it seeks to obtain information on the economic and social effects of the contingency caused by the virus, which was applied in April and August.

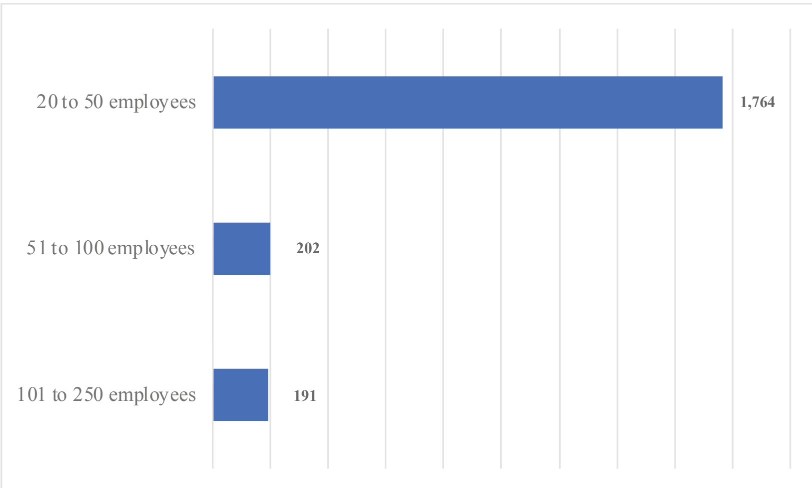

Fig. 12.10 The number of companies in the productive sector by company size knows about the Prosoft program offered by the federal government (*Note* Adapted from *Encuesta Nacional sobre Productividad y Competitividad de las Micro, Pequeñas y Medianas Empresas [ENAPROCE]*, [38])

Table 12.1 shows the health measures implemented by businesses in response to the contingency using virtual platforms and internet sales. The data show that microenterprises increased their use of digital platforms in the first months of the pandemic and then decreased their use. Although these data are dynamic, as they depend on the evolution in the control of the pandemic, it is inferred that MSMEs responded promptly by accelerating the use of digital media and platforms, showing more flexibility than large enterprises. Thus, the digital platform uses on the Internet stimulated MSMEs during the contingency; the need to generate indicators to know the effect of ICTs and details on the use of media and social networks in their organizations became evident. Consequently, microenterprises used other means of remote communication, such as digital platforms for sales, and moved meetings to virtual media. Therefore, it is important to know through indicators what platforms are on the Internet and how they are being used in MSMEs since ICT is a sector that has quickly adapted to digital communication and remote collaboration tools.

Based on the review of MSME indicators in Mexico, we detected the following findings:

- Taking as a reference the recommendations of the Lisbon Manual guide [31], no specific instrument was found in Mexico that measures through indicators such as:
  - (a) Access and use of ICTs in enterprises with segmented coverage by urban and rural areas.
  - (b) The RICYT guide of the Lisbon Manual does not consider instruments to measure the effects of ICT use in contingencies such as the COVID-19 pandemic.
- The following instruments were found with indicators that provide general information about the use of ICT in MSMEs:
  - (a) National Survey on Productivity and Competitiveness of Micro, Small, and Medium Enterprises (ENAPROCE), [38].
  - (b) Survey on Research and Technological Development (ESIDET), [39].
  - (c) Survey on the Economic Impact Generated by COVID-19 in Companies (ECOVID-IE), [40].

Table 12.1 Companies implemented health measures in response to the contingency using virtual platforms and Internet sales

Company size	*Large enterprises (%)*	*Small and medium enterprises (SMEs) (%)*	*Microenterprises (%)*
Face-to-face meetings were minimized, and communication was promoted through virtual media (April 2020)	3	13	84
Sale of goods and services online and digital platforms (April 2020)	1	8	91
Face-to-face meetings were minimized, and communication was encouraged through virtual means (August 2020)	11	38	51
Sale of goods and services online and digital platforms (August 2020)	11	42	47

Note Adapted from *Encuesta sobre el Impacto Económico Generado por COVID-19 en las Empresas, (ECOVID-IE)*, [40]

(d) No statistical survey instrument was found that measures and provides information on entrepreneurship activities in Mexico; however, the ENAPROCE survey provided incomplete information on support programs for MSMEs.

- In Mexico, there is no specific instrument that measures and offers information about digital social media and social networks in MSMEs. The ENAPROCE only considers the general use of computer equipment and the Internet as part of ICT but does not offer disaggregated information with activity details about the use and impact of social media on the business activities of MSMEs.
- The ESIDET and ENAPROCE instruments present information on the use of the Internet platform to support business or innovation activities. Therefore, using social media and networks is not contemplated as a management capability that should be harmonized with

the business strategy. ECOVID-IE 2020 survey presents an advance in indicators to know the effect of the pandemic on companies and its evolution over time. However, it does not show details on activities according to digital media and social networks.

12.4 Discussion

In Mexico, there are no indicators for ICT use in organizations that include disaggregated data on media and social networks in MSMEs; this would allow us to analyze opportunities for technological ventures through new products or services in the event of a contingency such as the COVID-19 pandemic. It is also observed that there is greater adoption of digital media and social networks due to the confinement during the pandemic; as well as the increase in the use of Internet platforms, becoming a technological asset for various sectors that require information, communication, interaction, and transaction activities to be carried out remotely.

To promote the use of the Internet, countries face the challenge of offering better communications infrastructure and sufficient bandwidth for users to cover their communication technology access requirements and carry out work, education, leisure, and social relations activities. Thus, the use of bandwidth on the Internet is essential as a right of access to technological innovation for every human being [41], even more so in the emerging situation of social distancing to face the COVID-19 pandemic. There are studies on the impact of Internet use on SMEs' online business [42, 43]; on innovation processes in firms [44]; on digital entrepreneurship [45]; on the impact of new generations on entrepreneurship [46]; on the use of digital social media in SMEs [47–49], and the capabilities of social media to support entrepreneurship and its marketing processes in SMEs [50, 51]. Therefore, it is essential for economic processes, public policy, and society in general to have indicators that support decision-making on entrepreneurship issues, as well as to understand the impact of ICT use in different business sectors and producers, for example, in the development of software and internet applications through digital social media.

In other studies, on the software industry sector in Mexico [52], the potential for regional development and growth is determined based on the search for information on its regional geographic influence and the analysis of data on participation in the national added value. These studies and indicators generally provide an overview by region and sector but do not offer disaggregated company size and age information. Other studies of the ICT industries sector related to entrepreneurship [53] present limited data on firm size and age of organizations. However, they refer to the use of digital social media by current organizations, and they do not supply indicators that provide details of processes and trends in the use of these Internet platforms and their social media and networking applications in Mexico.

Studies present a reduced view of the information on ICTs and entrepreneurship processes in MSMEs, so they are only given complementary data to the information whose main objective is to measure innovation processes. Innovation studies, albeit partially, take on relevance from their link with competitiveness processes, economic growth, and the impact on social welfare [54]. Some indicators are obtained from surveys related to the ICT sector, business processes related to federal government support, and programs to promote entrepreneurship. There are studies on the use of social media and its impact on innovation processes in companies [55–60].

12.5 Conclusions

As a result of the review and exploration of the ESIDET, ENAPROCE, and ECOVID-IE instruments, it was observed that the use of ICTs is substantially focused on administrative activities and programs to support entrepreneurship; however, there are no indicators available that scrutinize the particular use of digital media and social networks, nor the impact on the organizational management of MSMEs.

In addition, public policy and organizational management decision-makers demand reliable and accurate information with indicators that contribute to technological undertakings that strengthen their capacities and improve organizational resource management processes in business activities. For this reason, understanding the use of ICT and social networks in MSMEs is essential to expand their capabilities and improve resource regeneration processes; this, coupled with the need for digital transformation in crises such as during the COVID-19 pandemic, which affected both economic and social activities [61]. Similarly, opportunities for entrepreneurship and other communication channels to cover remote work requirements were discovered; new technological and social entrepreneurship projects emerged [62–69]; as well as new online services through social media for medical assistance and remote health monitoring.

It is inferred in this study that no specific instrument is available to obtain indicators to measure the impact of ICT and social networks in organizations. The existing survey instruments provide a general overview with partial knowledge of ICTs in MSMEs. Nor is there an instrument that measures social media use on platforms on the Internet favoring business activities in companies. On the other hand, concerning entrepreneurship, there are only indicators related to financial support programs by the federal government.

The COVID-19 pandemic accelerated the adoption of digital platforms and applications in business organizations to maintain operations, generating new teleworking schemes. Nonetheless, it also affected other sectors of society, such as health services and offering care and truthful and timely information about the pandemic. On the other hand, much digital data has been generated through ICT infrastructure and digital platforms on the Internet. However, the data has not been used for infected contact tracing; or for health control support; neither for observation and control of the community movement; nor know the communication and remote social interaction; as well as to support the design, implementation, and evaluation of new public monitoring policies for health control.

It is suggested that the instruments reviewed in this document integrate questions to obtain more information on the use of social media and understand how these processes can support business activities in organizations and the creation of new entrepreneurial projects.

The development of indicators is required to know the use of social media that they consider, based on the application of technology, based on the following typology [70]: social networking sites, bookmarks, social news, media sharing, microblogging, blogs, forums, collaborative authoring, web conferencing, geolocation-based sites, calendar and meeting, and social messaging. These indicators may help know the use of media and social networks in companies according to technology and concerning the end-user profile of the market.

The review of existing indicators of electronic sources of surveys in Mexico shows us that a more substantial number of instruments is required, and the existing ones need to be redesigned to obtain more helpful information for MSMEs. The emergence and effect of the COVID-19 pandemic in 2020 are generating changes in business models, communication forms, work process adjustments, collaboration forms, and organizational management activities. Therefore, the current indicators should be reviewed and updated to obtain relevant information in the design of public policy instruments, such as for entrepreneurs who require information on social media to improve the chances of success of their business projects based on the digital platforms.

An analysis has been presented with information that may be relevant for SMEs to generate new business models that support technological ventures in the ICT sector and support companies' development and financing in the complex environment because of the COVID-19 pandemic. Thus, it is also expected that the actors with influence in the design and implementation to generate public policies consider the adequacy of the instruments to strengthen their support programs for MSMEs in the best use of ICT and Internet applications to consolidate their objectives of corporate business.

The intensive use of ICT platforms and the adoption of Internet applications through media platforms and social networks drive collaboration and communication exponentially. The companies that already had an ICT platform for consolidated use in their management processes and used digital infrastructure are the ones that most quickly adapted their business processes to face the adverse effects of the COVID-19 pandemic. Therefore, the indicators of ICT use, as well as the use of media and social networks on the Internet, are necessary to obtain information from organizations to know:

- How do digital platforms use teleworking to maintain remote operations?
- How and by what means do the companies carry out internal and external collaboration and communication?
- How are new business models changing in the middle of the new context of confinement and public health restrictions?
- What are the keys entrepreneurial activities to use the media and social networks to support strategic business objectives?

MSME decision-makers should be provided with up-to-date information through official survey indicators to improve the chances of business success and cope with unplanned events such as the emergence of the COVID-19 pandemic.

Funding I thank the National Polytechnic Institute (IPN) through the PhD program in Innovation Management and Policy (DGPI) of the UPIICSA and the National Council of Science and Technology (CONACYT) for supporting and promoting the dissemination of scientific knowledge through the publication of this chapter. I am grateful for the support and advice of my thesis director, Dr Maria del Pilar M. Pérez Hernández. I am grateful to the *Instituto Politécnico Nacional* (*IPN*) through the PhD program in Innovation Management and Policy (*DGPI*) of the *UPIICSA* and to the *Consejo Nacional de Ciencia y Tecnología* (*CONACYT*) for supporting and promoting the dissemination of scientific knowledge through the publication of this chapter. I am grateful for the support and advice of my thesis director, Dr Maria del Pilar M. Pérez Hernández.

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CHAPTER 13

Marketing Strategy in MSMEs Facing the Covid-19 Pandemic

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13.1 Introduction

The world faced the worst economic crisis and recession on record caused by the SAR-CoV-2 pandemic (COVID-19), provoking a health and economic crisis that triggered the paralysis of economies and society due to a severe quarantine [1]. The Companies face unprecedented challenges to survive in the market, forcing them to implement new strategies and develop other skills to cope with current conditions.

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According to data from the National Institute of Statistics and Geography (INEGI), aligned with what is projected by international organizations such as the International Monetary Fund (IMF), the coronavirus crisis caused a collapse of 8.5% of GDP last year in Mexico. According to the National Council for the Evaluation of Social Policy (CONEVAL), in the third quarter of 2020, working poverty, that is, those with incomes below the value of food and basic products, reached 44.5% of the population compared to 35.7% in the first three months of 2021 [2]. These figures mean a low purchasing power of a significant percentage of the Mexican population in recent months, a situation that directly affects consumption habits and companies. This overview forced us to rethink how organizations operate and the strategies used to adapt to the new conditions.

The world economic situation that has arisen due to the SAR-CoV-2 pandemic, especially in America and the Caribbean Region and its economic costs, has been devastating for the health, productive activity, and rising unemployment rates and have had a major impact on the bankruptcy of MSMEs due to the imbalance of supply and demand. This scenario challenges the entrepreneur's productive ability to manage this crisis, to reduce the impact of the deterioration of productive capacities and human capital, as well as their integration into the value chain [3].

Due to the current economic crisis, there is genuine concern about the performance of MSMEs and their entrepreneurs to continue serving their markets, and the confidence in global suppliers has deteriorated. The crisis has also led to smaller production lots and loss of economies of scale, scope, and learning. This downscaling harmed employment, wages, and income distribution. Regardless of their size, MSMEs are affected, particularly in commerce, transport, business services, and social services, which provide 64% of formal employment.

Many already face a significant decline in their incomes, increased insolvency, and job losses in specific sectors, which has marked an impact on the labor market. Maintaining operations will be difficult for micro, small, and medium-sized enterprises [4].

ECLAC [5] shares that the economy in the Latin American region will be impacted by: (a) the decrease in economic activity of its main trading partners; (b) falling prices of primary products; (c) disruption of global value chains; (d) lower demand for tourism services; (e) continued risk aversion and a retreat in global financial conditions. The sectors that could suffer the greatest contractions—trade, transport, business services, and social services—provide 64% of formal employment.

Martínez and Rubio (2020) state that the humanitarian tragedy of the COVID-19 pandemic is impacting both local and global economies, which is also causing a global recession that threatens the operation and performance of companies. The situation tests companies' entire acquisition of luxury or by-products [6].

Given this panorama, marketing strategies are of great relevance for the performance of organizations since it is where the relationship of the company with the market is established, especially when the pandemic generated by COVID 19 has forced to change the ways of working in companies given the variations in the customer's purchasing behavior. So, what marketing strategies are MSMEs implementing? What kind of communication strategies are they employing? How has the current health crisis impacted the performance of MSMEs? The general objective of this study is to analyze the impact of the COVID-19 pandemic on the marketing strategies of MSMEs in the State of Guanajuato (Mexico). This research focuses on five specific objectives. First, to know the impact of the crisis derived from the pandemic in terms of sales, turnover, profitability, and pricing strategy of MSMEs. Second, to identify what communication strategies MSMEs are currently using in Guanajuato. Third, to know the main social networks that MSMEs prefer to use. The fourth objective is to assess whether there is a relationship between the company's size concerning the marketing communication strategy it adopts. Furthermore, the last objective is to determine the importance for MSMEs to make changes or improvements in their existing products/services to be more competitive.

13.2 Theoretical Framework

13.2.1 Digital Marketing in Business

The selection of marketing strategies, especially in the digital plane, is transcendental to stay in the market. Given the circumstances, guidelines, and current conditions, digital platforms would make this possible if businesses wish to continue having commercial activities and concrete sales.

In recent years, marketing strategies identified as the most efficient use by the companies are focused on strengthening the digital brand, "Inbound marketing," the implementation of digital marketing, social networks for communication, and advertising to create brand loyalty through advertising campaigns [7]. The strengthening of the digital brand implies the creation of profiles on social networks, ideal for strengthening ties with the target audience; the creation of a website with current business information; that the brand focuses on transmitting trust to demonstrate commitment and caring about the community and offers alternatives adapting to the new circumstances.

Valenzuela et al. [8], the International Monetary Fund (IMF) and the Economic Commission for Latin America and the Caribbean (ECLAC), and the Organization for Economic Cooperation and Development (OECD), validate the importance of digital marketing for SMEs in times of pandemic, being necessary to use tools that impact the consumer, and the best tool is the use of social networks [9].

The last decade has been distinguished by great technological advancement The National Survey on Availability and Use of Information Technologies reports 71.3 million Internet users in Mexican households, which translates into 63.9% of the population [10]. Figures stipulate that there is a significant proportion of the potential market that MSMEs can connect to through digital means to spread their brand and attract a greater number of audiences by taking advantage of new forms of communication, interrelation, and exchange through social networks such as Facebook, Twitter, Instagram, and YouTube. The new form of interaction with customers represents a challenge for companies since they have been forced to transform their advertising and communication tactics with customers, which implies a series of challenges that weaken SMEs due to their lack of relevant knowledge to be appealing to the consumer and the lack of financial liquidity to invest in current technology.

The use of digital tools represents an advantage for companies since it allows to have online communication, less limited, and with greater creative freedom within existing frameworks, such as websites, rich media banners, or video overlays, which opens the potential for the use of other forms of completely new marketing engagement. The easier for ordinary people to create and share content and apps, the greater the potential to provoke viral content overnight from culture-changing behaviors.

The impact of digital marketing on trading is more relevant facing the unpredictability of consumer trends and the rapid decrease in the useful life of products. Today, the life expectancy of any new brand is rapidly shrinking, and at the same time, the costs of creating it are growing.

Consumers now can and are willing to control the messages and media they interact with. Consumers value the opinions and experiences of other users to help them form their judgments about companies and products. Today's consumers expect more from the brands they use and the companies that support them; they value transparency, honesty, generosity, respect, and commitment. As a result of digital communication, largely purchasing decisions are more than ever, community, collaborative, and informed. Online consumers are taking control over how brands are perceived and positioned [11].

Despite the adverse conditions, this new digital era benefits companies that wish to seek opportunities in the international market, such as: establishing and nurturing business relationships with customers in diverse and distant foreign markets, regardless of economic, political, cultural, or other differences; collect reliable and useful information on buyers, competitors and environmental conditions in different countries, thereby contributing to better-informed international marketing decisions; obtain effective customization of costs and their market offerings in different countries; manage cross-border business transactions faster, cheaper, and easier, thereby increasing their competitive advantage and improving financial performance; and simplifying the way international business is conducted through electronic data transfers, wire payments, and online exports assistance [12].

Parkin [11] exemplifies the impact of digital marketing on the automotive industry, which transferred billions of marketing dollars from mainstream media to digital media due to the experience. Television audiences and newspaper readers began to fall all over the world. Records over the past eight years indicate that mothers in the United States spent seven times more time on the web than watching television. Most consumers are online. Digital marketing is no longer a peripheral experiment but the essential basis of the strategy of every reputable salesperson. Avant-garde marketers are building relationships with customers online, while most are still focusing on building websites, which are not enough, no matter how "optimized" they are.

The usefulness of digital marketing is related to "push marketing," where companies push their products toward customers, making them feel besieged, persecuted, and uncomfortable through e-mail that arrive without requesting it, sudden ads, at the same time, individuals watch a program on TV, floating banners while browsing the Internet, promotions offered to you while you walk inside the supermarket, flyers arriving in the mailbox of households, etc. The approach to consumer outreach is known as *Outbound*. Pull Marketing, or Inbound is another approach that creates attractive value propositions for the customer to approach. In this case, the consumer Is the one who communicates with the company and applies the marketing attraction strategy, a useful way to generate attention, close the business, and retain the target audience [13]. To start the path to loyalty, first, the customer must recognize the brand, product, or service, and the company that offers it; then, the business must devise advertising campaigns that influence the buying behavior of potential consumers, using elements that connect with them, causing emotions so that the brand or product, is recorded in the memory of the client generating a sense of satisfaction at the time the purchase is made [14].

13.2.2 Pricing Policy Strategy

According to Guitart [15], one of the pricing strategies focuses on value creation. Determining the customer's willingness to pay becomes crucial. Communication with customers must be open to know which attributes they value since these directly impact the purchase decision. Then, the economic value is calculated. Pricing must be supported by the decisions of various activities such as distribution, the product itself, and advertising, since these elements play a significant role in branding, which is evident in the case of luxury products where the communication strategy is oriented to exclusivity, to highlight the sublime quality of the product, emphasize its attributes and limited distribution. Consumer preferences and demands are constantly changing, new competitors and technology are emerging, and both prices and the economy are moving, so a good pricing policy must be continuously evaluated. In today's competitive framework, two pricing strategies can represent a competitive advantage, such as offering a differentiated product to the market and handling lower costs than the competition.

The modern customer has access to more information about market prices, so companies are challenged to learn how to develop pricing models that show value differences (social, emotional, epistemic, and situational). Now, the communication strategy should concentrate on communicating the value, not on agreeing on discounts and being prepared to react to future and different market conditions.

Some non-negotiable pricing policies rely on offering fixed discounts for volume, long-term contracts, and purchases of packaged products and services. Special policies may also be managed by market segment, particular goal, managing different margins depending on the product [16].

According to Kotler and Armstrong [17], there are several strategies to set prices, for example, the skim price, where a high price is set for a new product to obtain the maximum income, layer by layer, from the segments that are willing to pay that high price; although the company sells less, it achieves a higher profit margin. It should be noted that this policy is conditioned for it to work. For example, the image and quality of the product must justify the high price, and there must be enough potential customers willing to pay that price and complete the purchase.

Another strategy for new products, known as market penetration, consists of setting a low price to attract many buyers and increase their market share. If sales volume is high, costs decrease, which allows prices to decrease, thus attracting the final consumer.

Another of the most used policies is price adjustment, where base prices are established considering the various characteristics of customers and purchase situations. That is the origin of the bonuses, discount prices (as a reward for consumer behavior), and the determination of dynamic prices according to the differences in products, customers, or places [17].

Access to consumer data platforms and the advancements in artificial intelligence and data mining for their treatment has allowed companies to develop a personalized pricing strategy. Machine learning, for example, can predict how specific customers will respond to prices they do not yet know and help detect opportunities and threats worth managing, focusing our efforts on what is truly relevant [18]. This new tool is related to accessing and unifying data through sources such as ERPs, Google services, CRM, Facebook, servers, databases, files, and cloud platforms such as Microsoft Azure, Google Cloud, and Amazon web services.

13.2.2.1 Product Innovation

The rules in marketing have been transformed with the pandemic, and with this need to adapt. The teams have had to update, modify, and reevaluate their skills to offer tangible value to their customers. The new characteristics consumers value and should now consider in any marketing strategy are impatience, the desire for immediacy, and prompt reply, which apply to customer service and the internal company's processes. The current customer values the company's response time, and he cares about the "when" more than the "how." Some companies have adopted a strategy focused on optimizing tools, processes, and people to achieve greater agility.

According to González [19], innovation has become essential for an effective digital marketing strategy. The changes companies have adopted from the new reality are that organizations increased their presence in social networks by nearly 70%, 55% modified their digital platforms, and 50% carried out their events virtually. In the company, five possible circumstances explain a good performance of innovation. To have impeccable internal knowledge management, integration of external knowledge, the establishment of synergies between external and internal knowledge, the information absorption capacity, public contribution received, and the government institutions' support as core elements to drive innovation by local companies.

13.2.2.2 E-commerce

To understand e-commerce, Parkin [11] states that it is important to see the business as a whole and identify how to improve it, considering all the different aspects of the Internet. The first thing is to identify the crucial elements of digital marketing. The modern expectation is that a business has its website and is enabled to do e-Commerce (online shopping); companies want Internet users to visit and buy whatever the brand sells. To validate this assumption, there are three primary elements to consider within the website. The first is the front-end (first contact point with the virtual store deployed on the website), the second is the target market, and the third is the back-end (the e-commerce business's internal processes). The back-end is responsible for operational activities, such as payments, inventory, file storage, Cloud data, social media integration, messaging, and account management.

Within e-commerce, two concepts should not be confused, e-commerce *and* e-business. E-business is the real-time integration of Internet activities throughout the supply chain and all company processes. It integrates the *customer's "front-end"* experience (the virtual store deployed on the website) into all the company's "*back-end*" systems and processes that make the promise of complete customer satisfaction a reality.

Integrating digital strategies into business is important as it improves the knowledge, reputation, and image of brands (particularly those with a regional or global reach) and builds lasting customer satisfaction and loyalty in many countries [20].

13.3 Methodology

To develop this research, quantitative-descriptive research is carried out, through a non-experimental design, with a transversal scope.

13.3.1 Sample Structure

The population includes micro, small, and medium-sized enterprises in Guanajuato State. The National Statistical Directory of Economic Units (DENUE version 11/2020) of INEGI was used as a data source to determine the population and the sample. The selection criteria were as follows:

1. Have no more than 250 employees.
2. The government sector (legislative, governmental, justice delivery, and international and extraterritorial organizations) was excluded.
3. Companies that, according to the database, have not identified the sector to which they belong were not considered.

The sample size was 166 companies. The general design of the sample is based on the principles of stratified sampling, using two strata, the sector (primary, secondary, and tertiary) and the size (micro, small, and medium) (see Table 13.1).

Table 13.1 The sample structure and sampling error

Sector/Size	*No. of companies*
Primary sector	13
Secondary sector	59
Tertiary sector	81
Lost in the system	13
Microenterprise (1–10 employees)	97
Small (11–49 employees)	50
Medium (50–249 employees)	18
Lost in the system	1
Total sample	166
Sampling error (confidence level 90%)	5.82

Source Own elaboration, based on the results obtained through SPSS

13.3.2 Questionnaire Design

A questionnaire was designed with 37 items grouped into eight sections: general data of the companies, economic consequences, impact on the company's organization, innovative and technological activity, access to funding, performance indicators, business strategy, and marketing strategies. Different types of questions were used, from dichotomous to multiple-choice, using the Likert scale. The questionnaire is based on the survey of the Ibero-American Observatory of MSMEs and has added questions focused on the family business, business strategy, and marketing strategy. In general terms, the questionnaire is comprised of two blocks:

- In the first block, it is questioned about the general characteristics of companies such as sector activity, geographical location, number of employees before and after the crisis, personal characteristics of the owner or manager, family control of the company, characteristics of family succession, growth expectations on employment and sales, degree of internationalization, use of "work from home" model, among other variables.
- In the second block, information is obtained on how the crisis generated by the COVID-19 pandemic has impacted: business management, financial indicators, performance, innovation, business strategies to be implemented, competitive advantages, and marketing strategies.

For the development of this chapter, questions related to performance indicators, marketing strategies, and innovative activity were mainly used.

To determine the internal consistency reliability of the measuring instrument, Cronbach's alpha was used, as shown in Table 13.2.

Fieldwork and surveying were carried out from February to April 2021. The survey was aimed at business groups, business owners, upper

Table 13.2 Cronbach's coefficients Alpha per dimension

Dimensions	*Cronbach's Alpha*
Performance	0.884
Marketing strategies	0.769
Innovative activity	0.912

Source Own elaboration

management employees, and businesses' general managers. The survey was carried out by email, telephone, and/or by the social network WhatsApp where the link associated with the instrument was sent. When the information collected was ready to examine, the data were tabulated and analyzed through the SPSS 22 software.

13.4 Results

The micro, small, and medium-sized enterprises surveyed are mature companies with more than ten years in the market (57%). They are predominantly family businesses (71%) run by the company's owner, who has a university education in 57% of cases. There are 69% of companies run by the male gender. 82.6% of the companies declare that they have not obtained benefits or economic support as MSMEs. Only 6.7% of companies obtained a subsidy or economic benefit, from the state they are doing business in, because of the effects and measures of the COVID-19 pandemic.

The results of the impact of the pandemic on financial indicators show that, concerning the level of turnover, 54.3% of companies report a negative impact, and only 23% of companies did not detect any impact. Most companies (55.9%) claim that their sales in 2020 decreased compared to the same period in 2019, while only 25.8% of the entrepreneurs surveyed perceive that their sales remained stable. Aligned to the same topic, 49.4% of the MSMEs report a negative impact on their profitability; on the other hand; there are 20.6% do not perceive a negative impact on the benefits obtained nor on the profits generated for the company. 33.2% of businesses had experienced a significant increase in order cancellation by their customers, impacting directly on a sales decrease.

One of the crucial activities within business management is decision-making when facing vicissitudes that occur in adverse times of uncertainty, especially in the macroeconomics of a country. To face the storm generated by a series of external shocks that hit the economy, 34.6% of MSMEs decided to lower their prices as a strategic measure to continue competing in the market since the price is one of the major purchase criteria of Mexican consumers. Regarding competitiveness, 62.6% of the entrepreneurs perceive to offer better-quality products when compared to direct competitors.

Innovation plays an important role when one of the goals is to gain and increase market share. In the year 2020, only 38.7% of companies had the

Table 13.3 The degree of preference for marketing communication media

Communication strategy	%
Email Marketing	32.8
Advertising on Google	28.4
Advertising via SMS (mobile message)	18.5
Printed Media Advertising	15.3
Radio advertising	10.3
Paper mail	5.1

Source Own elaboration based on the analysis of SPSS results

vision to make changes or improvements to their existing products and services, and 38.8% launched new products and services on the market, giving rise to renewal and adaptation to change to be more attractive to the target market and new trends in consumer behavior.

Regarding marketing strategies and decisions, 52.3% decided to invest in implementing advertising campaigns and promotions, hoping that these generate a positive impact on their business performance. Table 13.3 shows the marketing communication strategy chosen to improve the marketing and dissemination of companies.

Email newsletters are critical to their content marketing success, and most millennials prefer communications from businesses to come via email. Over 95% of consumers check their email daily, and it is by far the preferred way to receive brand updates.

One benefit of using an email marketing strategy is creating personalized content. Companies usually have their database of their best customers and those who bring them the highest profit margins and on which they should focus. Collecting feedback and surveys will let the business keep a pulse on the customer experience, interacting and engaging, so they purchase from a specific brand. The email marketing strategy has some other advantages. It helps improve sales rates and communicate with the audience by notifying a promotion, newsletter, new releases, tutorials, etc. Also, to generate traffic to the website, improve the SEO, ensure each email contains a call to action (CTA), increase leads, reach the right people at the right time, produce cost-effective campaigns, and provide more value to their audience.

It is no surprise that Google Ads is one of the favorite advertising media, as it has several advantages, primarily, the segmentation of the ads. This allows the company to target the ads to people with specific interests in the company's products or services, so they show them relevant ads. The price is affordable, and the platform allows control of the costs since there is no minimum investment, and the manager can choose how much money to invest per month, per day, or ad. The executive in charge will only pay when someone clicks on the company's ad. In addition, Google Ads allows you to measure consumer behavior (track) since you can know if someone has clicked on your ad if the customer decided to buy, download your app, or called to pick up an order. Additionally, it allows the identification of the most effective ads and the customer's habits.

The strategic digital marketing decisions that entrepreneurs decided to implement to improve their company's performance is shown in Table 13.4.

According to the Development Bank of Latin America, users of the social network Facebook (now Meta) increased by 36% in 10 years, and there is a record of more than 438 million users in Latin America. In 2019 in Mexico, 65% of the population used social networks. Throughout Latin America, Facebook is the favorite occupying the first place. The generations that use it the most are Millennials (people born between 1981 and 1996) and Generation X (people born between 1965 and 1980). Facebook stands out for remaining avant-garde, the possibility to interact, and the algorithm that filters publications according to the interests of each user of the platform. This network can activate the area of the human brain associated with pleasure and the sensation of reward. The "like" or "share" buttons are self-affirmation tools that allow people to define the individual before others. People value a medium that allows them to inform, what matters to them, and what defines their tastes and personality. Facebook is an opportunity for individuals to present themselves on an individual level to the world and express who they are; this is possible

Table 13.4 The favorite social networks for companies located in Guanajuato

Digital Marketing Strategy—Social Media Preference	*%*
Facebook	59.8
Instagram	33.2
YouTube	14.9
Google Plus	12.6
LinkedIn	8.5
Twitter	8.0
Pinterest	6.9

Source Own elaboration based on the analysis of SPSS results through the reactions that potential customers have, to each brand post, advertising video, or new ideology, among others (when pressing the "like" button). Many people base their final purchase decision on their experience interacting with the brand through this medium.

On the other hand, Instagram is the social network that is most attractive to younger generations (between 16 and 23 years old). The platform has been able to integrate the options of photography and video simply and attractively for the user. One of the most innovative functions is the option of fleeting stories; brands have already detected this trend, so they use it to sell their products or services.

Concerning changes or improvements in existing products and services, the results show that, about size, 48.5% of microenterprises have modified the offer of products/services to address new customers; 53.3% responded to having made changes or improvements to existing products/services and 40% have launched new products/services on the market. Regarding preferences of current advertising media, 60% consider network advertising very important, and in second place is email marketing (34.2%). On the other hand, microenterprises prefer the *Facebook* social network as a strategic marketing communication tool during the pandemic.

For small businesses, the findings reveal that 45.1% have modified the offer of products/services to address new customers; 52.9% have reported making changes or improvements to existing products/services, and 35.2% have launched new products/services on the market. Concerning current advertising media preferences and their relationship with size, 67.5% of small businesses consider network advertising very important (62.7%). Secondly, email marketing (19.6%); Facebook is the preferred social network as part of the marketing strategy.

As for medium-sized companies, reports show that 46.1% have modified the offer of products/services to address new customers; 15.3% have reported making changes or improvements to existing products/services, and 19.2% have launched new products/services on the market. Regarding current advertising media preferences and their relationship with size, 65.3% of medium-sized companies consider network advertising very important, and secondly e-mail marketing (9%); likewise, they prefer the social network Facebook as a marketing strategy. In conclusion, most MSMEs use social networks as a marketing communication strategy, particularly Facebook (59.8%).

13.5 Conclusions

The objective of this research was to analyze the impact of the COVID-19 pandemic on the marketing strategies used by MSMEs in the State of Guanajuato, Mexico. The impact of the crisis on MSMEs in terms of sales, turnover, profitability, and prices was confirmed, so the objectives proposed were achieved. Likewise, the communication strategies and social networks used during COVID were described, and the importance of innovation activity in MSMEs was analyzed. Finally, the relationship of the company's size with the communication strategy of MSMEs was addressed in the results section. The decline in profitability, sales level, and turnover rates highlight the difficulties companies face. The decrease in aggregate demand in the country in practically all economic sectors generated internal and operational changes in companies, coping with the increase in fixed costs and the reduction in productivity.

The results show the lack of knowledge of entrepreneurs, innovative strategies, and new digital marketing trends to support the commercialization of their products or services. This situation justifies the reluctance many entrepreneurs suffer when investing and adopting technology.

Regarding the size of the business, although most MSMEs have access to the Internet and technological devices to operate, the level of adoption of networks ranges from low (micro) to medium (small), but all prefer Facebook as a strategic marketing communication tool. Moreover, as for the importance for MSMEs to make changes or improvements in their existing products/services to be more competitive, micro and small enterprises agree that it is very important, while for medium-sized companies, it is not (only 15% say that it is important).

The best-prepared MSMEs will be able to face the crisis with greater resilience and have the ability to ethically exploit the opportunity arising and be open to learning and relearn new ways of doing business. Understanding social dynamism results in a market with demands including the socially responsible company, and that if not attended to as indicated by the stakeholders, may be counterproductive in economic terms.

Some of the limitations detected during the development of this study were the difficulty reaching upper management since the state of Guanajuato is affected by insecurity, organized crime, and telephone extortion. These factors represent a barrier to communication and trust.

Given the findings, for future research, it is recommended to conduct a study to identify the reasons why MSMEs have not updated their way of contacting and connecting with their target market and know why it is considered an expense rather than an investment. It is also relevant to delve into the issue of strategic marketing communication with a focus on customization and customer engagement through networks.

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CHAPTER 14

World Research and Intellectual Structure in Digital Transformation on SMEs in Covid-19 Times

David Sabando-Vera, Néstor Montalván-Burbano, Marcela Yonfá-Medranda, and Katherine Parrales-Guerrero

14.1 Introduction

In recent decades, the phenomenon of digital transformation (DT) has been impacted by profound changes in almost all sectors of economies and at different organizational, operational, strategic, and management levels [1, 2]. These changes are in line with its definition, understood

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S. Estrada (ed.), *Digital and Sustainable Transformations in a Post-COVID World*, https://doi.org/10.1007/978-3-031-16677-8_14

as the effects caused or influenced by the use of digital technology in human life in general and in organizations in particular [3, 4]. Thus shaping a new trend called Industries 4.0, related to the Internet of Things (IoT), cloud computing, artificial intelligence (AI), and mobile computing [5, 6].

Digital transformation (DT) and its effects on organizations have been studied extensively due to its growing interest among academics and researchers [7]. Busulwa and colleagues find that the hotel and tourism industry has developed digital business capabilities to improve customer engagement, customer experience management, and hotel management [8]. Alenezi explores the effects of DT on various dimensions of the higher education system in its substantive functions of teaching, research, and engagement with society [9]. Vu and Hartley find that DT is the primary driver of labor productivity growth and recovery in the electricity sector in different economies [10].

Currently, companies are experiencing a disruption in their industries due to the rise of digital processes leading to a change in previously established structures and putting consolidated business models under pressure [11, 12]. Within this restructuring process, business innovation is essential in applying digital technologies to achieve the company's goals and thus improve products, processes, and business models to create value [13, 14]. In addition, digitalization influences various business activities, namely technology acquisition and business models, and provides opportunities for collaboration between companies and building relationships with customers and employees [15, 16].

However, organizations face challenges in the digitalization process. For example, Parida and colleagues mention that the main challenge

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consists of value creation, delivery, and capture [17]. Furthermore, Eller and collaborators explain that Small and medium-sized enterprises (SMEs) face challenges in adopting new technologies regarding resources and management skills. However, these challenges could be overcome by developing the required skills (hard and soft), investing in digital technologies, and developing a detailed strategy and measurement plan [18]. On the other hand, Almeida, Santos, and Monteiro consider that a post-pandemic world will require creating a distance working model with high interactivity and cooperation that allow people to work in companies in another geographical area [19].

The presence of the Covid-19 pandemic has accelerated DT in society due to the rapid diffusion and application of information systems (IS) technologies and internet-based infrastructures [20]. SMEs play an essential role in the global economic context by representing approximately 90% of businesses and 40% of GDP in developing economies and generating two-thirds of the world's jobs [21]. The digital transformation had a remarkable effect on this type of company compared to other businesses due to their commercial dynamics and great importance in almost every country globally [22].

In this space, the questions arise: How has research on digital transformation in SMEs evolved during Covid-19 times? What is the intellectual structure of this field of study in Covid-19 times? This paper aims to answer these questions and thereby contribute to a better understanding of the effects of digital transformation on economies. At the same time, this study contributes to the reflection on the development of digital transformation in SMEs at the global and Latin American levels.

To achieve this purpose, we conducted a bibliometric analysis to explore the intellectual structure of this field. In this way, the characteristics and research areas of digital transformation in SMEs can be determined by quantitatively evaluating the existing academic literature [23, 24]. It also allows for identifying emerging research areas and collaboration between institutions and researchers [25]. Therefore, these analyses make it possible to evaluate the performance of scientific publications and map their structure by employing a two-dimensional network [26, 27].

The results show that the intellectual structure is related to dynamic capabilities in business model innovation—likewise, the impact of the pandemic on SMEs and their reactions. At the same time, there is abundant literature about the barriers and practices of smaller companies in their integration process to Industry 4.0, primarily through digitalization strategies for performance improvement.

The article is structured as follows. The second section develops the materials and methods, detailing the database used and the systematic data collection process. In the third section, the relevant results of this study, trends, and new lines of research. The fourth section discusses the primary relationships between the results obtained. Finally, the fifth section includes the conclusions and limitations of the study.

14.2 Materials and Methods

In recent years, the exploration and evaluation of scientific literature have been possible to resort to various review methods such as systematic literature reviews, meta-analyses, and bibliometric analyses [23]. The latter, bibliometric analyses, provides insight into the intellectual structure of a research field by analyzing its scientific output through its performance and visualization of its structure [26, 27]. In addition, some researchers use this type of analysis to evaluate various fields of knowledge, such as management [28, 29], environment [30, 31], tourism [32, 33], and others.

This bibliometric analysis requires a systematic and rigorous process similar to systematic literature reviews to ensure its quality. These characteristics allow a four-stage methodological scheme:

14.2.1 Search Terms for the Research Field

Digital transformation describes the using technology that enables radical improvement in the business model, products, organizational structures, or performance [34, 35]. Under this conception, the terms: *digital transformation*, *digital disrupt*, *digitalization*, and *digitization* are the most commonly used to identify this field of study [2, 34]. When considering organizations, it is essential to analyze small and medium-sized enterprises (SMEs) as they play a vital role in global economic development by contributing to poverty reduction, income, and job creation, representing 90% of businesses [36, 37]. Therefore, it is necessary to explore this type of company's various names, such as small and medium-sized businesses, small and medium enterprises, SMEs, and others [26]. Combining the terms "Digital Transformation" and "SMEs" allows for the construction of the required information base.

14.2.2 Database and Document Selection

Bibliometric studies require a reliable database, so Scopus was selected. The selection criteria are related to: (i) its broad coverage of publications in different areas of knowledge in terms of time and volume; (ii) high-quality standards such as CiteScore and SCImago Journal Rank; (iii) easy access to references, and (iv) data download and analysis tools [38–40].

The data was extracted in January 2022, using the topic search: TS ((TITLE-ABS-KEY ("digital transformation*") OR TITLE-ABS-KEY ("digital* disrupt*") OR TITLE-ABS-KEY ("digitalization") OR TITLE-ABS-KEY ("digitization"))) AND (((TITLE-ABS-KEY ("small business") OR TITLE-ABS-KEY ("medium business") OR TITLE-ABS-KEY ("small-sized firm") OR TITLE-ABS-KEY ("medium-sized firm") OR TITLE-ABS-KEY ("small and medium-sized business") OR TITLE-ABS-KEY ("SME") OR TITLE-ABS-KEY ("SMEs") OR TITLE-ABS-KEY ("small firm*") OR TITLE-ABS-KEY ("medium firm*") OR TITLE-ABS-KEY ("small enterprise*") OR TITLE-ABS-KEY ("medium enterprise*") OR TITLE-ABS-KEY ("small and medium enterprise*") OR TITLE-ABS-KEY ("small and medium-sized enterprise*")))). Resulting in 1004 records.

14.2.3 Selection Criteria, Data Processing, and Software Selection

The global economy and business have undergone drastic changes and devastating effects since the COVID-19 outbreak [37, 41]. For this reason, we have established the criterion of excluding the years prior to the pandemic outbreak (less than 2020) and 2022 as it is the current year. The result was 612 records. All available documents and languages are considered inclusion criteria.

The data obtained were downloaded in CSV format (comma-separated values) with bibliographic and citation information of the related scientific production (authors, titles, years, and sources, among others). This information was processed using two software packages:

- Microsoft Excel: Allows pre-processing of data by checking outliers caused by omissions, errors, or duplication [42, 43]. Corrected for these errors, we obtained 612 records. Additionally, this software allows the analysis of the performance of various units of analysis such as authors, countries, and documents [27].

- VOSviewer: Software that allows the visualization of the intellectual structure of the field of study by constructing a two-dimensional bibliometric network [44]. A network of co-occurrence of keywords allows the analysis of this structure, revealing existing topics and themes [24]. In addition, other bibliometric studies in various academic disciplines have used this software [45–47].

14.2.4 Analysis of the Results

Bibliometric analyses comprise two main approaches: performance analysis and science mapping [27]. The former allows the evaluation of the performance of scientific production and its impact. In contrast, the latter allows the observation of the dynamic aspects of the intellectual structure of the topic of study [48].

14.3 Results

14.3.1 Subject Area

There are 612 documents on Digital Transformation in SMEs between 2020 and 2021. Figure 14.1 shows the most important thematic areas that have enabled the development of this topic. Business, Management, and Accounting leads this academic field with 253 papers, with a business focus on topics related to digital transformation, such as business models [49, 50], smart technologies [51], absorptive capacity [50, 52], internationalization [53, 54], sustainability [55, 56], value creation [57, 58], and Industry 4.0 for SMEs [59, 60].

The second subject area corresponds to Computer Science with 252 publications, focused on the technological part of digital transformation, in topics such as digitalization [61, 62], data management [63], big data [64], data mining [65], digital technologies [66, 67], digital twin [68, 69], digital readiness [70], artificial intelligence [71, 72], Internet of Things (IoT) [73, 74], and cloud computing [66, 74], among others.

Furthermore, Fig. 14.1 exhibits other minor subject areas such as Engineering (16%), Decision Science (11%), and Social Science (8%) out of a total of 22 subject areas.

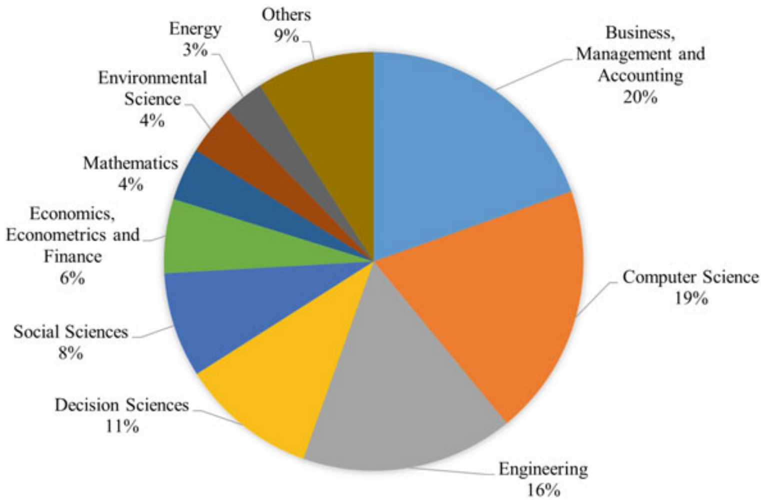

Fig. 14.1 Subject area (*Source* Scopus)

14.3.2 Type of Document and Language

Figure 14.2 shows the types of documents in the study area. Articles and Conference papers are the document types that account for most publications (86%). Articles occupy the first place with 313 documents, where the journal *Sustainability* is representative with 22 articles, and Conference paper with 217 documents. On the other hand, there are 217 Conference papers, with *Procedia* standing out (22 publications), followed by *IFIP Advances in Information and Communication Technology* and *Lecture Notes in Networks and Systems* (with 17 documents each). Finally, *Advances in Intelligent Systems and Computing* with 11.

The dissemination of this scientific output is according to seven languages. English is the most representative, as it is the predominant language of scientific dissemination [38]. Other languages are German (24), Russian (4), Spanish (3), and other minor languages.

14.3.3 Scientific Production

The scientific output of Digital Transformation in SMEs in 2020 shows some highly cited papers despite being recent. These studies address

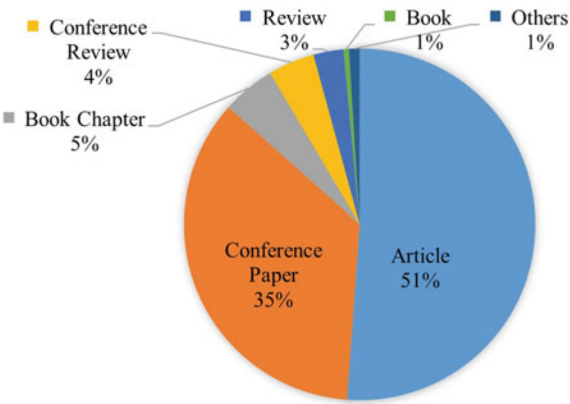

Fig. 14.2 Type of document

SMEs' background, consequences, advantages, and challenges due to digitalization in Industry 4.0 [61, 75–77]. Likewise, the role of the supply chain in the performance of smaller firms [51, 78] and the impact of digitalization on economic growth [62]. In addition, some articles examine the challenge faced by these companies due to the Covid-19 pandemic [79, 80].

In 2021, high-impact research explored the role of dynamic capabilities in business model innovation [50, 58] and the impact of the pandemic on SMEs and their reactions [22, 81, 82]. Similarly, some studies delve into the barriers and practices of smaller companies in their integration process into Industry 4.0 [67, 83, 84], primarily through the digitization strategy for performance improvement [53, 85, 86].

14.3.4 Countries Collaboration

Figure 14.3 shows the 75 countries that have contributed to the scientific production of Digital Transformation in SMEs during the last two years. In the top 10, there is a majority participation of European countries such as Germany, the Russian Federation, Italy, the United Kingdom, Portugal, Spain, Finland, and Austria. Therefore, the presence of Asian countries such as Indonesia and China. In 2020, these countries were more affected than others [87, 88].

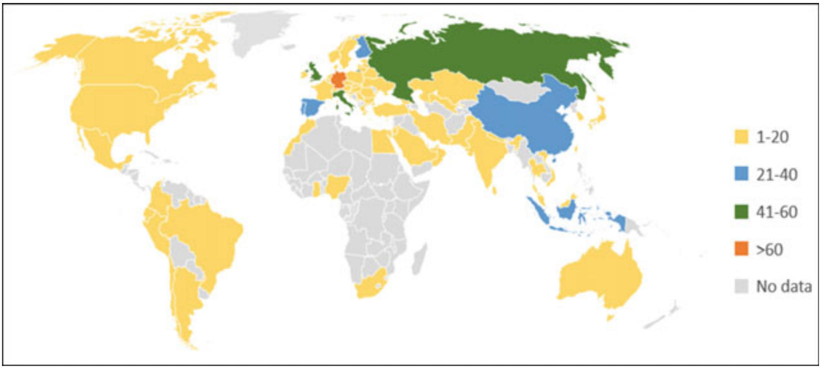

Fig. 14.3 Countries collaboration (*Source* Scopus)

Germany leads the field with 112 papers and 259 citations, collaborating with 23 different nations through 36 papers, with Austria, Spain, and the United Kingdom contributing the most with three papers each. Furthermore, it is worth noting that Germany's most impactful research has focused on the growth opportunities offered by digitalization and the strategies and process of digital transformation of SMEs in the framework of Industry 4.0 [50, 60, 89, 90].

On the other hand, Italy has the highest number of citations, which has achieved an average of 416 citations through 56 papers. These studies address the advantages of Industry 4.0 applications for sustainability [60, 76] and digital transformation in smaller companies [58, 61, 91]. The work of Erwin Rauch (affiliated with the Free University of Bozen-Bolzano) stands out, and he has contributed five research papers receiving 64 citations. Dominik T. Matt (Fraunhofer Italia Research) has also contributed to four publications. Both authors have conducted joint studies exploring Industry 4.0 in SMEs, its advantages, challenges, and requirements [76, 92, 93].

In Latin America, the COVID-19 outbreak emerged in the early 2020s, following Europe, soon becoming the center of the pandemic and registering the highest number of cases and deaths and significantly affecting the region's economy [94, 95]. Furthermore, some scholars explored the effects of SARS-CoV-2 on the digital transformation of the enterprise [79, 82, 96], the integration of Industry 4.0 [97], and ERPs [98]. Therefore, some studies analyze the impacts on agriculture [80] and the wine industry [99].

14.3.5 Co-occurrence Author Keyword Network

Bibliometrics offers several tools to analyze the intellectual structure of an academic field, one of which is co-occurrence analysis. This analysis makes it possible to find connections between concepts using authors' keywords [100]. In this way, it facilitates the observation of relevant topics and research lines developed in the study of Digital Transformation and SMEs in Covid-19 times. Thus Fig. 14.4 shows the science map constructed through VOSviewer with 1380 keywords, in which 55 co-occur at least five times; therefore, the visualization has 55 nodes (relevant topics) and six clusters (lines of research).

Cluster 1 (red color) "*SMEs in Covid-19*" is located in the center of Fig. 15.4, consisting of 17 nodes with 432 occurrences. The studies belonging to this cluster focus on challenges, difficulties, and solutions for small and medium-sized enterprises [18, 60]. These studies cover different topics, such as implementation of Industry 4.0 [75], digitization

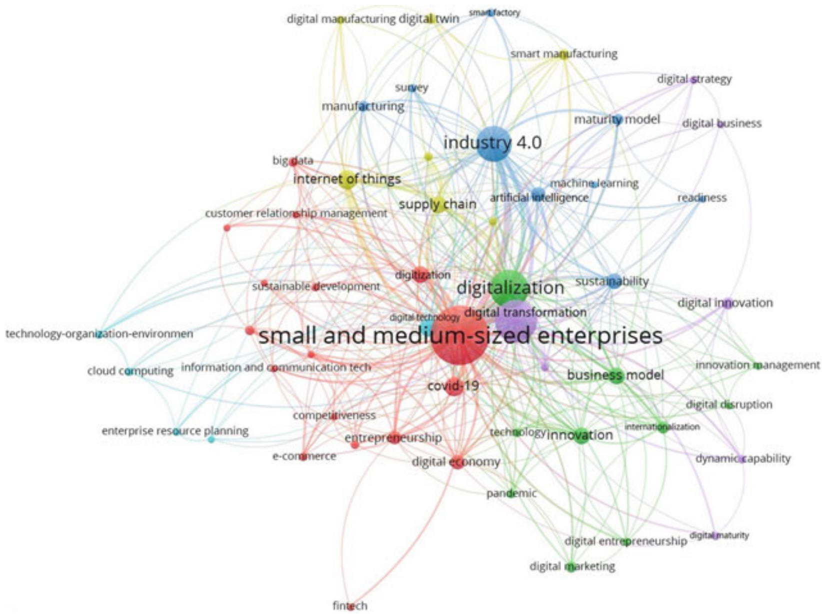

Fig. 14.4 Visualization of co-occurrence author keyword network (*Source* Scopus)

process [101], digital economy [102], value creation [57, 58], supply chain [78], sharing economy [103], entrepreneurship process [104], sustainable development [105], and adoption of information and communication technologies (ICT) [106]. In addition, many of these articles focus on different economic sectors such as manufacturing [77], food [58, 107], fintech [108], fashion [109], and tourism [110]. Other studies addressed the Covid-19 pandemic and its implication on the activities of SMEs [22, 111], as well as the approach to solutions involving digital transformation [105, 112–114].

Cluster 2 (green color) "*Digitalization and Business models*" consists of 10 nodes with 219 occurrences. In this cluster, the research addresses the effect of digitalization on business activities [110, 115, 116] and internationalization [117–119]. Furthermore, other scholars focus on the process and challenges of its implementation [120–122], even for the entrepreneurs [123]. Finally, several researchers studied the role of digitalization in the redesign of the business model [124, 125] and the resulting performance [126, 127].

Cluster 3 (blue color) "*Industry 4.0*" consists of 9 nodes with 188 occurrences. These studies explore Industry 4.0, its advantages [128, 129], the challenges and barriers in its application [61, 83], SMEs readiness [130, 131], execution of maturity models to assess the degree of implementation [132, 133], as well as its focus on sustainability [76, 134]. Similarly, this framework has been a reference for the design of business models [50], the adoption of artificial intelligence [71, 135], and the application of machine learning processes [136]. Likewise, several research projects have focused on the smart factory, the goal of digitalization in manufacturing [137, 138].

Cluster 4 (yellow color) "*IoT*" consists of 7 nodes with 96 occurrences. In this cluster, the studies explore the benefits of systems that target smart and connected devices via the internet. When these systems are from a B2C (business-to-consumer) perspective, this is known as the internet of things (IoT). This technology has a significant role in digital transformation studies due to its advantages in the enterprise's user-centered innovation process, especially in challenging times such as Covid-19 [81, 139]. Furthermore, different aspects concerning its adoption in SMEs have been examined [73, 140]. Meanwhile, when systems are from a B2B (business-to-business) perspective, it is referred to as the industrial internet of things (IIoT). Therefore, some studies focus on this concept for its applications in business [141] and because some scholars consider it an essential strategy for the digital transformation process [142, 143].

Cluster 5 (purple color) "*Digital innovation and transformation*" consists of 7 nodes with 183 occurrences. This cluster contains documents about digital innovation, and the process companies follow to adopt such an approach. This process of change is called digital transformation. These studies involve different mechanisms, such as digital innovation hubs (DIH) [144, 145], dynamic capabilities [58, 146], design thinking [147], and business process management (BPM) [90], among others. Similarly, some researchers have proposed frameworks to detail the digital transformation process of companies, the digital strategies involved [50, 148], as well as the evaluation of this process [149, 150] through the level of digital maturity [151, 152].

Cluster 6 (sky-blue color) "*Digital Technology*" consists of 5 nodes with 53 occurrences. This cluster comprises the keywords: *digital technology*, *cloud computing, technology–organization–environment (TOE framework)*, *enterprise resource planning (ERP)*, and *information system (IS)*. The papers belonging to this cluster focus on how digital technologies transform SMEs' business processes [54, 91, 153]. In addition, some of these studies examine the opportunities of these digital technologies in the field of information systems, specifically in an ERP system [154, 155]. Also, the use of the TOE framework to analyze different digital technologies such as IoT [156] and cloud computing [66, 73].

14.4 Discussion

The study of the Digital Transformation of SMEs is necessary to approach it considering one of the important events for humanity, such as the Covid-19 pandemic. Therefore, this paper analyzes 612 documents published between 2020 and 2021 in seven languages and produced by 75 countries from five continents, mostly developing countries (Fig. 14.3). The top 10 contributing countries include 8 European and 2 Asian countries, which were affected at the onset of the pandemic and required digital transformations in their SME business activity [e.g., 80–82, 112, 157, 158, 159, 160]. This involved considerations in their business models [79], sustainability [22, 105, 161], supply chain [162], and purchasing processes [163]. As well as economic impacts on the labor market and human capital [164]. Latin America's participation in this field of study is less than the European and Asian continents, but with significant repercussions when studying the effects of the pandemic on the digital transformation of the company and its integration into the 4.0 industry [79, 82, 96, 97].

The use of the scientific map of co-occurrence of authors' keywords complemented the analysis of the intellectual structure (Fig. 14.4). The main topics addressed were the management of SMEs in times of COVID-19 (red cluster), digitalization and business models (green cluster), and Industry 4.0 (blue cluster). Other smaller clusters addressed IoT, Digital Innovation, and Technology.

This study addresses the intellectual structure of digital transformation in SMEs at the Covid-19 time to understand how the company sought to change its practices and activities at a turbulent time for humanity.

14.5 Conclusions

This research aimed to assess the scientific structure of digital transformation in SMEs, specifically when COVID-19 appeared and was developed, through a bibliometric analysis using the Scopus database and VOSviewer software. In addition, the present study reveals the cognitive structure of this topic developed thanks to the collaboration of 75 countries.

The results showed the supremacy of scientific production in the areas of Business, Management and Accounting, and Computer Science. Likewise, the high production of articles and conference papers. In addition, we highlight the outstanding participation of Germany and Italy in research dissemination. Furthermore, the co-occurrence author keyword network revealed 55 relevant topics and six lines of research comprising the intellectual structure of this area: the management of SMEs in times of COVID-19 (red cluster), digitalization and business models (green cluster), Industry 4.0 (blue cluster), IoT (yellow cluster), digital innovation and transformation (purple cluster), and digital technology (sky-blue cluster).

However, this study has some limitations: (i) The use of the Scopus database and not considering other databases such as Web of Science and Dimensions; (ii) Not considering the use of regional databases such as Latindex and Scielo. These limitations could omit critical information and contributions in this field of study. Nevertheless, these limitations may broaden the scope and breadth of the subject matter presented. Therefore, this study is a guide tool for academics and researchers related to digital transformation in SMEs.

Finally, it is worth noting that in the wake of the SARS-CoV-2 pandemic, academia has shown a high level of interest in the ravages of this disease in the economic sphere, with a particular focus on small and medium-sized enterprises, which are the main ones affected. Therefore, researchers have developed studies to explore the lessons, challenges, and effects of this pandemic to develop proposals and solutions for smaller companies to adapt to this new reality through digital transformation. In addition, however, there is a need to explore the possibility of expanding research in this area. The following are some lines of research that future studies could consider:

1. Digital ecosystem for the work: Covid-19 has forced companies to adapt to new ways of working, which has increased the number of employees in the home office or under a hybrid system. This remote system is here to stay, so firms should guide their efforts toward developing and implementing digital workplaces adapted to the new reality and the needs of workers. Therefore, future research could contribute to exploring and developing these digital systems.
2. Development of digital skills: In many countries, due to the SARS-CoV-2 pandemic, governments have put in place mobility restrictions to contain the virus. However, this has led to a transformation in the way businesses and individuals communicate. Therefore, this situation has highlighted the importance of digital skills to cope with the crisis. For this reason, future research could direct its efforts toward exploring the different digital skills needed for different business conditions and developing a measurement framework for these skills.
3. Innovation in smart technologies: SMEs have faced many challenges due to COVID-19. This pandemic has led to their adoption of smart technologies to continue operation and achieve sustainability. Therefore, future research could broaden the innovative technologies needed for enterprises from various economic sectors.

Acknowledgements This study was supported by the research project of the ESPOL Polytechnic University: "Capital Intelectual, Innovación y Desempeño Empresarial en Ecuador" (Intellectual Capital, Innovation, and Business Performance in Ecuador) with code no. FCSH-GI-I2MAKER-20-2021, and the support of Centro de Investigaciones y Proyectos Aplicados a las Ciencias de la Tierra (CIPAT)—ESPOL Polytechnic University. The authors appreciate the anonymous reviewers for their suggestions.

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PART VI

Smart, Sustainable, and Resilient Communities

CHAPTER 15

Socioeconomic Impact on Rural Communities in 3 Municipalities of the State of Durango in the Face of the New Normal

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15.1 Introduction

The pandemic caused by the COVID-19 virus produced a global health crisis that has intensified deep inequalities and generated substantial changes in various sectors. Even though the great health crisis created a global imbalance, paralyzing socioeconomic activity, it provoked an

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S. Estrada (ed.), *Digital and Sustainable Transformations in a Post-COVID World*, https://doi.org/10.1007/978-3-031-16677-8_15

important reaction whose effects are still being felt and are likely to shape the future [1].

A COVID-19 pandemic is a health event, but it is also an economic and social emergency with socio-historical proportions, especially for the population living in conditions of vulnerability and poverty. This scenario can become a problem of a great magnitude capable of remaining for a long period of time, or it can plan another diversity of possibilities that favor development, seeking to modulate new strategies to promote social security in the areas of greatest vulnerability. This pandemic has increased the gaps between urban and rural in aspects, such as mobility, food, wages, transportation, and access to health and services, to name a few. Primary activities have also been significantly affected [2].

In Mexico, with the arrival of the COVID-19 pandemic, some sectors were more affected such as the health, educational, social, and economic sectors. Similarly, it has been shown that there is an international consensus that no state was prepared healthily, socially, economically, politically, and educationally to face this epidemic disease that has revolted the conventional lifestyle [3].

If we can talk about an important but neglected sector in Mexico, the rural sector. As a result of this pandemic and "quarantine", of isolation, poverty has increased, especially rural poverty, CONEVAL estimates between 8 and 10% increase in poverty levels, which means a return to levels of 10 years ago, after the crisis of 2008 [4].

The point is whether the normalcy to which you will return is what you had before the pandemic; you will return with a new normal. Here is to reflect on whether the normality to which we wish to return is the reality before the pandemic, or we are willing to propose a "new normal". In this context, the second alternative is the most likely, which will be carried out

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gradually, where the participation and commitment of people will give rise to this new just normality, a high level of valorization of life, and a vision to reduce inequalities in the most vulnerable communities [5].

Today the new normal of 2021 focuses on a return to daily activities under a scheme that reinforces frequent hand washing, an antimicrobial gel, and physical distancing (not social distancing) characterized by a human phenotype covered with masks, masks, or masks. The new normal should not approach any degree of social distancing, let alone isolation from people. Getting out of confinement is to interact under the sanitary guidelines and, above all, to the responsibility for the self-care of health; you simply have to take care not to get infected. The best way to prevent disease is to avoid exposure to this virus [6]. The confinement result from meeting the health recommendations of the Ministry of Health to avoid an increase in COVID-19 infections.

The guiding questions for this research were, how did the new normal cause changes in consumption behavior in the inhabitants of rural communities before and after the pandemic? What have been the problems you have had accessing the educational service? What are the electronic tools respondents have access to respond to the needs of prolonged social distancing? Are the technological skills that respondents possess sufficient to respond to the demands of the new normal?

In this context, it is important to conceptualize a rural community Sorokin and Zimmerman (1929) defined the traits of rural communities as the predominance of agricultural work, low population density, poor differentiation, social mobility, and personal ties of a primary nature [7]. In 2006, Paul Cloke, a leading researcher in rural studies, contributed to the construction of the concept of a rural community, defining it as areas where extensive land uses predominate, there are small settlements that have a close relationship between construction and the extensive landscape, and ways of life are created characterized by an identity based on the qualities or attributes of the natural environment [8]. Considering the coincidences of these definitions, it can be conceptualized as a group of people who live in the countryside or in open and natural places and are in direct contact with flora and fauna. In the various rural communities of Durango, the inhabitants live from work in the field from clearing land for agricultural activities. In this sense, the results of this study will be a precedent in the creation and development of strategies to generate and promote social and economic well-being in rural communities.

In the northern regions of Mexico, rural communities face many poverty problems. Derived from the health emergency due to COVID-19, the percentage of the population with a labor income below the cost of the food basket (working poverty) reached its highest level in the third quarter of 2020 (46.0%) as of this date, it has presented a quarterly recovery trend (with the except of the third quarter of 2021 which presented an increase of 0.9 percentage points), in such a way that for the fourth quarter of 2021, shows a level of 40.3%, which implies a decrease at the national level of 5.7 percentage points. Working poverty also decreased in rural and urban areas compared to the third quarter of 2020 (4.5 and 6.1 percentage points) [9].

There are very isolated communities in rural areas, which aggravates the problem of poverty since, due to social marginalization, there is a lack of access to certain minimum community services. In the fight against poverty, different options can be implemented in the different communities where they carry out their activities and have increased in the face of the new normal [10].

Durango is one of the 32 states of Mexico, located in the north of the country with a territorial extension of 123,451.2 square kilometers, equivalent to 6.3% of the country's surface occupying, the fourth place about territorial extension, and is politically divided into 39 municipalities, with diverse economic, social, technological, cultural, and environmental characteristics. It is one of the states with high poverty levels and an average marginalization rate. Marginalization is an indicator that allows measuring of states, municipalities, and communities according to the different levels of deficiencies to cover their primary needs. In this sense, there is a great disparity in the municipalities, ranging from a "Very Low" degree of marginalization in the municipalities of Durango, Gómez Palacio, and Lerdo to a "Very High" degree where the municipalities of Canelas, Topia, Tamazula, and Mezquital are located, the latter in addition to being the municipality with the greatest marginalization in the state, it is located in position number 22 with "Very High" degree of marginalization about all the municipalities of the country [9].

The National Council for the Evaluation of Social Development Policy (CONEVAL) considers that people are in poverty when they have at least one social deprivation and do not have a sufficient income to meet their needs, and extreme poverty when people have three or more social deprivations and do not have a sufficient income to acquire a food basket [9].

The population living in the rural areas of the state represents 45% of the total, that is, 508,499 inhabitants; however, only 16.2% of the economically active population works in the primary sector of the economy, representing 94,850 people working in agriculture, livestock, forestry, fishing, and aquaculture [9].

The research presented was carried out in the rural communities of 3 of the municipalities of the state of Durango. New Ideal is located 120 kilometers from the state capital, with an approximate height of 1920 meters above sea level; it has a territory with a total area of 1882.38 square kilometers. Its population as of 2021 a number of people 29,099, with low social backwardness, with multidimensional poverty, that is, vulnerable due to deprivation, 33.2%; not poor and non-vulnerable, 11.7%; vulnerable by income, 5.8%; moderate poverty, 47.3%; and extreme poverty, 2.0%. With an educational lag of 20.5%, deficiency in access to health services at 14.2%, and lack of access to social security at 71.1%, has deficiencies in the quality and spaces of housing at 1.4%, and basic services in housing at 11.7%, and presents problems in food 15.5% [9]. See its location in Fig. 15.1.

Suchil has a territorial area of 1472.20 square kilometers and a height of 2000 meters above sea level; with a population of 6775 to 2021, it presents low social backwardness, with multidimensional poverty, that is, vulnerable due to deprivation of 16.9%, not poor and non-vulnerable 6.8%, vulnerable by income 4.8%, moderate poverty 57.6%, and extreme poverty 13.9%. With an educational lag of 23.4%, deficiency in access to health services at 12.1%, lack of access to social security at 75.5%, has deficiencies in the quality and spaces of housing at 12.1%, and basic services in housing at 22.7%, and presents problems in food 25.1% [9]. See its location in Fig. 15.1.

Vicente Guerrero at an altitude of 1950 meters above sea level. It has 363.93 square kilometers, with a population as of 2021 of 23,416 people. It has a very low social backwardness, with multidimensional poverty, that is, vulnerable due to deprivation, 24.8%; non-poor and non-vulnerable, 14.5%; vulnerable by income, 11.7%; moderate poverty, 47.7%; and extreme poverty, 1.3%. It presents an educational lag of 13.7%, deficiency in access to health services at 28.4%, lack of access to social security at 62.7%, has deficiencies in the quality and spaces of housing at 1.7%, and in basic services in housing at 3.2%, and presents problems in food at 9.1% [9]. See its location in Fig. 15.1.

Fig. 15.1 Location of the study municipalities (*Source* Own elaboration from INEGI [CONABIO] [2022])

In the municipality of Nuevo Ideal, 11 communities were studied: Astilleros de abajo, Chinacates, Esfuerzos Unidos, Guillermo Prieto, Guatimape, Las palmas, El Nuevo Porvenir, Raúl Madero, Villahermosa, Tejame, and the municipal seat of Nuevo Ideal. In the municipality of Suchil, 5 communities were investigated: San Miguel de la Michilia, San Juan de Michis, Mesa de San Antonio, Gualterio, and the municipal seat of Suchil. While in the municipality of Vicente Guerrero 5 communities, El Ancón, Graceros, San Francisco Javier, San José del Molino, El Pozo, and the municipal seat of Vicente Guerrero.

Now, in the face of the new normal due to the COVID-19 pandemic, it made people have changed their daily lives and the way they do tasks and work because people were forced to stay at home to preserve the health of their families and their own. Where new marketing strategies emerged to acquire the desired products and goods through virtual platforms and electronic tools, which allowed the economy not to stop but to continue moving not with the same agility but circulating so that individuals were not affected by the acquisition of goods to meet the needs presented [11].

Recent research presents a tendency to address the issue with the importance and transcendence that COVID-19 has had in the change of consumer behavior and its implications, as well as the socioeconomic impact on rural communities in the state of Durango in the face of the pandemic. In this sense, Matallana (2020), in the work business challenges after the Coronavirus COVID-19, raises the great question that everyone is asking, what will happen after COVID-19? It is clear that this virus brought with it many effects on the world economy; all countries or the vast majority have been harmed healthily, socially, and economically; no country was prepared to face this situation [12].

In this environment, the interest of this study arises, and the objective of the research is raised: to analyze the socioeconomic impact of the new normal due to the COVID-19 pandemic in the rural communities of 3 municipalities in the state of Durango.

15.2 Literature Review

15.2.1 Rural Communities in Mexico

Socioeconomic inequality has deepened since the arrival of the twenty-first century in Latin America and particularly in Mexico. Rural communities and primary economic activities such as the agricultural, forestry, and livestock sectors have been paralyzed and impoverished, reaching rates of social marginalization rarely seen before. As a result of this stagnation, rural communities and the sectors above, have changed, such as the rental of small plots of temporary irrigation or working them through the median system or the party, to name a few. On the other hand, the increase in the work of rural women due to the migration of men, the aging of the population and cheap labor, as well as the sale of agricultural products at a low price, has resulted in agricultural activity no longer being profitable for the population of rural communities [13].

In this same context, in rural communities, the pre-eminence of agriculture, increasingly technical and market-oriented, was demonstrated, which is why the link between rural localities and urban areas and developing sectors, as suppliers of agricultural products, has been definitive [14].

Carton de Grammont describes that this theoretical approach must provide information on all the activities carried out by the rural population that is usually linked to the tertiary sector, in addition to showing agreement with the complexity of the category where different aspects are involved such as the division of the countryside city, technology, rural non-agricultural population, gender, and ethnicity, among other factors [15]. Rural activity shows the new economic, social, political, and cultural scenarios that occur in the current countryside, specifically that linked to the labor market because although the link with the land is no longer the central axis of rural life, the different members of the families have had to resort to other types of jobs or migrate to other places in Mexico or the United States and Canada. The range of economic means for the rural population was expanded so that income was no longer only provided by the head of the family, but children, women, and young people entered the labor market diversifying income, and in the face of the new normal caused by the COVID-19 pandemic this increased [16].

In the specific case of Durango, it is a growing state. It stands out due to its strategic geographical location, and the richness of its natural resources. However, it is one of the states where rural communities have the highest poverty levels in the country. The population living in the rural areas of the state represents 45% of the total, that is, 508,499 inhabitants; however, only 16.2% of the economically active population works in the primary sector of the economy, representing 94,850 people working in agriculture, livestock, forestry, fishing, and aquaculture activities. Of the area dedicated to seasonal agriculture, approximately half is practiced in unproductive soils. On the other hand, there is an underutilization of the soils classified as suitable, with only 40% of use, mainly due to economic and social limitations. The primary sector, as a whole, has decreased its participation as part of the total economic activity of the state, and today in the face of the health contingency, this has increased [17].

15.2.2 Conceptualizing the New Normal

The long confinement with physical and social distancing has affected the world's population economically, socially, and culturally [18]. The concept of the new normal was introduced in 2008 to refer to the economic conditions that arose in the face of the financial crisis and the great global recession that had its origin in the United States. Today, in the face of the great pandemic and long confinement due to the new coronavirus, a new normal has been resumed, a concept that has been reborn as a result of this event. Normal means what is repeated most often; it is a scheme that serves as a norm or a social rule that will have to be followed regularly. The normal is the habitual or current characteristics that a population, social, or family group must observe, without exceeding or suffering when turning them into customs [6].

The New Normal has impacted the rural communities of the state of Durango, increasing the obstacles to socioeconomic development, such as the appropriate conditions to carry out each of the activities, access to education, commerce, satisfaction of their needs, and labor diligence thereby increasing poverty and marginalization.

15.2.3 What Is COVID-19?

COVID-19 (*coronavirus disease 2019*), also known as novel coronavirus disease, is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2); both the new virus and the disease were unknown before the outbreak broke out in Wuhan, China [19]. The most accepted transmission route of SARS-COV-2 between humans is from person to person by the respiratory route, with an incubation period of 1–14 days. It presents in most cases with a clinical picture corresponding to a self-limited upper respiratory infection, with a variety of symptoms according to risk groups, presenting a rapid progression to severe pneumonia and multi-organ failure, usually fatal in the elderly and with the presence of comorbidities [20].

Recalling the first outbreak of this virus, in December 2019, cases of life-threatening pneumonia were recorded in Wuhan, Hubei Province, China. As of January 2020, this disease dubbed COVID-19 had spread to 19 countries with 11,791 confirmed cases, including 213 deaths [21]. This disease has spread all over the world, becoming a pandemic. Unfortunately, as of today (October 2020), there is no specific vaccine for the virus, and the treatment is being supportive, with the addition of antivirals and other drugs, without a clear benefit to date. Many of the patients deteriorate rapidly and require intubation and mechanical ventilation, causing the collapse of the health system in many countries due to the lack of ventilators and acute beds [22].

Symptoms associated with COVID-19 include fever, cough, fatigue, pneumonia, headache, diarrhea, hemoptysis, and dyspnea. Although in some cases, the symptoms are mild or even imperceptible (asymptomatic), the contagion is very fast. Although the number of cases that could become serious or lethal is proportionally low, the phenomenon of rapid spread can collapse the health systems that provide care to the most serious patients. Additionally, if the virus is contracted by people with other diseases or older adults, the disease becomes serious and, therefore, hospitalization for specific medical care is urgent [23].

On 11 March 2020, the World Health Organization (WHO), through its Director-General Tedros Adhanom Ghebreyesus, issued the following statement: "WHO has assessed this outbreak over the past few days, and we are deeply concerned, both by the alarming levels of spread and severity of the disease and by the action to address it. That is why we have decided to decree the state of pandemic (COVID-19)" [19].

15.2.4 Implications of COVID-19 in Mexico

The implications of a pandemic are of various kinds: economic, educational, social, political, and psychological. COVID-19 has demonstrated the pressing transformation required by traditional education systems and the importance of having a virtual education strategy, as well as students and teachers with skills and competencies for teaching and learning in cyberspace. The invasion of this virus has left evidence of the requirements of a pandemic to educational institutions: flexibility, platforms, methodologies, and content adapted to training changes participated by the screens [24]. They are giving rise to mobility from the face-to-face to the non-face-to-face.

This education, mediated by technology, has called for an express learning effort for a large majority of teachers [25]. In this context, access to distance education, through digital technologies they have been unequal, specifically, for the most vulnerable social groups, in this case, rural communities [26]. In this line, students in rural areas have not been able to sustain themselves and be up to date with this model of virtual education, given that in their homes, internet access is limited or does not exist, and the telephone signal is poor or failing that there is no [27].

An analysis by the Senate of the Republic in Mexico argues that the COVID-19 pandemic has negatively affected the global economy, where the public health emergency has produced an economic shock that affects both producers and consumers [28].

This study states that the measures that countries have implemented to mitigate the pandemic affect the reduction of trade, interruptions in supply chains, lower productivity and investment, contraction of economic activity, and consequently the closure of businesses and the loss of jobs at all levels, that is, mitigation measures are inseparable from the economic impact.

The Economic Commission for Latin America and the Caribbean (CEPAL), in its report entitled "measuring the effects of COVID-19 to think about reactivation", states that the pandemic will affect both developed and emerging economies. There will be a synchronized recession, considered the deepest of the century. However, the effects will be asymmetrical, and the countries of Latin America and the Caribbean are expected to suffer what is considered a lost decade; this is a severe economic crisis [29].

In Mexico, the Bank of Mexico (Banxico) has implemented some measures to mitigate the economic impact of COVID-19 pandemic, including the reduction of the interest rate, auction of dollars to provide liquidity to the market, and the design of a financial support plan by the Ministry of Finance and Public Credit [30] was announced.

Authors such as Hausmann (2020), propose that the economic situation, as a result of the pandemic, will be even worse for developing economies since the public revenues of these countries depend significantly on exports of raw materials, tourism, and remittances; incomes due to pandemic are vulnerable to decrease, which impacts on the population of lower resources, coupled with the fact that strategic investments are moving their capital to safer places in the world with less economic impact [31].

On the other hand, Werner (2020), in the case of Mexico, states that there will be an additional impact derived from the slowdown in the United States economy, the reduction in trade and Foreign Direct Investment (FDI), tourism, and remittances [32].

Along the same lines, CEPAL affirms that Latin American countries will be affected in five areas (1) less activity by the region's trading partners (such as China and the United States); (2) fall in tourism; (3) disruption in value chains, a situation that would mainly affect Mexico and Brazil, which are major importers of intermediate goods for manufacturing sectors; (4) fall in the price of raw materials; and (5) increased risk aversion on the part of global investors and worsening financial conditions [33].

The pandemic has caused the contraction of both production and consumption in all economic sectors in the world, so consumption alternatives have gained momentum, and therefore, changes in consumption patterns have emerged. In this sense, e-commerce has played a fundamental role in increasing electronic transactions. In the case of Mexico, there have also been changes in consumer behavior due to the closure of physical stores [34]. The author found that accelerated growth is projected in the online shopping adoption curve, which would reach an adoption rate expected until 2022; meaning that 91% of people who make an electronic purchase make a second purchase in less than three months, a trend that will continue even after the lifting of the health emergency [34].

15.2.5 COVID-19 and the New Normal

The spread of **COVID-19** around the world has changed people's lifestyles. In Mexico, there has been an increase in consumption through the Internet and, specifically, in the use of electronic applications, which has driven the growth of electronic commerce and the increase in consumption of digital entertainment [35]. The global landscape in the wake of COVID-19 is forcing consumers and businesses to adapt rapidly to e-commerce and offer digital solutions in any range of products and services. Particularly in China, consumers are turning to buy food online daily [36].

On the other hand, due to the extension of the COVID-19 outbreak at the beginning of February, online sales of certain products have registered significant increases in countries such as South Korea, Italy, and Poland. South Korean online *retailer WeMakePrice* reported a 700% increase in consumption of health and food products compared to the same period in 2019. As for Poland, the products with the highest increase were fast-consuming goods, such as dry food, which showed a 160% increase in electronic sales. In the case of Italy, one of the countries with the highest number of registered cases of COVID-19, online sales registered a peak during February, in contrast to 2019; in February, digital commerce registered an increase of 101.5% [36].

This shows how certain economic sectors, such as fresh food, are venturing into the digital economy, with significant growth in the demand for online purchases since the consumption that traditionally occurred at the material point is now migrating in an accelerated way to the internet sales; as is the case of the sale of food, educational offer, medical care, financial services, and *on-demand* content on digital platforms.

15.2.6 Socioeconomic Impact

The new normal and the socioeconomic problem is marked by elements such as poverty, difficulty in accessing employment and education, and food problems among, others.

Vanclay F. [37] considers socioeconomic impacts to be changed in one or more of the following areas:

1. The way of life of people, that is, how they live, work, play, and interact with each other in everyday life.
2. Their culture: that is, their beliefs, customs, values, and language or the dialect.
3. The community; its cohesion, stability, character, services, and facilities.
4. Their political systems: the extent to which people can participate in decisions that affect their lives, the level of democratization taking place, and the resources provided for that purpose.
5. The environment: the quality of the air and water used by the population, the availability and quality of the food they consume, the level of danger or risk, dust and noise to which they are exposed, the adequacy of sanitation, their physical safety and their access to control over resources.
6. Health and well-being; health is a state of total well-being from the physical, mental, social, and spiritual point of view, and not only the absence of disease.
7. The personal and property rights, especially if people are economically affected or suffer personal disadvantages that may include the violation of their civil liberties.
8. Their fears and aspirations, their perceptions about their safety, their fears about the future of their community, and their aspirations both for their future and that of their children [37].

15.3 Materials and Methods

This study began with a literature review on the New Normal, Socioeconomic Impact, COVID-19 and the New Normal and Consumption Behavior in Rural Communities Caused by the COVID-19 Pandemic. This review founded the theoretical foundation. The focus of this work is quantitative, where the variables New Normality, Socioeconomic Impact, and consumption behavior were analyzed as a technique the survey was used and as an instrument the questionnaire for the collection of information. Considering the above and according to the problem raised, the sample was determined, and the fieldwork was carried out. Finally, the data were analyzed, the results were discussed, and research conclusions were drawn [38].

15.3.1 Population

The population is made up of people from rural communities in 3 of the municipalities of the state of Durango, Nuevo Ideal, Suchil, and Vicente Guerrero. 21 locations were visited: Astilleros de abajo, Chinacates, Esfuerzos Unidos, Guillermo Prieto, Guatimape, Las palmas, El Nuevo Porvenir, Raúl Madero, Villahermosa, Tejame, San Miguel de la Michilia, San Juan de Michis, Mesa de San Antonio, Gualterio, El Ancón, Graceros, San Francisco Javier, San José del Molino, el Pozo, as well as Nuevo Ideal, Suchil, and Vicente Guerrero.

Sample. The sample was determined using the formula for finite populations.

$$= \left(z^2_{(1-\alpha/2)}p(1-p)\right)/\left(d^2(N-1)+z^2_{(1-\alpha/2)}p(1-p)\right)$$

where:

n = sample size.

N = population size.

= critical Z value, calculated in the tables of the area of the normal curve. For a confidence level of 95%.

p = is the proportion of the characteristic of interest and can be obtained from similar studies or pilot tests. A value of $p = 0.5$ provides the maximum sample size.

d = absolute accuracy level. Referring to the amplitude of the desired confidence interval in determining the average value of the variable under study.

It is obtaining a sample of 218 people to survey with a confidence level of 95% and a margin of error of 5%. The inclusion criteria included people from rural communities from 18 years old. Non-probabilistic sampling was used for convenience to favor the approach to the study subject [39], considering the conditions of social distancing caused by the health contingency due to COVID-19.

15.3.2 Type of Research

It is a study with a non-experimental design, which allows the researcher to have an approach to the study variables hypothetically speaking as real and gives allows systematizing the results obtained; cross-sectional, with the collection of information carried out in a single period; a descriptive scope, which specifies the important properties and characteristics of the phenomena being studied and describes the styles of a group or population. Explanatory, they try to establish the origins of the events or phenomena that are studied and correlational, which associates the variables according to a predictable model for a group or population [39].

15.3.3 Survey Design and Instrument Design

The survey was carried out in person and virtually; that is, for the communities near the city and with accessibility conditions, the face-to-face survey was used, going to each locality to carry out the fieldwork while for the communities with accessibility difficulties to apply it in person, the survey was done virtually for the collection of the virtual information, a form in *Google Form* was used and shared using social networks such as *WhatsApp and Facebook*. The information collection was carried out in December 2021 and January 2022.

The design of the instrument was carried out with questions according to the definition of each variable of the study, for which, after a literature review, two questionnaires were chosen and adapted to the subject of study, one of them from INEGI on the Economic Impact Generated by COVID-19 in Companies (ECOVID-IE) 2021 [40], and moreover created by the Madrid City Council, COVID-19 Survey 2020 Madrid Health [41], used and tested, complemented by questions created by the researchers considering the literature reviewed; some of them were open responses, and in others, the Likert scale was used. The questionnaire consists of 110 questions to analyze each of the variables in question. In the structure of the questionnaire, first of all, the objective pursued in the application of the same is explained, and the importance of responding to it by the respondents; it is also explained that the answer is anonymous and under the principles of privacy. To validate the questionnaire, a pilot test was carried out in which experts in the field participated, whose feedback allowed the strengthening of the instrument. For the processing and analysis of the data, the SPSS V25 tool was used considering a statistically significant value of 0.05.

15.3.4 Reliability Analysis

To verify the reliability or internal consistency of the instrument, Cronbach's Alpha was used. Reliability of 0.917 was obtained, which is considered strong reliability.

15.4 Results

This section shows the study results and recognizes the coincidences of these with the theoretical–empirical perspectives of research carried out in different environments. In the sociodemographic characteristics of the inhabitants of the rural communities that were analyzed, in the age by group considering the inclusion criterion, 28.9% were found in age from 15 to 20 years, 19.7% from 21 to 25 years, and 10.1% in the group of 41 to 45 years, these being the groups with the highest prevalence. It was also found that 54.1% are women while 45.9% are men. Marital status shows that 46.8% are single, 30.3% married, 13.8% in a free union, 7.3% widowed, and 1.8% divorced. The educational level reveals that 39% are professionals, 33% are in high school, 16.5% are secondary, 4.6% have master's degrees, 3.2 primary, 0.9% doctorate, and 2.8% have no studies.

Occupational activity shows that 31.2% are engaged in trade, 28.4% in education, 9.2% work in industry, 7.8% in agriculture, 6% in cattle raising, and 16.1% in other types of activity; concerning the latter, the activity that predominates is domestic work by women. From the occupational situation of the population of the rural communities studied, the results indicate the importance of trade as occupational work, where traders work individually, are people linked to the sector served since always, have a broad vocation of permanence, even when they are prepared people, lack the knowledge for trade and on the other hand have no interest in preparing in commercial issues, which has an impact on modernizing and professionalizing, making use of new technologies. In this same sense, the agricultural activity developed by the rural population is traditional; the economic level has prevented the acquisition of agricultural machinery that facilitates agricultural practice and increases productivity. In the case of domestic work by rural women in these localities, they do this work in the houses located in the city; they are people who come and go daily because they also have to take care of their families. This shows the work carried out daily by the rural population to survive the health events in recent months.

The socioeconomic status of the people surveyed, 75.7% belong to a medium level, 15.6% a low level, and 8.7% to a high level. In the employment situation, 70.2% are working, while 29.8% do not currently have a job. As for economic dependence, the results show that 49.5% have more than seven dependents. These results show the effort of the inhabitants to seek daily sustenance to support the family, even if, to achieve this sustenance, they have to carry out their work in insecure and informal conditions, with low or irregular incomes, long working hours, and lack of access to information, markets, financing, training, and technology. These results are shown in Table 15.1.

Concerning the effects caused by the COVID-19 pandemic on the inhabitants of rural communities in aspects such as employment, economy, use, and acquisition of computer equipment, which complements this characterization. The results obtained are presented below: was found that 83.9% of the people surveyed have children or family students, professional 28%, in high school 16.1%, in middle school 14.2%, in preschool 13.8%, in elementary school 11%, 1.4% with master's degree, and 0.5% Ph.D. In this same sense, 22.9% during the health contingency, suspended their studies. The diversity of rural contexts that occurred in the face of the health contingency where for a part of the rural population, the study options through technological resources could be a feasible alternative to have their permanent access in their homes, for another part of the rural inhabitants this availability it was occasional, costly and in many cases unattainable, influencing the permanence or absence of these in educational institutions.

Table 15.1 Socioeconomic characteristics of the inhabitants of the rural communities of the state of Durango surveyed

Indicator	*Characteristics*	*Value*	*Indicator*	*Characteristics*	*Value*
Age	15–20	28.9% (63)	Occupation	Agriculture	7.8% (17)
	21–25	19.7% (43)		Cattle raising	6% (13)
	26–30	8.3% (18)		Apiculture	0.5% (1)
	31–35	6.9% (15)		Mining	0.9% (2)
	36–40	6.4% (14)		Commerce	31.2% (68)
	41–45	10.1% (22)		Education	28.4% (62)
	46–50	6.4% (14)		Industry	9.2% (20)
	51–55	6% (13)		Other	16.1% (35)
	56–60	1.8% (4)	Socioeconomic status	High	8.7% (19)
	60 or more	5.5% (12)		Middle	75.7% (165)
Gender	Female	54.1% (118)		Low	15.6% (34)
	Male	45.9% (100)	Employment status	Yes	70.2%(153)
Marital status	Married	30.3% (66)		No	29.8% (65)
	Unmarried	46.8% (102)	No. of economically dependent	1	16.1% (35)
	Common-law marriage	13.8% (30)		2	17% (37)
	Widower	7.3% (16)		3	10.6% (23)
	Divorced	1.8% (4)		4	6% (13)
Educational level	No studies	2.8% (6)		5	0.5% (1)
	Elementary school	3.2% (7)		6	0.5% (1)
	Middle school	16.5% (36)		7 or more	49.5% (108)
	High school	33% (72)			
	Professional	39% (85)			
	Master's degree	4.6% (10)			
	PhD	0.9% (2)			

Source Own elaboration based on the survey data (2022)

In the labor part, during the health contingency, 50.9% lost their job, in this case, directly the person surveyed or a relative. This data is significant for the economy of rural communities, affecting family sustenance; the unemployment given has been the product of the security measures established by the organizations in the face of the COVID-19 pandemic. In this same line, in the labor situation in which they were before the contingency, 39.9% worked and studied, 31.7% were salaried workers, and 18.3% were self-employed workers; this shows the initiative of the rural population in the search for common welfare through employment and academic preparation. To the sector where they provided their services, 37.6% in the public sector, 36.2% did not work outside the home, this being understood as a dedication to activities such as agriculture, cattle raising, and apiculture, to mention some of them; 23.4% to the private sector and a mixed 2.8 (public and private); 39.4% say that the pandemic has not affected them at work.

However, 12.4% are doing work from home (*Home office*), 17% say that their work at home has increased considerably, and 11.5% were affected by reducing their salary and working hours. With this, the economic aspect is affected, by the monthly income of their household, showing 35.8% that they reach the end of the month with some ease, 27.5% with some difficulty, 12.4% with ease, 9.2% with difficulty, 8.7% with great difficulty, and 6.4% with great ease. The above results affect the economy of rural inhabitants, increasing the shortages in their homes, the lag in factors such as education, access to health services, access to social security, deficiency in the quality and spaces of housing, basic services in housing, problems in food and with it the increase in poverty. This data is shown in Table 15.2.

The aspect of computer equipment and technological tools has been a relevant element in this health contingency caused by the COVID-19 pandemic, and the rural communities of the state of Durango have not been the exception. In this sense, in internet access, research shows that 47.2% of the people studied use data and use WIFI, while 35.8% only WIFI. Regarding the acquisition of computer equipment, 30.3% acquired a desktop computer due to the needs presented by social distancing, 11.9% desktop and cellular computers, 9.6% laptop, and 9.6% cellular. They use digital platforms, to carry out school activities 52.8%, 23.4% for commerce, and 17.9% for commerce and school. These data indicate that, despite economic deprivation and adversity, information and communication technologies, computers, and cell phones are part of the daily life of the inhabitants of the rural communities studied and who acquired and adapted them to remain and face the demands of the new normal. These results are presented in Table 15.3. The results obtained from the descriptive statistics are presented below; the findings found are explained and described using the correlations of the variables and factors used in this study using the Pearson test.

Table 15.2 Complementary aspects to the characterization of the inhabitants of the rural communities of the state of Durango surveyed

Indicator	*Characteristics*	*Value*	*Indicator*	*Characteristics*	*Value*
Education			**Employment**		
Study or have a child, family member studying	Yes	83.9% (183)	During contingency, lost job or a family member	Yes	50.9% (111)
	No	16.1% (35)		No	49.1% (107)
Level of education of child or relative	None	15.1% (33)		Worked (salaried)	31.7% (69)
	Preschool	13.8% (30)		Worked (self-employed)	18.3% (40)
	Elementary school	11% (24)		Retired or pensioner (previously worked)	3.2% (7)
	Middle school	14.2% (31)		Unemployed, he had worked before	2.8% (6)
	High school	16.1% (35)		Unemployed, looking for my first job	1.4% (3)
	Professional	28% (61)		Studied and worked	39.9% (87)
	Master's degree	1.4% (3)		Performed unpaid domestic work	2.8% (6)
	PhD	0.5% (1)	Sector in which I worked	I didn't work outside the home	36.2% (79)
Suspended studies during the contingency	Yes	22.9% (50)		Private	23.4% (51)
	No	77.1 (168)		Public	37.6% (82)
Economic				Mixed	2.8% (6)
Your total household income how do they usually make ends meet?	With great difficulty	8.7% (19)	Professionally, how the pandemic has affected him	I have been fired	3.2% (7)
	With difficulty	9.2% (20)		I am self-employed, and I have had to cease my activity	8.7% (19)

Indicator	*Characteristics*	*Value*	*Indicator*	*Characteristics*	*Value*
	With some difficulty	27.5% (60)		I have suffered a reduction in salary/working hours	11.5% (25)
	With some ease	35.8% (78)		It has greatly increased my workload	17% (37)
	With ease	12.4% (27)		Now I do telework	12.4% (27)
	Very easily	6.4% (14)		It has not affected me at all	39.4% (86)
				I have been hired	7.8% (17)

Source Own elaboration based on the survey data (2022)

Table 15.3 Acquisition of computer equipment and technological tools by the inhabitants of the rural communities of the state of Durango surveyed

Indicator	*Characteristics*	*Value*	*Indicator*	*Characteristics*	*Value*
Internet access	Data	17% (37)	Use of digital platforms in:	Commerce	23.4% (51)
	Data, WIFI	47.2% (103)		School	52.8% (115)
	WIFI	35.8% (78)		Commerce, School	17.9% (39)
Acquired copy equipment	Laptop	9.6% (21)		School, entertainment	0.5% (1)
	Desktop computer	30.3% (66)		Commerce, entertainment	0.9% (2)
	Cellular	9.6% (21)		Entertainment	0.5% (1)
	Laptop, cellular	2.3% (5)		School, Work	4.1% (9)
	Laptop, Desktop computer, cellular	3.7% (8)			
	Desktop computer, cellular	11.9% (26)			

Source Own elaboration based on the survey data (2022)

15.4.1 *Descriptive Statistics for the Variable Socioeconomic Impact*

Table 15.4 shows the factors used to analyze the Socioeconomic Impact variable: Technological Tools, Employment, Technology, Migration, Health, Economic, Consumption Patterns, Education, and Technological Knowledge, which were defined from the review of the literature review.

15.4.2 *Correlations of Research Variables and Factors Used for Their Study*

Table 15.5 shows the association of the factors used (Technological Tools, Employment, Technology, Migration, Health, Economic, Consumption Patterns, Education, and Technological Knowledge) to analyze the variable dependent on Socioeconomic Impact, observing a statistically significant association (bilateral sig. less than 0.05), fulfilling the assumption of positive linearity between each of the factors.

Figure 15.2 shows how the new normal has impacted the rural communities studied socioeconomically, observing a great impact on the

Table 15.4 Descriptive statistics for the Socioeconomic impact variable

Socioeconomic impact	*Average*	*Desv. Standard*	*N*
Technological tools	1.74	0.738	218
Employment	2.54	0.503	218
Technology	2.17	0.411	218
Migration	1.56	0.498	218
Health	3.47	0.256	218
Economic	3.68	0.525	218
Consumption patterns	3.06	0.544	218
Education	2.38	0.315	218
Technological Knowledge	1.74	0.768	218

Source Own elaboration based on the survey data (2022)

factors: employment, education, health, the use and knowledge of information and communication technologies, and changing consumption patterns and migration used for this study. The impact has been significant, which has increased their vulnerability and lag in the indicators above.

15.5 Discussion

15.5.1 Descriptive Statistics

The results obtained in the descriptive statistical analysis indicate that the socioeconomic impact variable is significantly represented by the Economic factors with a mean of (3.68 ± 0.5), followed by the Health factor with a mean of (3.47 ± 0.3), then the Change of Consumption Patterns factor with an average of (3.06 ± 0.5), in this same order, the Employment factor with an average of (2.54 ± 0.5), the Education factor with an average of (2.38 ± 0.3), the Technology factor with an average of (2.17 ± 0.4), Technological Tools with an average of (1.74 ± 0.7), Technological Knowledge with an average of (1.74 ± 0.8) and finally the Migration factor with an average of (1.56 ± 0.5).

These data show that the rural communities investigated are economically affected, increasing poverty in these localities. This is a product of how they have been affected in their health, being infected by the

Table 15.5 Correlation of the Socioeconomic impact variable and the factors used for its analysis

		Socioeconomic impact	*Tech. Tools*	*Employment*	*Technology*	*Migration*	*Health*	*Economic*	*Consumption pattern*	*Education*	*Tech. Knowledge*
Socioeconomic impact	Pearson (r)	1	0.162*	0.587**	0.297**	0.430**	t.308**	0.518**	0.320**	0.475**	0.187**
	Sig bilateral		0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006
	N	218	218	218	218	218	218	218	218	218	218
Technological Tools	Pearson (r)	0.162*	1	0.115	0.277**	−0.055	0.001	−0.164*	0.187**	0.161*	0.781**
	Sig. bilateral	0.017		0.089	0.000	0.422	0.990	0.015	0.006	0.017	0.000
	N	218	218	218	218	218	218	218	218	218	218
Employment	Pearson (r)	0.587**	0.115	1	0.105	0.239**	-0.010	0.162*	−0.073	0.188**	0.178**
	Sig. bilateral	0.000	0.089		0.124	0.000	0.886	0.017	0.285	0.005	0.008
	N	218	218	218	218	218	218	218	218	218	218
Technology	Pearson (r)	0.297**	0.277**	0.105	1	−0.201**	0.211*	0.020	−0.105	0.054	0.259**
	Sig. bilateral	0.000	0.000	0.124		0.003	0.002	0.765	0.122	0.425	0.000
	N	218	218	218	218	218	218	218	218	218	218
Migration	Pearson (r)	0.430**	−0.055	0.239**	−0.201**	1	−0.054	0.035	0.010	0.052	−0.040

		Socioeconomic impact	*Tech. Tools*	*Employment*	*Technology*	*Migration*	*Health*	*Economic*	*Consumption pattern*	*Education*	*Tech. Knowledge*
	Sig. bilateral	0.000	0.422	0.000	0.003		0.423	0.604	0.886	0.448	0.552
	N	218	218	218	218	218	218	218	218	218	218
Health	Pearson (*r*)	0.308**	0.001	−0.010	0.211**	−0.054	1	0.170*	−0.133	0.237**	0.053
	Sig. bilateral	0.000	0.990	0.886	0.002	0.423		0.012	0.050	0.000	0.432
	N	218	218	218	218	218	218	218	218	218	218
Economic	Pearson (*r*)	0.518**	−0.164*	0.162*	0.020	0.035	0.170*	1	−0.073	0.127	−0.211**
	Sig. bilateral	0.000	0.015	0.017	0.765	0.604	0.012		0.286	0.061	0.002
	N	218	218	218	218	218	218	218	218	218	218
Consumption Patterns	Pearson (*r*)	0.320**	0.187**	−0.073	−0.105	0.010	−0.133	−0.073	1	0.065	0.217**
	Sig. bilateral	0.000	0.006	0.285	0.122	0.886	0.050	0.286		0.338	0.001

(continued)

Table 15.5 (continued)

		Socioeconomic impact	*Tech. Tools*	*Employment*	*Technology*	*Migration*	*Health*	*Economic*	*Consumption pattern*	*Education*	*Tech. Knowledge*
	N	218	218	218	218	218	218	218	218	218	218
Education	Pearson (r)	0.475**	0.161*	0.188**	0.054	0.052	0.237*	0.127	0.065	1	0.149*
	Sig. bilateral	0.000	0.017	0.005	0.425	0.448	0.000	0.061	0.338		0.028
	N	218	218	218	218	218	218	218	218	218	218
Tech. Knowledge	Pearson (r)	0.187**	0.781**	0.178**	0.259**	−0.040	0.053	−0.211**	0.217**	0.149*	1
	Sig. bilateral	0.006	0.000	0.008	0.000	0.552	0.432	0.002	0.001	0.028	
	N	218	218	218	218	218	218	218	218	218	218

*The correlation is significant at level 0.05 (bilateral)
**The correlation is significant at level 0.01 (bilateral)

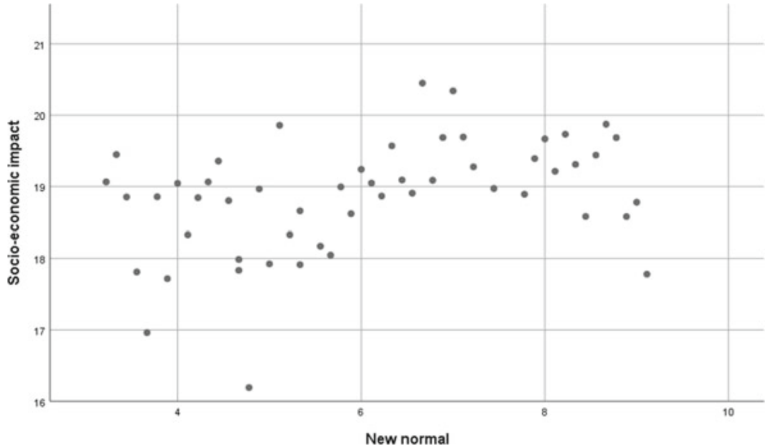

Fig. 15.2 Graph of dispersion points of the socioeconomic impact and the new normal (*Source* Own elaboration based on the survey data [2022])

COVID-19 disease and consequently having to isolate themselves apart from the social distancing that has been incurred. Likewise, they were affected in their employment, before which they are looking to carry out activities that allow them to get out of this situation. This coincides with what was mentioned by [10], who mentioned that to combat poverty that has increased with the new normal, different activities can be implemented in rural localities to improve their economic condition. These effects are also similar to those obtained by [31], who comments that income has decreased due to the closure of businesses or the decrease in working capital, which has impacted the population with fewer resources.

The Change in Consumption Patterns has been propitiated by the restrictions caused by social distancing; in this case study, the inhabitants of rural communities experienced forced by the situation and limited by the use of information technologies, from the little access to computer equipment and technological tools, however, they entered the dynamic above, this change occurred when the inhabitants made use of electronic commerce to pay for services such as water, electricity, telephone, pay-TV, taxes; digital content such as entertainment, information, education, culture; buy medicine, food, to name a few. The platforms they used were Amazon, Mercado Libre, Spotify, and Netflix. This confirms what [34] has stated, who says that in Mexico, there have been changes in consumer behavior due to the closure of physical stores. However, it is important to mention that the change of patterns that has arisen has been carried out with great difficulty due to the lack of adequate and sufficient technology.

Another important factor is Migration, which in this study shows that there were people from these rural communities who had to emigrate to the United States to seek to survive for their families.

When it comes to education, rural communities were affected by the closure of schools and going home and working virtually; in this sense, many families were limited and being carried out in this activity, not having the technology and the appropriate equipment. In some cases, they had to suspend their school activities and postpone them until the right conditions were in place.

The use of Technological Tools and Technological Knowledge also impacted Education, on the economic activities carried out by the inhabitants of rural communities because they lack it and, in the best of cases, have the Technological Tools and basic Technological Knowledge that has decisively influenced the socioeconomic impact of the rural communities studied.

15.5.2 Correlations

The results show the correlation between the Socioeconomic impact variable and the factors used for its analysis. They were showing a correlation of the factors used (Technological Tools, Employment, Technology, Migration, Health, Economic, Consumption Patterns, Education, and Technological Knowledge) to analyze the variable dependent on Socioeconomic Impact, observing a statistically significant association (bilateral sig. less than 0.05), fulfilling the assumption of positive linearity between each of the factors.

These results indicate how the socioeconomic impact derived from the COVID-19 Pandemic has particularly affected rural communities in Durango, especially young people and women. Confirming the impact on aspects such as employment, education, health, migration, the use of technological tools, technological knowledge, and technology itself, where this has caused a reduction in household income and has forced to reduce the satisfaction of their primary needs.

The companies and institutions had to close due to the security measures, and the workers had to return to their homes to continue working there, but in other cases, they were dismissed; on the other hand, the inhabitants of these rural communities that are dedicated to the production and commercialization of their agricultural, cattle raising and apiculture products, they also had to stop in the face of social distancing, caused by the health contingency, and this came to generate economic problems in the homes of rural communities.

Education is another aspect that has been affected as a result of what has already been mentioned, a significant educational lag has been generated in these localities, and even when there is a high level of resilience in their inhabitants, it is relevant that help is provided by government agencies to overcome the obstacles to access to education while the pandemic ends.

It is imminent that the use of technology has been a great facilitator to carry out commercialization strategies, coinciding with what has been stated by [24]. Who mentions that information technologies have been covering the needs of the population through virtual platforms and electronic tools, but we must not forget that for rural communities, this has been a great limitation. On the other hand, and implicitly the lack of coordination on the part of the different governmental instances that can implement strategies for social and economic reactivation in these communities [33].

15.6 Conclusions

Under the conditions of a context of inequality in which the COVID-19 pandemic is developing, it has caused a socioeconomic impact with different characteristics in the rural communities of Durango. The study shows that the pandemic showed that inequalities generate a setback in all aspects, but especially in employment, health, and education, so it is important to create and implement strategies that allow vulnerable rural communities to recover and get ahead.

Of the population of the rural communities studied, 50.9% lost their jobs, being economically affected, causing a reduction in their income and seriously affecting their family nucleus; highlighting that, of the people investigated, 49.5% have 7 or more economically dependent. This was caused by the temporary closure of companies due to the social distancing required by the authorities as a security measure, and in other cases, definitively by the crisis caused by the COVID-19 pandemic; likewise, this also caused unemployment and lack of opportunity to get a new job.

Under the circumstances, the rural inhabitants were underemployed; this led to their income being very low and on the other hand, the limitation of access to social security. It is important to mention that rural workers are vulnerable people; their rights, in many cases, are not recognized or respected; in addition, they are not protected by labor law.

Education was also affected by the closure of schools in rural communities. El 22.9% of the sample analyzed suspended their studies during the health contingency due to the lack of computer equipment and technological tools to take the virtual classes; others had to work to help support their family when their parents became unemployed, increasing the educational lag that already existed. In this same line, the limitations of mobility and the closure of schools mentioned above increased the burden of care work within the homes, incurring this unbalanced in the women of the communities studied.

The health factor is undoubtedly the most important causal element in the face of this event that has come to mark the socioeconomic action of rural communities in the state of Durango, Mexico, and the world. This, in turn has indirectly affected education, employment, and other indicators of this study. In this same context, the communities studied lack health centers, and when there are health emergencies to receive care, they have to move to the state capital.

On the other hand, 52.8% of the sample made use of information technologies to carry out school activities while 23.4% for commercial activities, indicating that technology, tools, and technological knowledge have become necessary to face the challenges and demands of the new normal, where for rural communities they have represented an obstacle to continue forward, causing an economic, and social recession in these localities.

Work at home has increased considerably, the number of hours and the intensity of working hours has doubled, and family members have had to enter to perform not only daily activities but also domestic activities, for example, school and the *home office* that since the pandemic moved to the home.

The change in consumer patterns has been another of the aspects generated by the restrictions raised as a result of social distancing. The inhabitants of rural communities experienced it forced by the situation and were limited by the use of information technologies. However, faced with the need to pay for basic services such as water, electricity, telephone, pay television, taxes; digital content such as entertainment, information, education, and culture; buy medicine and food, to mention some, broke paradigms and made electronic transactions even with the uncertainty and distrust of technological advancement.

Another important factor is migration; the results indicate that there were people from these rural communities who had to emigrate to the United States to seek subsistence and give a livelihood to their families.

Finally, it is important that the different government agents must establish appropriate strategies that help counteract these effects in rural communities and participate in a social and economic reactivation that promotes well-being in the rural population.

15.7 Future Lines of Research

Comparative studies of socioeconomic impact in the rural communities of the different states that make up the Mexican Republic.

Comparative studies of socioeconomic impact in rural communities in the state of Durango with a gender perspective.

Comparative studies of socioeconomic impact in rural communities in the different states make up the Mexican Republic with a gender perspective.

Acknowledgements This study was carried out with the support of the Tecnológico Nacional de México, a product of the project: Impact of the new normal in the rural communities of the state of Durango to each of the people who directly and indirectly provided their support to carry it out.

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PART VII

Digital and Sustainable Agendas: Overview and Foresight

CHAPTER 16

Digitalization of Manufacturing Development in Latin America and the Caribbean

Fernando Santiago, Clovis Freire, and Alejandro Lavopa

16.1 Introduction

This chapter contributes to debates around the Fourth Industrial Revolution (4IR) and its implications for industrial development in Latin America and the Caribbean. More specifically, it takes stock of observed trends toward the digitalization of global manufacturing activities and explores factors that influence the uptake of 4IR in the Latin America and

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S. Estrada (ed.), *Digital and Sustainable Transformations in a Post-COVID World*, https://doi.org/10.1007/978-3-031-16677-8_16

Caribbean region's manufacturing sectors. While the discussion addresses general developments in the region, special attention is paid to the situation in the region's largest industrial economies, namely Argentina, Brazil, and Mexico.

Unlike other recent scholarly contributions that focus on individual countries or firms [1–7], this chapter sheds light on the potential of countries in Latin America and the Caribbean region to leverage 4IR as a driver of industrialization, job creation, and sustainable and equitable growth.

Our findings offer insights into the differences in the ability of individual Latin American and Caribbean countries to endorse 4IR. These differences are reflected in the countries' distinct levels of development in terms of their domestic industrial base, human capital, infrastructure, and regulatory environment, as well as in their level of electrification and digitalization—which has a direct impact on connectivity, broadband access, and applications of advanced digital production (ADP) technologies—shortages in investment and limited efforts in research and development (R&D) and innovation. The region lags other developed and developing regions in 4IR preparedness.

After this introduction, Sect. 16.2 takes stock of ongoing debates around 4IR, their likely implications for global manufacturing activities, and the prospects of industrial development in developing countries. Section 16.3 presents the main data sources used in our assessment. The analysis draws extensively on background work carried out by [8, 9], and [10]. The evidence combines macro-level data from publicly available databases, with data from a firm-level survey conducted as part of a larger study on the resilience of manufacturing firms in developing countries during the COVID-19 pandemic. Building on these datasets, Sect. 16.4 provides new insights into the level of engagement of Latin American countries with 4IR technologies and reviews some of the factors shaping this engagement. Section 16.5 discusses the findings considering the available literature on the adoption of 4IR technologies in the region and other developing countries. Finally, Sect. 16.6 concludes with some policy recommendations and suggestions for further research.

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16.2 Implications of the Digitalization of Manufacturing on Development

There has been much debate surrounding 4IR. Its advocates assert that firms and countries should hasten to endorse 4IR as they otherwise risk losing out on substantial cost reductions and savings in terms of resource utilization, opportunities to adopt new value creation processes and innovative business models, novel sources of employment, and other potential benefits associated with 4IR [11, 12]. Critics of the 4IR emphasize the unconvincing historical evidence put forward to support the periodization of industrial development, which has led to the current 4IR as the most advanced stage of industrial development.[1] In its original formulation, the notion of Industry 4.0 was a carefully crafted communication strategy and marketing campaign intended to rally the support of the German population for an ambitious process of industrial modernization necessary to sustain the global competitiveness and leadership of Germany's manufacturing sector [15, 16]. The true revolutionary or evolutionary nature of 4IR remains a matter of research and empirical confirmation [1, 17], notably because the origins of several 4IR-related technologies date back several decades [17]. In this chapter, the path toward 4IR is understood as a cumulative capacity-building process in areas such as productive and innovative capacities. The heterogeneous economic structures in developing countries are expected to significantly influence their ability to tap into the rapid trends toward the digitalization of manufacturing.

Recent contributions to the literature claim that the distinctive feature of industrial development in the 4IR era is the increasing trend toward the fusion and co-evolution of ADP technologies with biotechnology or new materials, among other technologies [8, 17]. Andreoni et al. [17] assert that the 4IR's disruptive power lies precisely in this possibility

[1] In a recent piece, Motta et al. [1] refer to the work of Perez [13] who, based on the notion of technological revolutions from a neo-Schumpeterian perspective, identifies five technological revolutions; hence, according to Perez, the 4IR is, in fact, the sixth revolution experienced by capitalist economies. Alternative interpretations suggest that global society is marching toward a so-called Society 5.0 [14], one that follows from hunting society (Society 1.0), agricultural society (Society 2.0), industrial society (Society 3.0), and information society (Society 4.0). In essence, Society 5.0 describes "A human-centered society that balances economic advancement with the resolution of social problems by a system that highly integrates cyberspace and physical space" [14]; that is, it goes beyond the realm of economic activities more generally, and of industrial development, specifically.

to fuse individual technologies to create complex integrated technology systems with increasing transversal areas of application. The result is the emergence of never-before-seen levels of complexity and interdependency between traditionally separate and specialized fields of knowledge, bringing together the physical (manufacturing) with the virtual (digital) realms in close interaction with each other and between these realms and humans.

As the relevance of ADP technologies in global manufacturing is expected to increase, manufacturing firms are likely to witness a cumulative process of convergence and integration of digital and manufacturing systems, a growing shift toward mass customization, and other major changes in the organization and operation of production and global value chains (GVCs) [18, 19]. Such technological, market, and organizational dynamics can induce considerable transformations beyond the productive realm, with broader impacts on social, ecological, and economic activity.

The ability of developing countries to effectively navigate the changing environment and benefit from its effects on industrial development by establishing the necessary conditions to address the technological changes brought about by 4IR remains uncertain [8, 20]. Recent contributions to the literature question whether 4IR might weaken developing countries' prospects for industrialization, or whether it can open new avenues for manufacturing and export-led growth [21]. Similarly, while 4IR might contribute to the upgrading of certain economies and increase their prospects of overcoming the middle-income trap [22], success is not guaranteed, as the process of technological upgrading and the upskilling of the workforce may affect these economies' competitiveness relative to other low-cost countries or industries, thus jeopardizing the transition toward the accumulation of higher levels of technological capability. Moreover, there is a real risk that developments in frontier technologies, including ADP technologies, could either increase inequalities, exacerbate existing ones, or even create new digital divides across the globe [10].

Countries can only build and strengthen the necessary capabilities to endorse the anticipated new technological paradigm of 4IR by systematically engaging with industrialization [9]. This conclusion attests to the importance of learning-by-doing and the path-dependent dimensions of industrialization [23, 24], which set the framework conditions for the adoption of ADP technologies of the 4IR in a country or region [25]. In tandem with industrialization, the diffusion of 4IR technologies is only possible through digitalization. Thus, improving digitalization, particularly of small and medium enterprises (SMEs), would likely boost productivity, thereby contributing to bridging development gaps between and within countries.

Developing countries should not expect to leapfrog effortlessly from a low industrial development base and skip the fundamental stages of capability building to adopt and immediately capitalize on 4IR [22]. Instead, they must engage in gradual and sustained learning processes, developing and accumulating the necessary technological capabilities to adopt and adapt ADP technologies. Developing countries should promote structural change and invest in the capabilities needed to endorse—and hopefully succeed—amidst new technological and competitive market conditions [8]. Proactive policies should contribute to the establishment of the necessary framework conditions to leverage 4IR and guide industrial development toward increased welfare, inclusiveness, and sustainability [8–10, 26].

The emergence of 4IR compels developing countries to align their development strategies along two dimensions [21]. The first 4IR strategy pursues the establishment of framework conditions to help domestic agents endorse 4IR and offset any potential disruptions. In addition to policies promoting the upskilling and reskilling of the workforce, efforts must be undertaken to support firms in coping, adapting, and eventually thriving in the face of changing market and technological conditions by creating spaces for new businesses, jobs, and markets [8]. Second, developing countries should build 4IR strategies based on a broad understanding of production beyond manufacturing activities, thereby expanding the sources of productivity and job creation.

That is, 4IR introduces new dimensions to industrial and technology policies as well as to investment in what Andreoni et al. [27, p. 171] refer to as "foundational productive capabilities",[2] or capabilities that enable learning about new technological and organizational solutions and their application in creative and flexible ways to foster industrial development. Such capabilities are scarce in developing countries [27]. Expanding these capacities is a gradual process, and several preconditions must be met to make effective headway in the digitalization process [17]. Foundational capabilities that enable the uptake of 4IR technologies consist of three key elements:

[2] Emphasis in the original by the authors.

- *An enabling infrastructure*, including energy and digital infrastructure, as ADP technologies impose high demands on network utilities, including affordable and reliable electricity and high-speed, low-latency Internet connectivity. Significant capital investments and reliable power generation infrastructure, as needed to operate industrial robots, slow diffusion of robotized production. Hence, automated machinery and robotized production are economical and cost-effective only under very specific conditions, which are often lacking in developing countries [29]. In the absence of reliable and affordable access to electricity, firms rely on manual and semi-automated technologies.
- *Production capabilities*, as only firms with sufficient productivity and operational efficiency, long-term investments in fixed capital, an adequately skilled workforce, and hence a reasonable level of technology absorption capacity can invest in and employ ADP technologies. A twin challenge arises from 4IR: on the one hand, firms need to evaluate and make decisions on adopting emerging frontier manufacturing technologies; on the other, firms must explore how to best retrofit their existing production capacities. Like the experiences of the adoption of information and communication technologies (ICTs), the scope for developing countries to leapfrog tends to be greater in using such new technologies rather than producing them [28].
- *Innovation capabilities* are crucial for the adoption and adaptation of ADP technologies. They imply a combination of firm-level dynamic capabilities—namely capabilities to procure, invest, retrofit, redesign, and retrain the workforce—, and a strong national innovation system, a specialized and skilled workforce, and clear regulations on the development, and adoption, and dissemination of new technologies.

A recent report by UNCTAD [11] proposes a similar framework, building on an index that assesses national capabilities to equitably use, adopt and adapt frontier technologies, including those generally associated with 4IR.[3] The index comprises five building blocks: (i) ICT

[3] The index considers 11 frontier technologies: AI, IoT, big data, blockchain, 5G, 3D printing, robotics, drones, gene editing, nanotechnology, and solar PV.

deployment, (ii) skills, (iii) R&D activity, (iv) industrial activity, and (v) access to finance. The first three building blocks are aligned with elements of national technological capabilities such as physical investment, human capital, and technological effort [29]. Industrial activity is related to the assumption that the development of technological capabilities is path-dependent and is based on research on economic complexity,[4] while the pattern of a country's industrial activity influences its likelihood of adopting frontier technologies. Access to finance is a building block for innovation based on a Schumpeterian view of the finance/innovation nexus. We apply this framework in Sect. 16.4 to assess the extent of 4IR capabilities in Latin America and the Caribbean compared to other regions.

16.3 Methodology and Data

We combine macro- and micro-level data to carry out a cross-country comparative assessment of the engagement of selected Latin American countries with 4IR, the type of engagement, and the factors shaping this engagement. This section describes the data used in our analysis.

16.3.1 Macro-Level Analysis

Three different indicators are applied in the macro-level analysis. First, we use UNCTAD's frontier technology readiness index and the scores of its components to assess the preparedness of regions and countries to use, adopt and adapt frontier technologies, which may include ADP technologies (for a detailed discussion on the methodology to compute the index and its different dimensions, please refer to [10]).

Second, we assess the technological capacities associated with ADP technologies in the Latin America and Caribbean region, using economic complexity as a proxy. Technological capacities are perceived as part of non-tradeable capabilities; they are estimated through techniques used in the economic complexity literature. The data used in our analysis were obtained from UN COMTRADE datasets based on import data reporting bilateral trade covering 240 economies for the period 1995–2020, using

[4] See [30] for a review of this strand of literature.

the HS classification (6-digit level) related to industrial robots, additive manufacturing (or 3D printing) and computer-aided design and computer-aided manufacturing (CAD/CAM) techniques.[5] The methodology used to calculate economic complexity is detailed in [31] as a revised version of the method proposed by [32], used to estimate the capabilities associated with products and economies. Finally, we discuss the nature of markets for ADP technologies as the third dimension of readiness drawing on [8].

16.3.2 Micro-Level Analysis

Our micro-level analysis builds on UNIDO's COVID-19 firm-level survey (https://www.unido.org/covid19_surveys) following the approach used in [33]. The survey was carried out in 26 developing and emerging industrial economies between November 2020 and June 2021, and collected information from over 4000 firms. The survey was conducted using an online survey platform.

Although the survey's main objective was to assess the current and expected impact of the COVID-19 pandemic on manufacturing firms around the world, it also included a distinct module on the type of digital technologies used by firms. As data on the level of technology being used by developing country manufacturing firms are scarce, the collected data are a unique source of information about the industrial application of digital technologies. The UNIDO survey asked firms to select one of five options to identify the production technologies being used. The options ranged from simple analog methods to technologies employed in rigid, lean, and integrated modes of production to the most cutting-edge digital technologies (Table 16.1).

Generation 0.0 refers to a pre-digital production system: it includes all types of analog technologies that can possibly be used in different stages and functions of manufacturing production. The subsequent technological generations—Generations 1.0 to 4.0—correspond to digital production technologies employed in manufacturing. Generation 1.0

[5] These are related to HS codes 847950, 847780, 847710, 847720, 847730, 847740, 847751, 847759, 847790, 845811, 845819, 845921, 845931, 845951, 845961, 846011, 846021, 846031, 846221, 846231, 846241, as in the analysis of the development and adoption of advanced digital technologies in [8].

Table 16.1 The UNIDO COVID-19 firm-level survey: Definitions of technological generations

Technological generation	*Definition*
G0.0—Zero generation: analog production	No digital technologies are used during any stage of the production process (e.g., personal contact with suppliers or via phone; use of machinery that is not micro-electronic based)
G1.0—First generation: rigid production	The use of digital technologies is limited to a specific purpose in a specific function and activity (e.g., use of CAD only in product development; use of non-integrated machines operating in isolation)
G2.0—Second generation: lean production	Digital technologies involve and connect different functions and activities within the firm (e.g., use of CAD-CAM linking up product development and production processes; basic automation)
G3.0—Third generation: integrated production	Digital technologies are integrated across different activities and functions, allowing for the interconnection of the whole production process (e.g., use of ERP systems; fully "paperless" electronic production control systems; industrial and service robots)
G4.0—Fourth generation: smart production	Digital technologies allow for fully integrated, connected, and smart production processes, where information flows across operations and generates real-time feedback to support decision-making processes (e.g., digital twins; real-time sensors and machine-to-machine communication; collaborative robots (cobots); management decision-making supported by big data and artificial intelligence support)

Source [9]
Note CAD = Computer-aided design; CAM = Computer-aided manufacturing; ERP = enterprise resource planning

and 2.0 technologies have existed since numerical control programming systems were introduced (late-1950s), although the development of tools such as CAD has surged in recent years owing to parametric engines. Generation 3.0 technologies enable the integration of production processes, while Generation 4.0 technologies entail the "smartness" of real-time interaction and data exchange, allowing for the exploitation of the full potential of digital technologies in terms of connectivity and flexibility by relying on the most advanced application of robotization, sensorization, big data, artificial intelligence (AI) and communication devices, among others [9]. In what follows, Generations 3.0 and 4.0 technologies are used as a proxy for ADP technologies.

16.4 Results

Industrial innovation and industrial development are two powerful drivers of economic diversification and value addition, economic growth, and sustainable development [34]. Unfortunately, the road toward 4IR is often extremely uneven. The capabilities necessary to promote industrial innovation remain heavily concentrated across and within regions and countries. In what follows, we assess the uptake of such technologies in Latin American countries both at the macro-level—based on UNCTAD's frontier technology index and the economic complexity of trade in ADP-related goods—and at the micro-level—based on recent firm-level data collected by UNIDO on the adoption of ADP technologies. The results suggest that the Latin America and Caribbean region is less prepared to endorse 4IR than Asian or other developed regions. However, a closer examination shows a mixed picture within the region, revealing country-dependent strengths and weaknesses.

16.4.1 Readiness to Adopt Frontier Technologies: A Macro-Level Perspective

According to UNCTAD's recently developed frontier technology readiness index [10], Latin America and the Caribbean generally lags most other regions regarding preparedness to use and adopt 4IR-related technologies. The region's average index score is only higher than that of North- and sub-Saharan Africa but lies below the global average (Fig. 16.1).

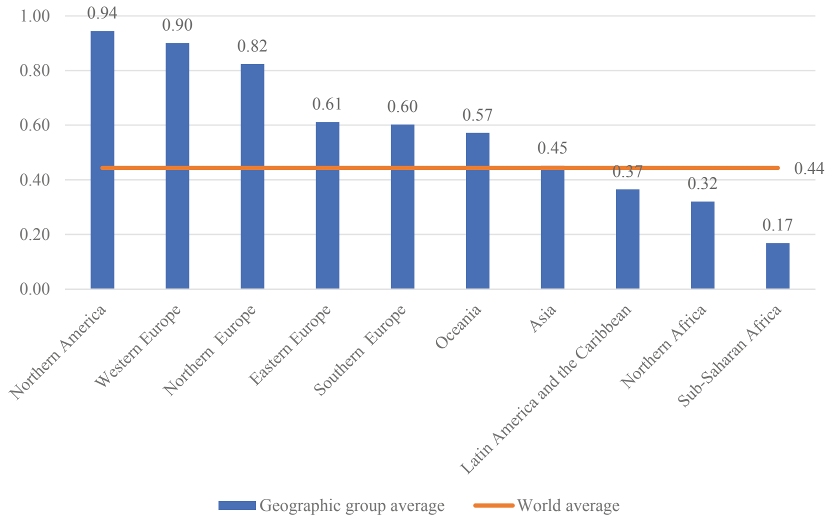

Fig. 16.1 Averages of the frontier technology readiness index's scores by geographic grouping, 2019 (*Source* Authors based on data from [10])

When examining the index's five components, we find that the Latin America and Caribbean region trails farthest behind in the technological component (R&D) (Fig. 16.2), which assesses the number of publications and patent registrations from the region related to 4IR technologies. Its industrial activity score is also well below the global average, while access to finance is the region's only component that outperforms the global average. In comparison, the scores of Asian countries generally match the global averages, with a notable overperformance in R&D and access to finance.

As can be expected in such a diverse region, the distribution of scores for the frontier technologies readiness index's components shows an uneven preparedness of individual Latin American and Caribbean countries. The largest disparities emerge in ICT infrastructure and skills (Fig. 16.3).

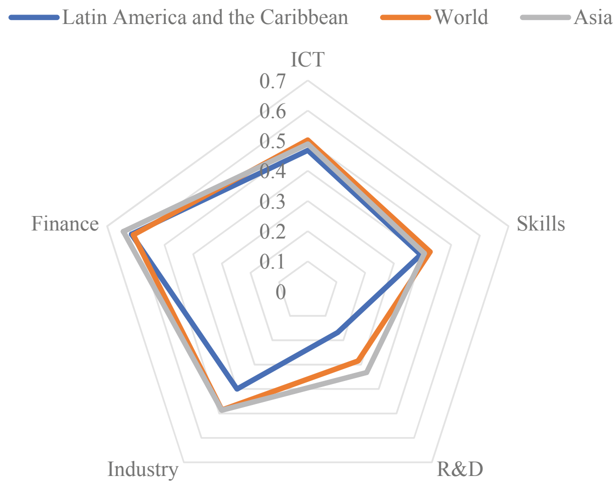

Fig. 16.2 Averages of the frontier technology readiness index's components, selected regions, 2019 (*Source* Authors based on data from [10])

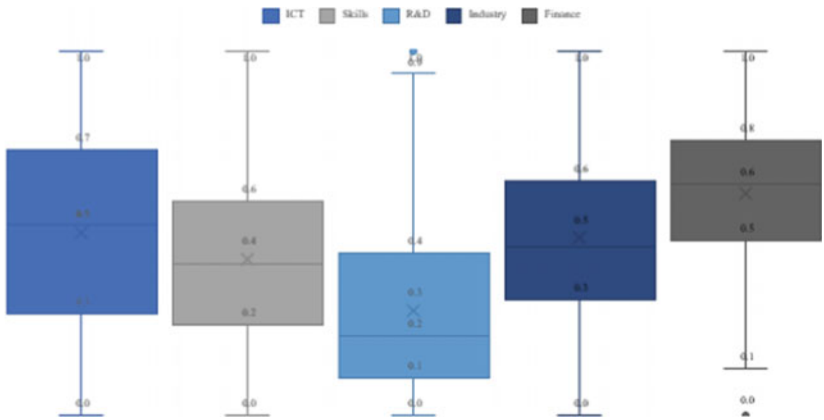

Fig. 16.3 Distribution of scores of the frontier technology index's components, Latin America and the Caribbean, 2019 (*Source* Authors based on data from [10])

Next, we review individual country experiences. The index scores of Argentina, Brazil, and Mexico reveal how unique every case is (Fig. 16.4). For example, Argentina has higher scores in skills and R&D compared with the global and regional averages, but a lower score for access to finance. Mexico has a high score in R&D and industrial activity, with the other components scoring above global averages. Brazil, in turn, has higher values in all components. Positive trends in these countries may arguably be insufficient to push the region's overall dynamics.

In tandem with the preceding discussion, when using economic complexity as a proxy for technological capacity in the specific case of ADP technologies and the economic complexity of Germany as a benchmark (index = 100),[6] similarly concerning conclusions about 4IR readiness of Latin American and Caribbean countries can be drawn. The unweighted average technological capacity of the countries in the region is only 1, comparable to the unweighted average for countries in North- and sub-Saharan Africa, and below the global average (8) (Fig. 16.5).

When examining the level of technological capacity in terms of advanced digital technologies in Argentina, Brazil, and Mexico, we find variation within the region and low levels of capacity relative to the global average (Fig. 16.6). In Latin America and The Caribbean, only Brazil (17) and Mexico (8) report higher than global average scores. For comparison purposes, China scores 44.

We find that the technological capacity in advanced digital technologies is positively correlated with patent family applications in 4IR technologies and with the value of 4IR exports (Fig. 16.7). This finding suggests that R&D and trade involving 4IR products go hand in hand with the accumulation of technological capacity in ADP technologies.

These correlations may explain why the ability to produce and trade in advanced digital technologies is so heavily concentrated in just a few countries. UNIDO's work confirms this in assessing the structure of intellectual property rights around technologies such as additive manufacturing, CAD-CAM, robotics, and machine learning, which are concentrated in very few countries and firms [9]. Around ten countries only—the "frontrunners," which include the United States, Germany, the Republic of Korea, Japan, and China, among others—account for 90 percent of all global patents and 70 percent of all exports directly associated with such

[6] Based on our analysis, Germany has the highest economic complexity in terms of advanced digital technologies.

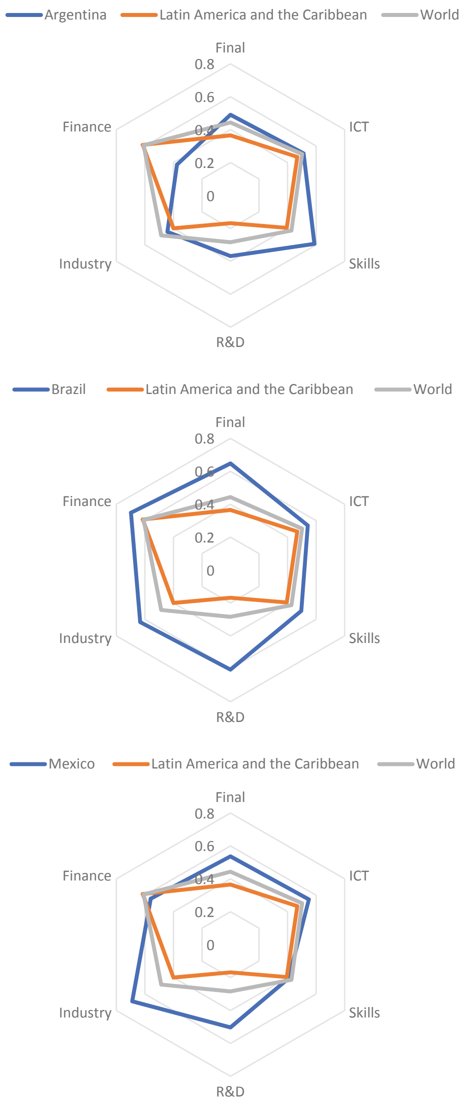

Fig. 16.4 Averages of the frontier technology readiness index's components, Argentina, Brazil, and Mexico, 2019 (*Source* Authors based on data from [10])

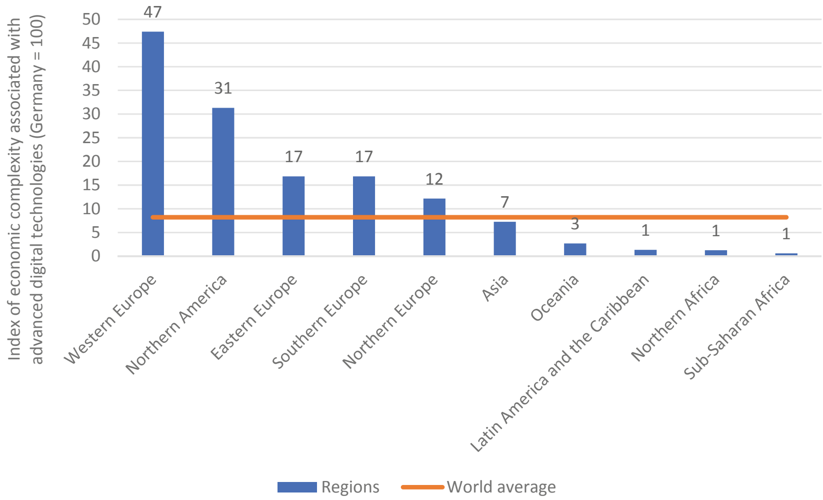

Fig. 16.5 Economic complexity associated with the export of ADP technologies, selected regions, 2020 (*Source* Authors based on [31] and data from COMTRADE)

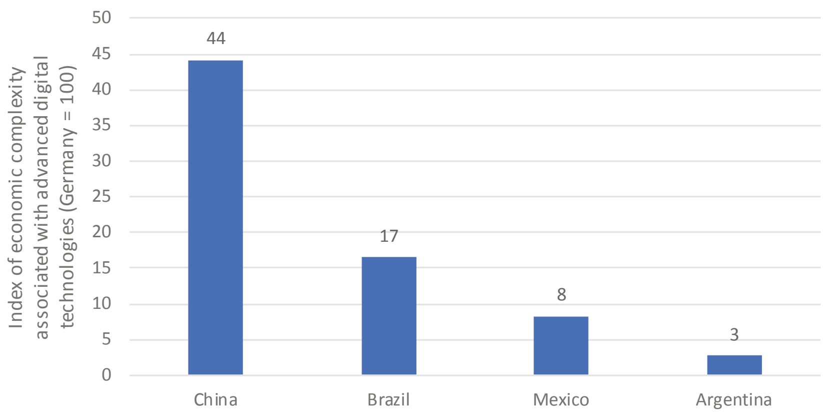

Fig. 16.6 Economic complexity associated with the export of ADP technologies, selected countries, 2020 (*Source* Authors based on [31] and on data from COMTRADE)

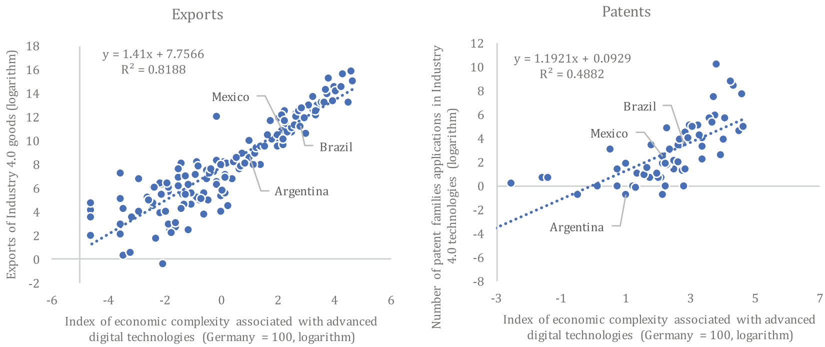

Fig. 16.7 The technological capacity in ADP technologies is correlated with patents and exports of 4IR technologies (*Source* Authors based on [31], on data from COMTRADE, and from [9])

technologies. Another 40 countries—the "followers"—actively engage with these technologies, albeit with far more modest intensity than the frontrunners. The rest of the world either indicates very little activity—the "latecomers"—or fails to participate in the global development and use of such technologies—the "laggards."[7]

The relative distance between Latin American countries and the frontrunner country group, i.e., the countries that represent the technological frontier and drive the dynamics in the technologies underpinning advanced manufacturing, is remarkable. Performance of the Latin America and Caribbean region is below that of other developing regions. As can be expected, the largest manufacturing economies in the region, Argentina, Brazil, Colombia, and Mexico are also the most advanced regarding adoption of ADP technologies. All these countries are included in the Follower group. However, while Brazil reports the ability to develop ADP technologies—as indicated by its extensive patenting activity—and to export[8]

[7] These findings are consistent with [35], which indicates that 2000 firms are particularly active in R&D globally and hold the lion's share of patents in advanced digital technologies.

[8] Exports of ADP-related capital goods are above the average global market share once frontrunners are excluded [9].

them, the other three countries are mostly users[9] of these technologies. Only four other economies in the region are latecomers (Chile, Costa Rica, the Dominican Republic and, Venezuela), while the rest are identified as laggards.

16.4.2 Diffusion and Determinants of Adoption at the Firm-Level

The discussion so far suggests that countries in Latin America and the Caribbean trails behind other regions in engagement with 4IR. Regarding both readiness to adopt frontier technologies and the complexity of 4IR-related products already being produced, the region's scores are far below those of advanced countries and other developing regions. Further firm-level evidence confirms this finding, even in countries more actively engaged with the new technologies. This section presents evidence on the adoption of ADP technologies by manufacturing firms in a selected number of Latin American countries. This evidence is drawn from a UNIDO survey of global manufacturing firms conducted during the first half of 2021 (see Sect. 16.3 for details).

In line with other emerging evidence on the uptake of 4IR technologies in both developed[10] and developing countries, the results presented here indicate that the adoption of ADP technologies remains low, that it is heavily concentrated by industry [17] and size of firms [8]. Contrasting with the significant buzz around the adoption of 4IR technologies, few manufacturing firms have achieved sufficient scale and integration to move beyond the pilot phase when it comes to implementing 4IR technologies [37].[11] Efforts to facilitate the diffusion and uptake of such

[9] Imports of ADP-related capital goods are above the average global market share once frontrunners are excluded [9].

[10] Even the most advanced European countries should expect 4IR to result in mostly incremental changes: "Rather than creating new industries, the greatest digital opportunity for Europe lies in the transformation of existing industry and enterprises" [36, p. 2]. The inclusion of SMEs remains one of the biggest challenges most European 4IR strategies face.

[11] Based on McKinsey & Co.'s global survey of manufacturing firms conducted in 2020 among more than 400 global manufacturing firms, 74 percent of respondents indicated that they were facing challenges to breaking away from the "pilot trap" (emphasis in the original by the authors) as regards the implementation of 4IR technologies. The figure illustrates a slight increase relative to the 70 percent share of firms reporting a similar situation in the 2017 survey [37].

technologies tend to concentrate on a small set of firms, mainly large multinationals in specific industries [8, 19].

According to the results of the UNIDO survey, around 75 percent of manufacturing firms in the developing country sample for which information was collected operate far from the technological frontier (Fig. 16.8). These firms either do not use digital technologies at all (analog firms) or, if they do, still use the most outdated generation of digital technologies available in the market (Generation 1.0). The use of 4IR technologies remains negligible, with only 1.5 percent of the sample reporting any meaningful engagement with such technologies. Regarding digitally advanced firms—that is, those engaged with Generation 3.0 or 4.0 technologies—, while the share of adopters increases, it remains below 15 percent of the sample. The data reveal a stable distribution across regions, with the largest share of firms that use ADP technologies in Asia, followed by Latin America[12] and Africa.

The picture in the three largest Latin American countries is similar (Fig. 16.9). The majority of firms in the two countries more actively engaged with frontier technologies (Argentina and Brazil) still operate far from the technological frontier. Around 2/3 of firms surveyed in these countries reported that they did not use digital technologies at all, or that used outdated Generation 1.0 technologies. The situation is even more pronounced in Mexico, where this value jumps to 80 percent of firms.[13] At the opposite extreme of the technological ladder, no firms reported using 4IR technologies (Mexico), or if they did, they represented less than 3 percent of the sample (Argentina and Brazil). Like other developing regions, the picture emerging is extreme structural heterogeneity where small islands of modernity coexist with a sea of backwardness [38].

According to the literature, the slow uptake of 4IR technologies can be explained by high uncertainty around the possible implications of 4IR for economic and social dynamics, particularly in developing countries. Firms have difficulty perceiving any potential productivity and efficiency gains of 4IR technologies or establishing optimum strategies to upgrade and retrofit existing production capacities [39]. They need to take incremental steps and test technological options based on their desired end

[12] The UNIDO COVID-19 firm-level survey collected data for seven countries in Latin America: Argentina, Brazil, Bolivia, Ecuador, Mexico, Peru, and Uruguay.

[13] It is important to emphasize that the Mexican sample size was significantly smaller than Argentina and Brazil.

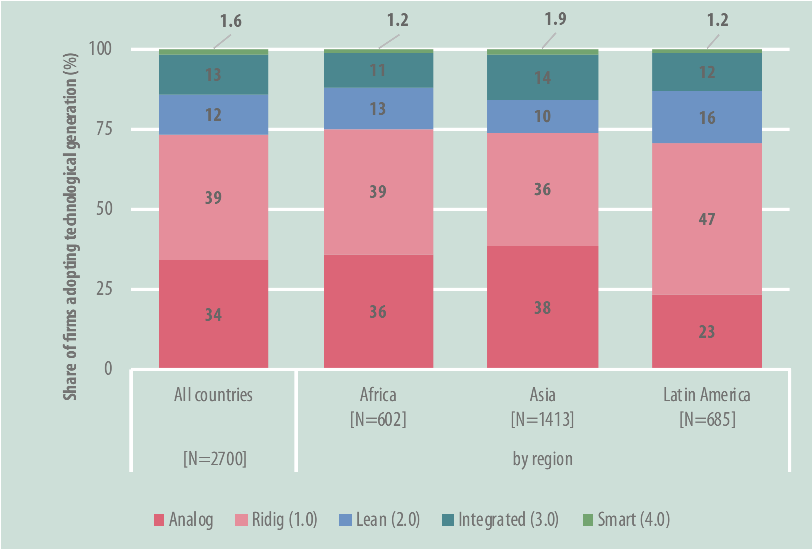

Fig. 16.8 Share of manufacturing firms by the generation of ADP technologies used in regular operations: regional averages (*Source* Authors' elaboration based on UNIDO COVID-19 firm-level survey [https://www.unido.org/covid19_surveys])

goals before committing to full implementation. This scenario was already painted by [28], who claim that barriers to the adoption of innovative technologies, particularly ICTs and digital technologies, arise from insufficient awareness of the nature of such technologies and their applications, difficulties appraising these technologies' value propositions relative to (competing) existing technologies, while difficulty assessing expected returns on investment contrast with perceived high upfront investments [40].

Anecdotal evidence from the case studies of Argentinian [1] and Brazilian [2] firms indicates that the situation of firms in Latin America is consistent with the preceding discussion. While firms may be able to engage with ADP technologies, they often lack the knowledge that would allow them to estimate the economic benefits they could derive from the integration of such technologies [1]. Interestingly, however, at least in the case of Argentinian SMEs, difficulties estimating the potential

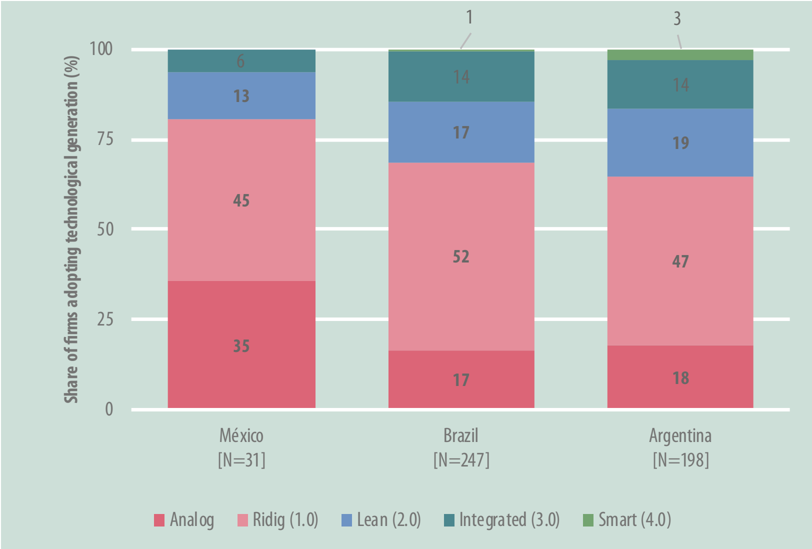

Fig. 16.9 Share of manufacturing firms by the generation of ADP technologies used in regular operations: Argentina, Brazil, and Mexico (*Source* Authors' elaboration based on UNIDO COVID-19 firm-level survey [https://www.unido.org/covid19_surveys]. *Note* Countries ordered by share of firms that have adopted ADP technologies [Generations 3.0 and 4.0])

economic benefits of the uptake of ADP technologies may be attributable to short-sightedness among firms [1]. The firms perceive the integration of such technologies as a modernization process rather than an opportunity to innovate and thereby create new business models, which would allow them to enter new markets or pursue some form of product or process innovation. The absence of quality digital infrastructure, a dearth of highly skilled workers, or the need to modify existing organizational practices or introduce new business models aligned with the new technologies represent additional obstacles [1, 2], which is consistent with the findings of our macro-level analysis.

Consistent with the findings in the literature, the results of UNIDO's COVID-19 firm-level survey demonstrate that large firms in the Latin American countries included in the survey tend to be more digitally advanced than SMEs (Fig. 16.10). Looking at the overall sample of Latin American firms, while less than 10 percent of SMEs use ADP technologies, over 20 percent of large firms do. These differences are even greater in the case of Argentina and Mexico. By contrast, the shares of firms using ADP technologies are equally distributed in Brazil, with around 15 percent of SMEs and large firms applying Generation 3.0 or 4.0 technologies.

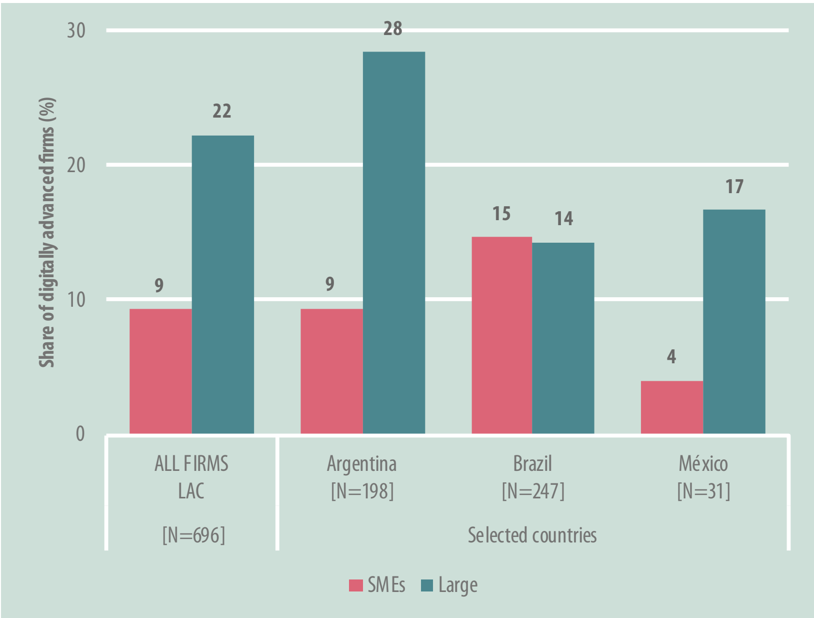

Fig. 16.10 Share of digitally advanced manufacturing firms (Gen 3.0 or 4.0) by size and country (*Source* Authors' elaboration based on UNIDO COVID-19 firm-level survey [https://www.unido.org/covid19_surveys]. *Note* SMEs are defined as firms with less than 100 employees)

Firm size is not the only relevant factor in digital adoption. The structure of the economy and the specialization of production also influences the engagement of firms with ADP technologies. These technologies have permeated more rapidly in some industries than in others. As documented in [8], firms operating in technology- and digital-intensive (TDI) industries show higher rates of ADP technology adoption than those operating in other segments of the manufacturing sector. TDI industries are classified as those that have medium–high or/and high digital and technology intensity according to the standard classifications typically used in the literature. They include two branches of manufacturing: (i) computer and machinery and (ii) transport equipment.[14] The association between the industry the firms operate in and their engagement with ADP technologies underscores the importance of countries' economic structure when assessing the level of adoption of new technologies. Other things equal, countries with a greater orientation toward TDI industries have more potential than the rest to engage more rapidly with 4IR.

Results from Latin America confirm this finding (Fig. 16.11): in the full sample, the share of digitally advanced firms is much larger in TDI industries than in others (19 percent vs. 12 percent). This is particularly notable in the case of Mexico, where 25 percent of firms in the sample operate in TDI industries that use Generation 3.0 or 4.0 digital technologies compared to only 4 percent of firms in other industries.

Firm size and industry type are contextual factors that influence the adoption of ADP technologies in different countries. However, firm-specific factors also matter. As discussed in [33] and [41], firms' production and innovation capabilities are major determinants of ADP technology adoption. Regardless of firm size and industry type, firms with higher innovation capabilities tend to embrace the latest vintage of digital technologies more frequently than the rest [8]. Using the UNIDO COVID-19 firm-level survey, innovativeness can be captured by examining whether firms reported introducing some form of process innovation in 2018–2019. The results are consistent with the literature:

[14] That is, ISIC rev. 3 codes 26 to 28 and 29 to 30.

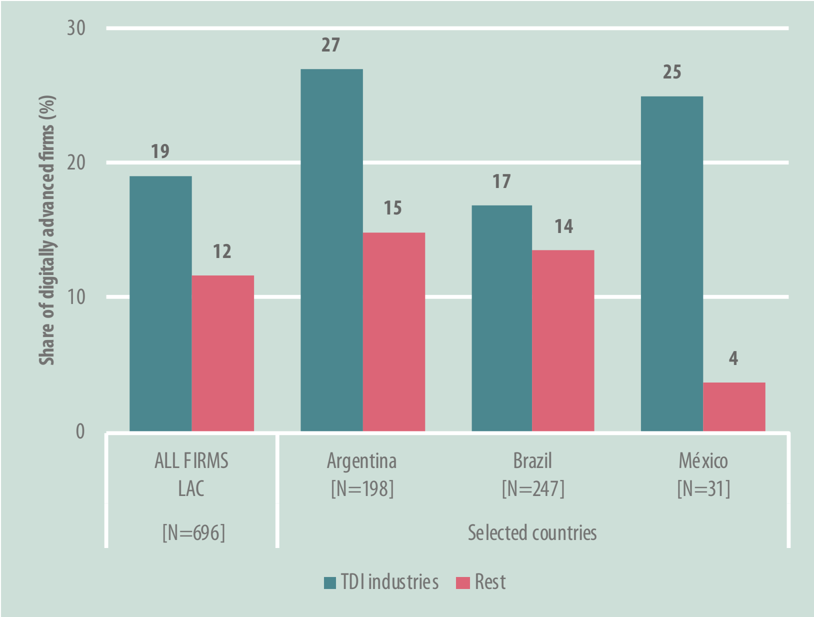

Fig. 16.11 Share of digitally advanced manufacturing firms (Gen 3.0 or 4.0) by industry type and country (*Source* Authors' elaboration based on UNIDO COVID-19 firm-level survey [https://www.unido.org/covid19_surveys]. *Note* TDI is technology- and digital-intensive)

innovative firms in Latin America tend to engage with ADP technologies more than non-innovative firms (Fig. 16.12). This observation is confirmed in each of the three countries examined separately in this chapter; differences in the level of engagement with ADP technologies are more pronounced than for the full firm sample in our database.

This finding points to the significance of building technology and innovation capabilities at the firm as a prerequisite for the absorption and broad-based diffusion of ADP technologies in the Latin American region.

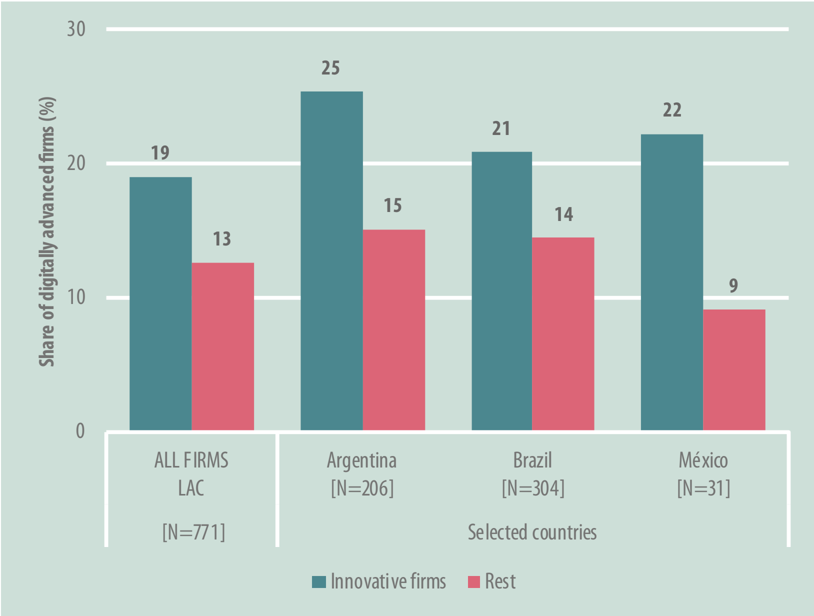

Fig. 16.12 Share of digitally advanced manufacturing firms (Gen 3.0 or 4.0) by process innovation and country (*Source* Authors' elaboration based on UNIDO COVID-19 firm-level survey [https://www.unido.org/covid19_surveys])

16.5 Policy Implications

The finding that the Latin America and Caribbean region is lagging in readiness and adoption of 4IR technologies should not, by necessity, be of concern. In theory, countries in the region could adopt follower strategies to catch up with more advanced countries [42, 43]. They could implement diffusion-oriented strategies focused on improving their capacities to absorb and adapt foreign technologies. This could be achieved through cumulative minor innovations, thereby enabling a continuous co-evolution of domestic productive and technological structures [42, 44]. The challenge, in practice, is substantial, however, for several reasons. The attitude of countries in the region toward active industrial policies remains timid; moreover, the articulation of such policies with technology policies remains problematic [44]. As a result, the region's production structure has witnessed a general decline in the share of knowledge-intensive industries, particularly its manufacturing activities.

From a policy perspective, while several Latin American countries have already introduced dedicated strategies to foster digitalization as part of manufacturing development [20], the rhetoric has yet to be translated into practical, consistent, and well-thought-out policy action and investment plans. Policy efforts generally remain incipient relative to developments observed in other developed and developing countries and regions [6, 20]. Policy responses appear insufficient to revert recent trends toward deindustrialization and waning competitiveness of manufacturing in Latin America and the Caribbean relative to other developed and developing regions. In a recent review of Colombia's productive transformation policies, the OECD highlighted the importance of including digitalization as a relevant dimension in the country's future agenda for production development [7].

Governments in Latin America are leveraging a diversity of stakeholders to inform the design and development of national strategies around digitalization and advanced manufacturing [20]. While these participatory approaches are consistent with good international practice as documented elsewhere [36], it remains to be seen how they will translate into more harmonious, co-evolutionary processes between policy-making and technological capability building efforts to support a smooth adoption of 4IR in the Latin America region. For example, the lack of systematic development and investment plans to enable 4IR in Latin America and the Caribbean is in stark contrast with the situation observed in more industrialized countries [36] and other dynamic developing economies such as China [6], where public funding plays a catalytic role in leveraging additional investments by other, particularly private, entities. Public funding has played a major role in potentiating ongoing investment and partnership efforts by private and academic organizations since the early stages of the development of Germany's *Industrie 4.0* strategy [16].

The absence of systematic efforts to promote domestic demand for home-grown technologies in close connection with promoting scientific and technological capability building efforts is a well-known structural bottleneck of Latin America and the Caribbean [45]. These structural characteristics help explain why the region is trailing behind in industrial development and competitiveness relative to other developing regions.

Even Brazil, where the intensity of R&D investment has traditionally been the highest in the region, lags considerably behind peer countries in East Asia. Dominguez et al. argue that foreign knowledge still tends to crowd out domestic technological efforts in activities behind the technological frontier [46].

In Mexico, where the structure of production and the composition of exports indicate extensive participation of industries with a strong penetration of 4IR technologies—electronics, chemical, automotive, or aerospace—opportunities to leverage the dynamics of those industries would require purposive efforts to address the disconnect between (digitally) advanced firms in those industries and other firms along domestic supply chains. This disconnect is expressed by low domestic value added relative to other countries with a more successful integration record and the ability to upgrade within GVCs. Strategic efforts to learn from dynamic 4IR-related industries could be curtailed by extreme digital capability gaps between domestic firms and the 4IR islands of excellence that operate within those industries [3, 6, 47]. Bridging capability gaps may be both costly and lengthy [39]. Moreover, possible enclave effects are of concern, which would intensify verticalization and the concentration of power within the 4IR islands [48], and technological dependency of domestic firms relative to more advanced ones. Improving investments in innovation and addressing infrastructural bottlenecks, particularly in the energy sector, represent major challenges that need to be addressed.

In Latin America and the Caribbean, creating favorable conditions for a more even distribution of knowledge and other capabilities could foster a transition toward the adoption of advanced digitalization of manufacturing and make this process sustainable. In the case of Argentinian firms, there is a gap in the supply of suitable 4IR solutions, particularly about firms wishing to retrofit and upgrade existing technologies, thereby providing them the opportunity to pave the path toward 4IR [1] incrementally. An extension of this is the missing segment of supplier firms specialized in software solutions tailored to firms willing to test engagement with 4IR, without an upfront investment in frontier technology solutions.

On a positive note, Latin American countries can tap into the emerging, dynamic start-up ecosystem. As the cases of Chile and Colombia suggest, policy experimentation and learning in line with start-up promotion have been extensive over the last decade—commencing with the pioneering efforts of Start-up Chile—with dedicated policies reflecting equally dynamic experimentation, learning, and continuous improvement processes [7]. In countries such as Colombia, further policy efforts aim to help consolidate, and transform the initial experiences in stronger institutional settings, with adequate governance mechanisms, consistency with regulatory frameworks applicable to innovative financing, and the strengthening of linkages with other complementary policy instruments such as venture capital, skills upgrading, and other business services [7].

Initiatives at the provincial level, with Nuevo Leon 4.0 in Mexico as an example, or even at the city level, such as RutaN in Medellin, Colombia, offer other fertile ground for learning to inform future industrial and technological interventions on the continent. The add-on would be opportunities to challenge the traditional centralization of economic policy decision-making and technological capabilities in the region toward increased digitalization. Countries in the region should leverage on international collaboration and peer learning. One option to explore is initiatives to nurture entrepreneurial and start-up ecosystems such as in Nuevo Leon and the Basque Country. Nuevo Leon's MIND4.0 Monterrey start-up accelerator is modeled on the Basque Country's BIND4.0 as open innovation and acceleration platform. These interventions allow connecting with global talent by attracting national and international start-ups with potential technological solutions for a selected segment of large, dynamic domestic firms in Nuevo Leon or the Basque Country.

16.6 Final Remarks

The discussion in this chapter corroborates several of the findings of individual country case studies from Latin America and the Caribbean. To exploit the opportunities and address the challenges of 4IR, countries in the region must overhaul their traditional passive attitude toward well-articulated industrial and technology policies [44, 45] and link them to broader national development strategies as observed in more successful industrialization experiences elsewhere [49, 50].

Several scholars assert that profound qualitative structural transformations in the region are necessary, which can be linked to the region's characteristic socioeconomic dynamics [1, 2]. The diffusion of ADP technologies and the dominance of external agents in the development and provision of such technologies are increasingly challenging the traditional approach by domestic firms to integration in GVCs and international trade. Domestic firms must tackle a dual challenge. First, they need to incrementally upgrade manufacturing capacities by retrofitting and reskilling the labor force [39]. Second, they need to create the necessary conditions to adopt and integrate new waves of increasingly sophisticated and digitized capital equipment required by technological suppliers and, notably, by client firms [1, 2].

In the context of 4IR, the tendency of Latin American countries to under-invest in innovation, chiefly through systematic R&D, could perpetuate the region's traditional technological dependency [1, 2], which entails the persistent risk of lock-in of its productive specialization in low-technology industries with limited capacity to foster more dynamic technological accumulation and productive upgrading [44]. Latin American firms would thus be trapped in a situation in which investment in new plants might be difficult, and risk avoidance might be exacerbated given the path-dependent nature of investments and the high level of uncertainty characteristic of emerging technologies [28, 42].

Promoters of 4IR in the region should take note of the high concentration of innovation capabilities in a limited number of countries. According to [30] and [42], the strong intellectual property rights protection in developed countries may impact more negatively on countries which are rapidly catching-up than low-income economies with very low technological capabilities, weak export performance, or exports that are arranged by inter-firm trade in the form of contract manufacturing and foreign direct investment. Strong intellectual property rights protection entails the risk of confining dynamic countries to the middle-income trap, as technology partners may become competitors. As traditional markets become threatened by increasingly protectionist attitudes, latecomers need to develop complementary capabilities such as marketing, distribution, and protection of their technological activities [51].

As regards internal factors, Motta et al. [1] advocate industrial policy interventions to foster the emergence of a segment of domestic firms specialized in retrofitting as well as the integration of new ADP technologies into existing productive capacities, including through customized software solutions and other knowledge-intensive services; this is in line with the recommendations of [39]. This proposition is interesting, as it challenges the accepted view that while firm-level catching-up in the production and use of ICTs and related technologies is possible, it remains a relatively complex and uncertain process [28]. The scope for developing country firms to leapfrog tends to be greater in terms of technology use rather than in producing such new technologies,—a few of these countries possess the technological capabilities required to become a leader in 4IR [16].

In the pursuit of industrialization in the context of 4IR, Latin America and the Caribbean may benefit from their recent, yet already substantial experience with policies targeting start-up promotion. According to [7], the goal should be to identify mechanisms to connect start-ups to different production and innovation ecosystems in the region. At the same time, to address the needs of firms in other manufacturing segments, successful experiences could be replicated or scaled up. These could contribute to the acceleration of digitalization by a larger segment of firms where the presence of such technologies remains low.

Strengthening policy-making capacities will be important as well. As discussed in our introductory section, there is a need for further comparative research to inform the heterogeneous conditions that characterize the countries in Latin America and the Caribbean to leverage 4IR as a driver of industrial development. Research gaps range from the dearth of comparative data to detailed studies at the sector- and firm-levels. Bridging these gaps should be a priority for researchers and practitioners alike.

Like individual firms that face difficulties assessing the costs and potential benefits to be gleaned from the adoption of advanced digital technologies, policymakers in the region are confronted with major knowledge gaps in how digital technologies might foster an industrial transformation of local economies [7, 20]. Policymakers are slowly preparing for 4IR; they are in the learning mode, looking for experiences to inform domestic decision-making. A study by [20] documents that the foundation of the national responses to 4IR by the region's major industrial economies, namely Argentina, Brazil, and Mexico, has been the development of diagnostics and case studies on the state of digitalization in emblematic manufacturing activities in each of the respective countries, for instance, automotive, aerospace, chemicals, or textiles. Alternatively, diagnostic studies have focused on specific technologies and their applications, for instance, in developing electric vehicles, health technologies, computers, robotics, and 3D printing [20]. Natural resource-based countries such as Chile have placed a strong emphasis on learning about digitalization in mining, agriculture, and food-related activities. Surveys on the adoption of digital technologies by firms have also been launched and involve collaboration between the government and private entities, notably industry chambers, in countries such as Argentina, Brazil, or Colombia [5, 7]. Further research efforts would produce comparative data suitable to inform common challenges and opportunities, thereby sparking cross-regional collaboration in research, the promotion of digitalization, and ultimately, new paths toward industrialization in an increasingly digital world.

To promote structural transformation in the economic and technological catching-up of the economies in the Latin America and Caribbean region, governments should pursue strategies in three areas. First, they should promote the digital revolution beyond e-commerce and mobile money to foster digital transformation in productive sectors, particularly SMEs. Second, they should scale up modern industries and strategically enter value chains related to 4IR. Third, they should continue promoting economic diversification to close the gap between traditional and modern sectors of the economy. By harnessing 4IR, modern sectors can drive both productivity and export growth. However, more diversified traditional sectors will drive job creation, fuel structural transformation, and provide the basis for further productivity growth and higher wages.

Acknowledgements The authors acknowledge useful comments by two anonymous reviewers to this chapter, and comments by participants at the International Conference of the RIDIT (ICRIDIT 2022 Berlin Celaya). Niki Rodusakis helped with proofreading and editing of the English language.

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CHAPTER 17

Challenges and Opportunities of Digitalization in Mexico

Mónica Casalet

17.1 Industry 4.0: Drivers and Barriers

The diffusion of digital technologies in society and production introduces intensive, disruptive change, which leads to a re-conceptualization of the sociotechnical system in production and the types of governance that orient the transformation from analog to digital. Traditional explanatory focuses on business strategies, processes, technologies, final products, and relationships with suppliers and customers are conditioned by the new technological complexity, with strategic effects that contribute to increased productivity and operational flexibility, still unintegrated in Mexico. Current developments in digitalization are not limited to specific sectors, but impact all branches of activity, with growing integration and blurring borders. The fourth industrial revolution, commonly called industry 4.0 (I4.0), is not about the industry. It is described as the

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S. Estrada (ed.), *Digital and Sustainable Transformations in a Post-COVID World*, https://doi.org/10.1007/978-3-031-16677-8_17

next level of manufacturing where machines will redefine themselves in how they communicate and perform individual functions. The notion of I4.0 fuses the virtual and the real world, with an emphasis on engineering applications like robotics, digitalization and information systems for management and production planning, and automatization systems for data acquisition from production lines; it uses machines and links manufacturing sites in a comprehensive supply chain [1–4].

The Internet of Things (IoT) has enabled advanced services through physical and virtual interconnection. The main characteristics of the IoT are the integration of technologies for identification and follow-up. This new process is characterized by the application of information technology in all phases of modern manufacturing, from design, fabrication, and product consumption to customer services. Each phase implies knowledge and connection, supplemented by additive manufacturing to personalize products. These changes are not reduced to the productive setting; they have implications for society since they permit a more complex economy based on the intensive use of digital information.

17.2 Continual Growth of Data in Challenging Organizations and Companies

The integration of cloud computing and big data, applied to production and services, facilitates new business models and contributes to the personalization of products. The proliferation of new business models adds renewed scope to manufacturing activities, leading to faster and more precise decision-making. Digitalization is key for opening new businesses as well as for improving customer experience and optimizing coordination among processes at the international level [5–9]. The process of digitalization has contributed to a new debate on configuring company strategies for the geographical relocation of production, accenting sometimes contradictory trends of location and relocation, according to the product and sector [10]. New platforms and devices transform the nature of uncertainty inherent in business processes and services, as well as the forms of dealing with such uncertainty [11, 12]. The growing expansion of I4.0, linked to individualized production or adapted to the changing needs of consumers, represents the new tendency of digitalization based on technological leaps, whose sociotechnical solutions combine new proposals for industrial organization, technical abilities, and the division of work. In this context, the strengthening of industrial activity is combined with the digital revolution [7, 13, 14] to satisfy the heterogeneous needs of customers and take advantage of market opportunities. I4.0 is developed through flexible processes, based on the modularity of the chain of value, which enables handling complex information about products, production, and logistics; through standards and protocols, it facilitates exchange between production units in different locations.

The technology of digital fabrication is still not massively used, since its application and assimilation provoke gradual changes in the production of large companies and especially in small and medium-sized (SME) suppliers, as it opens new spaces for commercial and productive exchange and for entrepreneurial development. All nations, companies, and markets are potentially affected by digital transformation. Yet not all countries innovate in the same way, nor do they have the infrastructure and social consensus to generate trust and information so that people and organizations can manage the risks of digital privacy and security. The I4.0 that arose in Germany and spread throughout the European Union has promoted this model by applying specific orientations in industrial policies and innovation; it has also created new modes of public–private collaboration that have led to new information networks and prospective studies, congregating interinstitutional and multidisciplinary work groups (the case of Plattform Industry 4.0 in Germany, the Plan Basque Industry 4.0 closely aligned with the German model, and the Manufacturing USA initiative in the United States, which along with the National Science Foundation, NASA, and the National Institute of Standards and Technology [NIST] guarantee the generation of intelligent manufacturing standards by linking industry with new areas of knowledge).

In the more industrialized nations of Latin America (Argentina, Brazil, Colombia, and Mexico), these projects are manifested in fragmented form even in companies with trajectories, in suppliers, and in companies that use mature technologies,[1] such as those in the automotive, aeronautical, and information services sectors. Shortages in technical, organizational, and infrastructural capacities complicate the uncertainty of disruptive changes. At the macroeconomic level, economic crises and the difficulties in successive political changes in those same Latin American countries

[1] Mature technology is related to management information systems, automatic data processing in business, and telecommunications technologies that permit remote access to information. Related advanced technology corresponds to the wave of digitalization based on IoT, robotics, artificial intelligence, machine learning, and blockchain [42].

have delayed investment; the consequences have been stagnation and the inability to reconnect with an innovative role in the industrialization process and in the consolidation of a more just society.[2]

The disruption of the unprecedented health, economic, and social crisis of COVID-19 has accelerated the diffusion and incorporation of digitalization into the daily relationships of service consumption and social communication (food, entertainment, work and social conferences, and training). At the international and national level, forced lockdowns have imposed on society a familiarization with the digital applications required for telework, online transactions, and distance learning. The need to meet daily demands has led to forced incorporation of telework, despite the heterogeneities of the productive structure, the shortages of digital infrastructure, and the absence of digital skills. At the industrial level, latent concerns are the future path of digitalization in production, the magnitude of social costs, and the viability of business strategies in export sectors based on the utilization of mature and advanced technologies.

The devastating effects of the pandemic on the national economy and employment, along with the lack of definition of strategies of industrial support and the prolonged interruption of supply chains with Mexico's principal trading partner (the United States), have raised unanswered questions about business investment capacity in digital transformation. Fundamental concerns have included the conditions of transition in the production process, in the digital recuperation of suppliers, and in the continuity of labor in improving advanced competencies.

17.3 Methodology

The study centered on various questions concerning why and how digitalization processes evolve in Mexico. The review of a wide international bibliography has revealed key information about sociotechnical systems of complex interaction among humans, machines, and the environmental aspects of organizational systems [1, 3, 4, 21–23]. Topics of interest

[2] Because of the need to explain the expansion and characteristics of the new I4.0 model, production in Latin America emphasizes various lines of analysis: processing information on the international appropriation of I4.0 and identifying the national and regional possibilities [15–17]; conceptual reflection on the paradigm's changes and the effects of I4.0 on production; and business and professional capacities in industry and global chains [18–20].

include the digital resources employed and the way these resources affect the firms' organization by activating new strategies to innovate business models, with user intervention, in a process of co-creating value by personalizing products. Most of the academic and advertising literature on I4.0 has been the product of industrialized nations and research backed by international organizations, since the process of digitalization is still anchored in those nations. A review of the international literature, however, showed that while industry 4.0 is recent, international contributions have approached and evaluated sociotechnical systems, and have taken into account that new forms of governance include interinstitutional participation [15].

The bibliometric analysis of I4.0 prepared by Muhuri, P., et al. [2] found that the most common keywords indexed in Web of Science (WoS) and Scopus were discipline, countries, and highly prolific institutions.

The nucleus of work presents the findings of an exploratory study focused on a set of Mexican companies of various sizes that progressed in applying digital technologies. Once a directory had been created of one hundred OEMs and firms from various tiers in the automotive and aerospace sectors, twenty companies were selected to complete a questionnaire (which included an explanatory note on the reasons behind the research and the importance of technological information for team formation, organizational changes, achievements, and deficiencies in technical training). The questionnaires were supplemented by interviews with the directors of industrial clusters in the Mexican states of Baja California and Queretaro. Additional interviews were conducted in public research centers linked to direct research with industry, and business associations.

Empirical research carried out in companies in Mexico's technologically advanced sectors has provided elements for evaluating real problems and longstanding shortages that have hindered the current transition and past innovations.

The study data explained: (i) the motivation for introducing new digital processes in production; (ii) the characteristics of the transition process from analog to digital; (iii) the internal and external obstacles that companies face in implementing the digitalization process, in which deficiencies in training play an important role, since few actors with an overall vision of the problems are capable of integrating the technological and social complexities of the dimensions under study; and (iv) the existing viability for constructing strategies and encouraging action by public-sector and private-sector actors in a digital ecosystem of the type, operation, and scope appropriate for offering a new multidisciplinary narrative capable of understanding the intersection of various fields and strategies.

The online questionnaire completed by the companies in productive sectors (automotive and aerospace) as well as the interviews with public- and private-sector actors focused on three points: (i) how companies prepare for the transition toward digital transformation, and their elements of information; (ii) the technologies that facilitate the process and how they are inserted into management strategies; and (iii) the technical capacities of companies for adopting and improving the use of advanced technologies.

17.4 Basic Questions Answered by the Companies

17.4.1 Ways and Directions Companies Advance in Acquiring Information and Applying Digital Transformation

The companies and clusters surveyed stated having used multiple means to obtain information on digitalization (intelligent factories or I4.0). Such means have ranged from conferences organized by business chambers in conjunction with the state Secretariats of Economic Development (in Querétaro and Baja California) to sponsored visits to companies and industrial groups in several countries (the United States, South Korea, the Autonomous Community of the Basque Country, Germany, and China). The intention was to make known the new nature of the processes and the opportunities for growth in implementing a business plan to respond to customers' needs, especially in the automotive industry, where connectivity between suppliers and customers is a determining factor in the chain of production, along with intra-business associations (contractors and suppliers). Public research centers in both states played an important role in preparing solutions in processes (processing and computing systems) for companies, especially SMEs, to improve processes and utilize data and business plans.

During the study, multiple public- and private-sector actors were shown to have participated in sensitizing and extending knowledge on the application of I4.0 to society and industry, in order to generate trust at the company level and reduce uncertainty in adapting and incorporating changes in production processes, as well as in the management of new product development, new associated services, and new business models.

All of these dimensions are considered very relevant in most companies, despite their differences in size, sector, markets, and implementation based on management strategies and technical capacities. At a secondary level of importance are motivations linked to improved efficiency in quality processes, cost savings, and customer relationships. Digitalization permits obtaining information on customers and standardizes interfaces by facilitating decision-making.

The companies' responses indicate that despite the existence of a somewhat clear path to digitalization, the real situation is that companies are less oriented to advance in acquiring technological capacities, especially in the event of needs and shortages in strategic resources. For most of the analyzed companies, relationships with customers and suppliers were not determining factors in the implementation of I4.0 but were evident in the absence of business plans and prioritization in their investment in technology, in order to ensure a variety of customers and suppliers.

The application of digitalization to implement new business plans assumes a new logic of creation and captures the value that affects the entire company, strengthens internal coordination, and facilitates the use of valuable information for simulation programs that support decision-making. The incorporation of digital technologies, carried out parallel to the companies' daily activities, represents an incremental adoption of sociotechnical changes; management maintains a duality of hierarchical lines without flexible organizational changes, facilitating the digitization of multiple areas (operations management, digital systems, and marketing).

The view of I4.0 that has been encouraged by various consulting firms and business chambers has prioritized digitalization as a facilitator of increased operational efficiency and a generator of information for systematizing data that can lead to new business. This perspective is linked to the adoption of new information and communication technologies developed in the mid-1990s, which motivated companies to incorporate hardware and software to develop infrastructure that was more responsive to supply and company services. At the same time, however, national and state government supports were directed to the expansion of ICT and the development of interorganizational links (especially the participation of SMEs in the value chain).

In 2019, no public proposals were designed to grant incentives and stimuli at the macro level for digital transformation, except for the programs adopted by state governments and the advertising generated by the clusters. To date, this situation has worsened, generating in large companies and in SMEs a paralysis that goes beyond cautious behavior regarding the introduction of digitalized technologies; the crisis is mostly due to the unavailability of financial resources. The absence of public strategies for business supports has weakened companies' preparation for digitalization and stagnated the supply of new competencies for digital transformation.

17.4.2 Technologies That Facilitate Digitalization

Incorporated digital technologies depend on infrastructure, equipment, and inclusion in the production chain of an export sector that ensures investment during the period of international and national certification. In most companies, the view of digitalization is related more to gradual evolution, improvements, and adjustments, than to a new configuration in which social actors, devices, and platforms intervene in real-time. The empirical information confirms that in the control and supervision of production processes and relationships with suppliers, there is an important use of human control and facilitators like Enterprise Resources Planning (ERP) and Customer Relationship Management (CRM). Both technologies permit taking advantage of the greater integration of information and processing in diverse commercial functions. The coexistence of multiple resources, strategies, and modalities constructs hybrid opportunities for absorbing and appropriating knowledge, equipment, and improvement in learning; in addition, the speed of incorporation depends on familiarity with the use of technologies in previous stages.

The export sector's integration into a chain of production, along with access to digital platforms, has facilitated the participation of SMEs in digital transformation. The use of mature technologies has been broadly incorporated into business practice, including the use of ERP management systems that are not machine-based. The progress of digitalization depends on the company's sector, size, and leadership ability. The automotive industry's early association with information technologies and the strategic management of innovation (lean manufacturing and Six Sigma) reacted swiftly to market uncertainty and the coordination of technological progress with new business plans. Most of the surveyed companies participate in the production chain of the automotive and aeronautical sectors, where improved quality and supplier relationships justify efficiency in production processes (subject to international and national certification). This position confers leadership in international and domestic production on both the automotive and aerospace companies, product and production development, and the use of digital tools and methods for testing and securing production processes. For instance, product designers and production planners exchange data continuously to ensure optimal planning in the configuration of production [24]. The international literature on digitalization processes contains little consensus in understanding the early phases of digitalization as a technical process, which converts analogic signals into digital signals, creating data for the processing and use of the information system [8, 25]. The arrival of I4.0 will affect the style of work, transforming the traditional work-as-survival into work-for-life, and finally, life as work [26].

The technologies most often quoted, although not the most utilized by companies in the case of Mexico, refer to big data analytics and cloud computing. Their importance is associated with interest in developing new products, services, and relationships with suppliers. These technologies facilitate communication, collaboration, and information skills for development with new proposals of value [9, 11]. Data analysis through advanced algorithms is key for making decisions in real-time and improving the quality standards of products and processes, and is one of the I4.0 technologies most demanded by companies to develop products and adapt products to customers. The analysis and processing of enormous sets of data, with instant follow-up and prediction, support decision-making in multiple levels and sectors. Data analysis is not a new technology; business intelligence systems have been used, in addition to business analytics, in both production and services. The novelty lies in the volume of data processed, and the variety, speed, and complexity given the multiple related sources [27–31].

The problem is verifying the reliability of these data [32] and updating employees' skills as technology evolves. Cloud computing satisfies the demand for flexibility and ease of access to software and content, independent of location or time [33]. The cloud offers a place to compile and analyze data in large and growing volumes [9]. However, bandwidth limitations have created latent problems, especially over long distances and in places in Latin America, including Mexico, where infrastructure has deficiencies. Both technologies are related to computer consulting services and proposals offered by public research centers to position companies in a new market and facilitate access to interconnection with suppliers and customers. Other technologies mentioned in the interviews were:

- **Platforms to support new business models**. These platforms cover a broad range of activities, access to capital, work, training, and technical assistance for operational inputs and services; they are easy to escalate and are able to produce rapid effects in networks.
- **Artificial intelligence (AI)**. Although this tool is utilized in management to a limited degree to support decision-making, AI can provide new problem-solving solutions, and increased automation will improve productivity and efficiency while reducing human stress and environmental impacts [34]. AI is the subject of incipient debate on how to ensure regulations and ethical frameworks of conduct. Another point mentioned in the interviews is the importance of sensors, robotics, and 3D printing, which is generalized in automotive suppliers and companies in the aeronautics industry.

The prevalence of various technologies seems congruous with the motivations, the possibilities of insertion in a supply chain, and the capacities of infrastructure and equipment (at times with needs for retrofitting) to have access to new business models. Technology, however, is not the sole conductor of I4.0, which is characterized principally by the set of key business models contributed by digitalized systems [8, 9].

I4.0 introduces a change from centralization to decentralization that can be represented in a single machine, an assembly line, or software. The interdependencies and impacts generated at the organizational level in the technological abilities of different sizes of businesses are unknown. Therefore, the role of research is fundamental at companies, university institutions, and in links with industry, to identify the trends toward a more substantial relationship of co-production with customers and suppliers, and thus evaluate the complexity of change. In the more industrialized Latin American nations, sectorial research in the future may increase the emerging inequalities that are evident in problems of connection, operability, and integration that hinder and reduce the speed of change.

17.4.3 Obstacles to Digital Transformation in Companies and Their Environments

Digital transformation is a process that requires the integration of technologies, businesses, and learning strategies; it involves shared consensus in the application of digital infrastructure, devices, and intellectual capital management. Business processes in digital transformation are less constrained than in traditional models, as the technological borders are more porous and lead to quick decisions. Such internal efficiency requires training and leadership ability to identify technologies that facilitate digital transformation [35]. Digitalization based on information flows and software generates greater diffusion of knowledge, with a new demand for human resources with hard and soft skills as part of a permanent process of innovation, along with the integration of various areas and disciplines that affect the development of all companies beyond simple organizational adjustment. In general, technological progress moves ahead of technical skills and the organization and remodeling is required for society to utilize technology on an inclusive basis [9].

17.4.4 Digital Literacy Becomes a Priority

In the case of Mexico, the generation of new interdependencies is not immediate in organizational structures or in the various tiers of the chain of production since a hierarchical culture of management predominates. The multilevel character of digitalization articulates areas like information systems, marketing, and operations management, where a multidisciplinary vision is constructed to make knowledge mainstream in companies and in society. This is the source of the commitment to promote digital agendas to consolidate the use of basic skills among the population. Digitalization is a complex process in which hardware and software industries converge; telecommunications need financing, regulations, and increased internal communication to motivate employees to complete new training in job profiles, where it is increasingly difficult to distinguish between manufacturing and advanced services.

The obstacles companies encounter in the process of digital transformation have external and internal levels; in the latter, most responses coincided in emphasizing the lack of human resources with an adequate profile, and weaknesses in infrastructure and connectivity. International studies of the necessary employee skills during various phases of digital transformation point to the combination of proactive scientific and technological skills, and the exchange of interdisciplinary knowledge in solving strategic imperatives at the level of information systems and in creating new business models [34, 36–38].

Digital learning and skills include the habitual use of technology to improve and innovate processes, in which programming becomes a determining skill for interacting with equipment and platforms. Digitalization involves talent in new cognitive skills, non-cognitive skills, and even personality traits to confront complex problems and solve them in collaborative form with support from technological disciplines (programming, robotics, and science, technology, engineering, and mathematics—STEM, virtual reality, and augmented reality) [8, 12, 24, 39, 40].

In Mexico, few companies invest in developing new digital capacities, nor have they appropriated digitalization as a permanent process of collaborative innovation that integrates the force of interaction (suppliers and customers) in improving new businesses and services. The lack of skills includes big data, cloud computing, and the platform of interaction with customers. Heterogeneity in applying technologies for different purposes and phases of the production process influences the coexistence of various skills, whose evolution and scope demand future research at the company and sector level. The incorporation of ICT in Mexican companies has historically been linked to incremental innovations; the novelty of digitalization lies in trans-sectorial disruptions and alteration of the global chains of value that affect the location of manufacturing [10]. The responses of educational and technological institutions with formal, lowly documented offerings in interdisciplinary research do not correspond to current and future needs for integration in information systems, to strategic management for digital transformation, or to the importance of creating a digital culture.

The mainstreaming of digitalization affects all human activities, and fundamentally economic activities—demands not contemplated in the nation's current and previous public policies. Investment in internal training was mentioned by a few companies that organize courses with company support (OEMs) and outside collaborators. Outstanding work of this type is the training activity organized by the aeronautical clusters of Baja California and Querétaro, in association with both international and national universities and companies.

Many firms mentioned the lack of digital talent. However, they have not advanced in designing job profiles or searching for intermediate solutions, such as access to programming boot camps that offer a platform for retraining and improving skills in weak areas such as programming, design, cybersecurity, and data science. Mexico lacks specialized human resources with the digital skills to develop new products and services related to the handling of information, communication, content creation, and problem-solving.

A broad range of courses and programs on robotics and artificial intelligence exists in Mexico, but few are related to big data [41]. The supply of graduate training (doctoral or master's programs) in digital technologies is relatively limited compared to the number of degree programs in other areas. Public and private investment has not been directed in an enterprising manner to maintain constructive dialog in the design and projection of diagnoses of existing skills, along with necessary skills for the future, to orient investment and the supply of training in niches that the nation requires (health, industry, tourism, and agri-food sectors). The training demanded at the company level emphasizes learning in data analysis (use of information for new markets and customer profiles), the development of security methodologies, and intelligent digital solutions like monetarization, control, machine operation, and artificial vision. The largest companies with the most sizable communication networks are best positioned to obtain qualified human resources and pay higher salaries. The SMEs that participate as suppliers in the supply chain show cautious behavior and evaluate their results. Another demand the companies mentioned was the lack of infrastructure, along with digital assets and the ability to develop them. The responses do not arise from an evaluation of impact or effects, according to the facilitators and their contributions to the digital transformation process [8, 42–44].

17.5 Connectivity

Another internal problem faced by the companies is connectivity, which plays a determining role in digital systems, especially in the appropriation of IoT. The security of I4.0 affects intelligent networks, ICT solutions, cloud services, big data, invoicing systems, and the management of customer relationships. Digital development includes four subdimensions: the availability of broadband, both fixed and mobile, the transmission speed of connectivity infrastructure, and network affordability. In industrialized nations, the demand for advanced connectivity has increased due to technological sophistication [45, 46]. According to the Global Connectivity Index, Mexico is in the category of intermediate adoption (adopters) of connectivity, with metrics similar to those of Argentina, Brazil, Colombia, and Spain. In terms of equipment for accessing connectivity, eighty-five out of one hundred Mexicans had a smartphone by the end of 2018. This figure means that such devices totaled 106.5 million, with a growth of seven percent during the previous year. In classifying these smartphones, forty-five percent have attributes that characterize them as low-end, forty-nine percent correspond to mid-range, and only six percent are high-end [47].

The survey on the availability and use of information technologies in households (*Encuesta sobre Disponibilidad y Uso de Tecnologías de la Información en los Hogares*—ENDUTIH, 2018) [48] developed by Mexico's National Institute of Statistics and Geography (*Instituto Nacional de Estadística y Geografía*—INEGI) indicates that more than forty percent of the population still lacks Internet access and that the nation's digital gap persists. The ENDUTIH survey (2019) [49] reveals that 34.4 million people (almost thirty percent of the nation's population aged six or more do not use the Internet). The statistics compiled by INEGI through the economic census of companies of 2018 indicate that companies in Mexico have used connectivity in their production processes; the most intensive companies are the largest, with eighty percent of the total, and increase productivity through their growing use of the Internet.

The digital transformation of I4.0 implies robust and secure connectivity infrastructures to prevent undesired leaks of information and inspire confidence among users. It also demands the creation of standards and interoperability, given the incompatibility of data processing, storage, and integration in covering greater geographical areas.

Undeveloped broadband and infrastructure represent important limitations for increasing productivity in Latin American nations, especially for the services sector. Successful cases are enclaves located in national clusters in Argentina, Brazil, Mexico, and Uruguay [20]. In Mexico, as part of the recent adjustments for budget austerity, the Secretariat of Communication and Transportation (*Secretaría de Comunicaciones y Transporte*—SCT) suppressed the Sub-secretariat of Communications and Technological Development (*Subsecretaría de Comunicaciones y Desarrollo Tecnológico*), the office responsible for reducing the digital gap through Internet access and the development of skills among the population.

17.5.1 Lack of Financing

In terms of external obstacles mentioned by the respondents, the lack of financing was relevant. This perception confirms that access to financing was a problem even before the COVID-19 pandemic, especially for SMEs in the supply chain that requires economic support to prepare for the new digitalization process and expand new businesses. In other countries, the expansion of I4.0 evolved with selective support from government policies, generating a space of experimentation based on public- and private-sector collaboration for developing projects, regulations, international and national standards, and information for SMEs, and consolidating a narrative of public- and private-sector involvement with implications for society in information [50–54].

When the companies were completing the survey, uncertainty was already affecting investment in production, due to company distrust based on decreased expectations for economic growth and the higher costs of local financing in an uncertain international and domestic situation. The pandemic's speed of expansion has deactivated the continuity of global chains of value that were interrupted by the severity of COVID-19, affecting production and the consumption of goods and services in Mexico and abroad. Difficulties have occurred in determining the orientation and future composition of new networks, due to the impact on multiple subsystems.

The companies affiliated with the program for in-bond manufacturing and export services (INMEX) mentioned annual decreases in their exports of forty-one percent in April and fifty-seven percent in May. One of the most seriously affected sectors is tourism, in hotels, restaurants and cafeterias, and airlines (Table 17.1).

17.6 Findings and Research Results

The study suggests further research to influence future decisions, such as analyzing the international movements of business investment and delving into the nation's digital process, business models, and incorporation of logistics systems. At present, there is no funding for studies on the process of digital maturity attained by companies showing evolution in the use of digital resources, organizational flexibility for creating a digital culture (agility in decision-making, internal and external collaborations),

Table 17.1 Main findings on the adoption of new technologies

Drivers of I4.0 readiness in Mexico	Business chambers of commerce and industry, regional secretariats of economic development (Queretaro and Baja California), automotive and aerospace clusters, public research centers
Means	Conferences, links with developed countries (the United States, South Korea, the Autonomous Community of the Basque Country, Germany, and China); visits and stays in developed countries and with public research centers
Problems that I4.0 can solve	Problems in efficiency, quality, and customer relationships; lack of concern for creating a business model; duality in the company structure (digitization versus traditional); insertion in the supply chain; the demand for advanced connectivity for appropriating IoT; cybersecurity, ICT solutions, cloud computing, big data
Internal obstacles	Digital literacy, lack of development of professionals focused on technology, big data, and platforms to generate new businesses. Perceived barriers can lead to decisions not to invest in new technologies. Firms hesitate to prepare the organization for further developments within emerging technological domains
External obstacles	Lack of incentives and interinstitutional coordination to ensure the supply of qualified human capital

and capacities (connectivity, content, experience, and technological architecture). Such dimensions would explain how companies integrate digital opportunities in terms of devices, infrastructure, logistics, and organization. Industry 4.0 has introduced many changes and the production process is becoming more interconnected. The concept of integration is the core competency of digital transformation. The companies interviewed reported numerous incompatibilities in information exchanges and coordination within industries. In the transition from traditional processes to I4.0 ecosystems, new advanced technologies and new business models both within and between organizations need to be developed.

In addition, real information can be provided at the micro level about how these companies are able to resolve various situations and contribute to improving their resources [55–57]. Evaluation has not been made of the pandemic's effects on the production structure, the widening gap between large companies and SMEs in Mexico, and the impact on intensive technological sectors that are fundamental in the process of diversification and incorporation, with the greatest added value for closing productivity gaps and experiencing sustainable long-term growth [58].

17.7 Reflections on an Unpredictable Future

The progress of digitalization in industrialized nations, according to empirical references and theoretical analyses, suggests improving infrastructure with faster connections, widespread Internet access, specialized skills, and wages [59]. The I4.0 logistical networks have revolutionized modular supply chains with consumer data and purchasing behaviors by transmitting specific requests to flexible production processes with the capacity to cover large distances in an a la carte economy. Although this debate focused on industrialized nations, for Mexico, the signing of the USMCA and the strategies to recover post-pandemic economies may represent an opportunity at the international level for relocating production and elevating digital skills and wages, in the two productive sectors. Proximity to the United States may recreate advantages for expanding markets, by incorporating new domestic and foreign suppliers in chains.

The effects of the pandemic have paralyzed production in international and national chains of production, worsening companies' lack of liquidity and representing supplementary costs linked to protocols of employee health and protection. The economic depletion already visible in 2018 made a still uncorrected nosedive in 2020, especially in the automotive sector, which was affected by the shortage of basic elements like semiconductors. The stimulus programs enacted by the incoming United States administration to alleviate the effects of the COVID-19 pandemic for families, companies, states, and the renovation of American infrastructure, may have positive effects for Mexico's companies, along with the contribution of remittances sent by Mexican migrants in the United States.

The signing of the USMCA was favorable for both productive sectors; although the results will not be immediate, the agreement may represent an opportunity to expand the digital economy. Even SME suppliers may have the opportunity to acquire low-cost tools to make their organizations more efficient and increase national supplies.

The situation is complicated by the climate of insecurity and uncertainty regarding contractual compliance, and conditions are unfavorable for growth. The absence of social agreements on public- and private-sector collaboration has a negative weight and hinders new searches for solutions for reactivating the economy, investment, infrastructure, and the creation of a regulatory setting with secure data. In addition, there is a lack of private and public investment to confront digital gaps and unequal digital skills.

Multidisciplinary research is fundamental for understanding the nature of sociotechnical change, for orienting inclusive public policies at the national level, and for directing production sectors that have shown increasingly unequal economic yields and job loss (SMEs that are domestic suppliers) due to the COVID-19 pandemic. Attention to the effects of the pandemic has provoked increased recognition of research and scientific opinion, achievements that the policies of scientific diffusion and divulgation had not attained [60]. The difficult task will be to maintain the public- and private-sectors' interest and trust in supporting research on company insufficiencies and opportunities in a still uncertain future. Inescapable risks at the individual and collective level have not been addressed by the state, political parties, or the private-sector in decision-making in data governance, precarious employment, and age or gender discrimination. The state must play broad roles beyond the market, contributing leadership to guide projects and investments that will define the future. In this case, the reference is investment directed to the governance of the digital sociotechnical system, whose action can influence and contribute to the adoption of change, and whose conflictive situation will depend on the management of multiple dimensions. Such dimensions include the external and internal challenges that USMCA may create and the orientation toward diversity in unknown situations—situations that require differential times and results to recover the population's trust in a massive flow of disinformation.

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CHAPTER 18

Conclusions: The Challenge Towards the Future Is Digital and Sustainable Transformations from a Systemic Perspective in a Changing COVID World

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Under pandemic effects, industries worldwide have been changing how they operate, organize, and perform. In this scarce-resource environment, savings and efficiency have been required to maintain working the Economic Systems. The old business models have been changing to novel and unexpected models and gave pace to creativity and entrepreneurship hand by hand with digital technology adoption and sustainable practices.

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S. Estrada (ed.), *Digital and Sustainable Transformations in a Post-COVID World*, https://doi.org/10.1007/978-3-031-16677-8_18

Whether these changes have been smooth or radical, the resulting dynamics are stressing tensions and contradictions among systems: resources are needed to keep operations going on but to invest in technological modernization, to maintain employment in a human friendly organization as to bet on retraining human capital and automate processes, to redesign the product to adapt to the changing client's needs but to retain current customer base and build loyalty, to strength customer–supplier links to explore new platform models and redefine business ecosystems, to manage outbound marketing coupled with inbound marketing strategies in such way to optimize sales and foster business positioning in traditional and digital channels, to avoid and minimize waste as to profit from these actions. So, to cope with these conflicts, organizations are demonstrating a tremendous fitness to provide solutions and much flexibility to accommodate their resources, processes, structures, and cultures.

COVID-19 imposed a familiarization with digital applications required for telework, online transactions, and distance learning. The so-called gradual change has been accelerated, but some disruptive changes are needed to the available infrastructure, productive structure, and current strategy to cope with this leapfrog. A new public–private deal is necessary to enhance investment capacity despite prolonged or intermittent periods of interruption in production and supply chains.

A Post-COVID World has not arrived yet. In some countries, we are suffering the fifth wave. The virus takes another variant that is more contagious but much less lethal, and vaccination is far behind worldwide. In other countries, the pandemic has been declared endemic. The fight against global warming is currency and compromises to eradicate CO_2 emissions are still seen to be accomplished. Digital transformation is underway and requires much more investment and connectivity infrastructure in the public and private sectors. Digital upskilling and retrofitting are a crusade. Revamping traditional to Digital and/or Circular Economy is still in a latency phase. But also true, changes have been accelerated by the COVID-19 pandemic.

A future view of the world has demanded tracing back on the recent past to understand and assess past events, so we stand firmly on the present. This moment has been generally termed the New Normal; possibly having a sort of multiple meanings worldwide, there may be a consensus that is not going back to the pre-Corona situation. Life has changed undoubtedly.

The several intertwine and diverse interpretations and reflections on what has passed may hold a common ax, the prevalence of gaps, inequalities, behaviors in digital and sustainability development since the pre-COVID world and the higher visibility of trends, contradictions, or even worsening conditions due to the COVID-driven health and economy crisis.

The chapters herein presented are evidence of these prevailing conditions. They were written by scholars from various fields, particularly on innovation. Some have spoken at the International Conference of the Research and Teaching Network on Technological Innovation (ICRIDIT 2022), and others have responded to the call for papers specially drafted for the book. The main theme of the ICRIDIT was the same in this book, except for an emphasis on innovation. Nonetheless, innovation in this book has become essential in understanding how society is becoming digitized while pursuing a sustainable transformation.

All contributions are original and meet international criteria that guarantee academic quality. The authors present the following categories:

- Theoretical contributions: concept development, literature review identifying gaps, or critical analysis. This kind of contribution presents the results of research in which several publications have been analyzed and systematized. Such research must include one of the requested follow-up topics to account for progress, criticisms, or trends. One of its main characteristics is that they present a detailed bibliography of at least 50 references.
- Contributions with methodological applications: in this category, new practices for studying a particular phenomenon are supported, explained, and shown. This type of research includes both theoretical and practical aspects.
- Empirical research contributions: this document shows the original results of research projects in detail and answers questions from a particular field or topic.

18.1 Theoretical Contributions

The digital transformation is intertwine with sustainability, but far behind being a natural condition appearing spontaneously, it is backed by subtle mechanisms that propitiated the interrelationship at different levels. To be considered as a double transformation is useful to think of it as a complex array process that requires a purposeful design to avoid negative effects, but also the implementation is stewarded by the deployment of several capabilities, i.e., planning, knowledge management, customer orientation, data analytics, innovation, flexibility, and agility. Like many other phenomena, it does not appear as an outcome of COVID-19 restrained activities, but it has gained awareness, strength, and visibility.

As several digital technologies are being adopted and deployed among nations, industries, firms, and business processes or societal endeavors such as cities, health, or education, there are many more challenges to understanding how sustainability is related to digital transformation, but also many more lessons on how this phenomenon is occurring. For its part, the ecosystem literature stresses the importance of keeping a systemic and dynamic view of digital resources co-evolving with users requiring settling societal sustainable overarching goals, acquiring renewing capabilities, framing new competition rules, and triggering increased interaction and multiple reconfigurations of stakeholders' networks. The literature on smart cities showed that urban planning and development might lead to digital and sustainable transformation and confirms the need for purposeful investment and facilitating usage through access, upskilling, and citizen empowerment.

Currently, Industry 4.0 is capital to understanding the double transformation. It provides valuable knowledge on changes in the manufacturing environment and the value chains as the potential gains and opportunities to improve performance from the digital-sustainability nexus. A great deal is to embrace a sustainable enriched value, productivity is at the edge, but efficiency and sustainability must be achieved simultaneously. Digital transformation is an enabler, but sustainability must be a commitment. Knowledge management abilities precede sustainable business models, strategy, culture, digital readiness, and socio-environmental constraints. The resistance is present and persistent and may be organizational or knowledge-based, but it is important to be aware of this situation, compromise on management change practices, and engage in organizational learning. The gradual mastering of digital transformation helps pursue sustainable value creation as it seems there is a hierarchy among sustainability's sustainable functions and dimensions.

Innovation is a leading factor in Digital and Sustainable Transformation. It may appear as a business process innovation, a business model innovation, or a sustainable innovation. In helping the production and operations management, innovation helps improve firms' efficiency, reconfigure supply chains, or facilitate sustainable practices. In business models, innovation contests where and how value is created and delivered. Sustainable innovation does impact the business' triple bottom line and may generate organizational changes that trigger business model reconfiguration. There is a synergistic and sequential interrelationship with digital technologies in all these cases.

In the first chapter of this book, Estrada and Reyes pointed out that digital transformation was a challenge to sustainable transformation. In the second, Larios-Hernández folded this argument with the digital rebound issue. Digital transformation is a sustainability depredator. It is not only about adopting superior technologies, but the digitalization process is based on an ICT platform requiring a complex network of industrial supply chains that stresses natural resources, energy consumption, and materials waste. Thus, digital technology adoption leads to a digital rebound. The developers and users' industries must be aware of this issue and widen the scope of sustainability, adopting a top management sustainable strategy that entails product stewardship throughout the whole value chain. This strategy comprehends responsible business leadership and an organizational mindset encouraging business propositions that increase sustainable value proposals. Therefore, sustainability is a must in designing any digital transformation initiative.

The pandemic disruption of business activities for firms is an extremely traumatic experience, so survival and overcoming processes need to be in-depth studied. As a point of departure, Villasana-Arreguin proposes to investigate the ability to recover from the adverse experience, namely resilience, pointing to business organizational capabilities as drivers. In general, these capabilities are related to strategies and business models. It is worth noticing the coincidence regarding the identified capabilities to impulse sustainability from digital transformation, as in the case of agility, flexibility, and innovation. These are dynamic capabilities requiring adaptability, collaboration, knowledge, and learning abilities. Thus, resilience includes changes in strategies, business models, and management systems aligned with pursuing a digital and sustainable transformation. Also, resilience and sustainability are committed to corporate governance, improving infrastructure, effective use of technology, and resource availability. These points explain why businesses can overcome crises by showing resilience through a digital (and sustainable) transformation.

COVID-19 affected businesses at several organizational, operational, strategical, and managerial levels, as digital transformation has widely influenced business activities, processes, and models. There is a consensus that COVID-19 has accelerated digital transformation, but how has the relationship been. Sabando and colleagues provide evidence of how research approached the phenomena during the COVID-19 pandemic. They are interested in small and medium enterprises. Through a systematic literature review, they track down emerging issues: dynamic capabilities, advantages, barriers to adoption, integration practices, strategies, performance improvement, and challenges and impacts. These topics sustain strong lines of research devoted to studying the digital transformation of SMEs, but an emerging one is to look at the management of SMEs during COVID-19 times. The pandemic forced SMEs to review their business models, sustainability, supply chains, and purchasing processes. Likewise, it affected its labor market and human capital. Throughout these topics, their integration into Industry 4.0 is highlighted. Current literature explores lessons, challenges, and effects of the COVID-19 pandemic and reflects on proposals and solutions to recover from this experience. A promising way forward would be digital transformation without forgetting its inherent impact on sustainability.

18.2 Contributions with Methodological Applications

The works presented in this volume with this approach describe how countries and businesses are using digital technologies and applications, the main challenges they faced, and provide reflections on how COVID disrupted the efforts made and some policy guidelines to overcome the shortcomings.

The chapter by Martínez enlightens how a subsidiary from a developing country implements Industry 4.0 among its manufacturing lines. She approaches the case through participatory observation and in-depth interviews. The main challenges encountered were the technology infrastructure, the adequacy of industrial jobs profile, and the competitiveness quest to find project profitability. First, the modernization and cyber communication of analog machines as the cybersecurity protocol. In the second place, the human resource reallocation, retraining, and talent attraction. Lastly, to capture awareness of Industry 4.0 initiatives from the top-down and relate it to the lean approach. A first sight examination may lead to the idea that sustainability outcome may be only on the economic dimension or rubbing the environmental endeavor. However, the strategies on a smart vision, automation, smart flow, quality and safety, and connectivity affect all three aspects of sustainability.

Chapters 8 and 9, by González and Gerónimo and Sahoo, respectively, explain the tourism and travel industry in Latin America and South Asia. The first is about the Circular Economy and the second on Digital Economy. Both stated that this industry already looked after these issues decades ago. A joint interpretation is desirable to give an idea of the practices in a digital and sustainable transition. Through survey analysis, they arrived at the following.

The destinations, businesses, and tourists have changed their behaviors on mobility, customer service, information, payment, and energy management. For local transportation, tourists use public services and car-pooling services as automatic check-in, phone as a key, and biometric access. In customer service, there is a promotion for using local biodegradable products and eco-friendly water care practices -such as sheets and towels recycling and reusing-and bots a robot's usage to attend to common services requests. There is more acquittance to use touchless kiosks to provide information and to make payments the contactless transaction is familiarly used. Furthermore, hotels' facilities include automatic spotlights and solar panels to manage energy consumption. The sustainable practices are certified, focusing on social responsibility, enhancement, and performance optimization. To overcome the COVID-19 downturn, Sahoo proposed an improvement in customer experience. Through a stage model of the customer journey, she investigates the behavior toward digital services available to different age groups. She finds that older people are still skeptical for security reasons and the elder prefer traditional travel and tourism services while the younger posit a positive perception of digital services.

From a socioeconomic perspective, the COVID-19 pandemic contention measures altered the investment environment through financial instability, asserted pressure to improve business models through lower success probabilities, and disrupted social behavior and consumption habits. These issues were accompanied by accelerated adoption of ICTs and a boost in the use of apps on media platforms and social networks. As ICT adoption was mobile-based and enabled teleworking, digital platforms lead a prominent role in citizen information, leisure, education, social relations, health control, business opportunities creation, entrepreneurial projects, management practices, training, decision-making, SMEs' survival, and business progressing on digital maturity. Zea's chapter scratches several indicators on the use of ICTs in Mexico to provide foundations for these considerations and verify that there are no indicators on digital media and social networks. He justifies the urgency to elaborate on them. Social media and social networks influenced the perception of coping with the pandemic, opening entrepreneurial opportunities, and accelerating digital transformation and consolidation. And they also leave a myriad of data to understand the socioeconomic impact of their increasing usage in innovation and inclusive development.

Companion to Zea's narrative of ICT usage indicators is the case study elaborated by sisters López-Salazar, and Molina-Sánchez presented in Chapter 13. The population witnessed how the COVID-19 recession eliminates jobs, affects precarious employment, and divests purchasing power; meanwhile, micro, small, and medium enterprises figure out how to keep business feasibility and confront modified consumption habits, value chain disruptions, and production shortening. The MSMEs were defied on their entrepreneurship capability improvement and the necessity to build, recreate, or revamp marketing strategies. A collapse of about 10% of GDP translated to a lowering of purchasing power of an important part of the population and, according to a survey by López-Salazar et al., broke by half the average performance indicators on sales, profit, and turnover of small businesses. The MSMEs population responded to this situation by changing its offer.

To be more appealing, about a third either introduced improvements on existing products and services or launched new products. Around two-thirds increased their quality, but at least one-third commanded its pricing policy toward lowering prices. Just over 50% invested in advertising and promotion. One-third still have bet on traditional channels. At least 20% trust the new digital communication strategies. In their digital communication mix, they rely on email marketing and try to engage clients through social media networks. Their segmentation strategy is to engage X-generation customers through Facebook, while millennials use Instagram. Certainly, there are size differences in behavior, being much more conservative medium size enterprises than smaller firms to engage in innovation and deploy digital marketing strategies.

How are world regions performing in the digital transformation? Santiago and collaborators share a regional view of how Latin American countries perform. The conclusions may be extended to other developing areas, emphasizing the South Asian case. Both regions are industrialization latecomers, and several have strong specialization in tourism and natural resources exploitation. Each of the two is lagging behind the world average on the digital readiness and digitalization level of its industries assessed with several indicators, as shown with economic complexity indices as proxies of technological capacity or with original methodology (i.e., UNCTAD's frontier technology readiness index) or first-hand data from UNIDO's efforts. The key to drive is the industrial development of manufacturing, but some foundational capabilities must be developed to participate in the Fourth Digital Revolution.

To begin with, enabling infrastructure to provide affordable and reliable electricity and high-speed and low-latency Internet connection. Following are production capabilities to endorse productive and efficient plants, robust long-term investment in fixed capital, and technological absorption capabilities. Finally, innovation capabilities include a firm's dynamic capabilities, a strong national innovation system, qualified human resources, and a clear regulation to develop, adopt and adapt new technologies. Countries in the regions show different behavior based on their accumulative capacity-building processes, adoption of digitalization, and policies to upskill and re-skill the workforce. Furthermore, there will be differences in sectoral technology intensity, propensity to innovate, and size inside countries. Larger and innovative firms and modern industries are more digitally advanced.

18.3 Empirical Research Contributions

The book provides several case studies on digital transformation and sustainable outcomes. From industrial policy, economic activities, businesses, and rural communities. In Solleiro et al. contribution to this book, the authors signal current flaws of the Mexican policy to invest in digital infrastructure and coordinate a set of strategies that are more rhetorical than actionable. This situation is highlighted in the specific case of pursuing the ninth Sustainable Development Goal on Resilient Infrastructure, Industrialization, and Innovation and the 5G technology deployment. Consubstantial to the achievement of this SDG is the STI policy, which is underperformed, as seen in its increasing reduced budget, insufficient innovation and technology development programs, and short-term vision. As in many other Economic or Social areas, the COVID-19 crisis exposes weaknesses in adopting digital technologies, in general, and the 5G infrastructure. The management of technology in businesses is far from innovation and local knowledge sources, flimsy technology development capabilities, a wimp use of digital technologies, access difficulties, lack of infrastructure, skills shortage, a dearth of capabilities for policy interventions on the software development, equipment innovation, information security, digital creation capacity, public–private agreement to retrofit infrastructure as to articulate collaboration between users and creators of knowledge.

The case presented by González and Barragán can be a tale of how sustainable innovation struggles with climate change challenges, food security, and poverty alleviation as it harnesses digital technologies or a specific case for embracing digital transformation in the primary sector that can be named precision beekeeping. This approach stresses the importance of customizing digital technologies to particular problems and uses, i.e., to monitor bee colonies, nutrition, and dispersion problems. The paper asserts that there is a link between digitalization and innovation but raises the issue of the traditional knowledge role to play and the broadening of innovation toward other strains, the open, social, and frugal innovation types. Thus, finding a productive arrangement that mixes traditional techniques and skills with cutting-edge technologies is challenging. Concerning innovation type, the quest is to create sustainable value. The first is responding to adding stakeholders to the network, the second is for participation exchange, and the last is for lowering costs.

Chapter 7, written by Sharma and collaborators, reminds us that digital transformation is a process beginning before the COVID-19 pandemic. An authoritarian innovation was put in place by the Indian government to demonetize the economy and aid in eliminating the black money market. The bottlenecks that impeded the non-cash expenditure were the Internet connection, the lack of technology for users, security issues, and hacker activity. Current instruments of cashless transactions aid in augmenting GDP, reduce social costs, increase financial inclusion, and impact the traditional banking industry. Furthermore, it helps to improve customer satisfaction, facilitate trusted online transactions, and curb black money and counterfeiting. The authors concluded that negative and positive effects appeared in the short run, but in the long term, there are only economic benefits. This lesson may provide value for the ongoing digital transformation COVID-19 speeded.

The Ecuadorian Tourism Industry has been studied on behalf of the meaning of digital transformation. Based on the organizing vision and institutional isomorphism theories, Toscano and contributors conducted in-depth interviews with industry leaders to elaborate and interpret the framework. As in other works of this book, the main challenges for digital transformation derived from a low readiness: lack of government support, weakness of the technological infrastructure, and low-skilled workers. The chapter proposed three types of challenges, coercive, normative, and mimetic. Digital transformation is a necessity for the tourism industry that requires an articulated policy, robust infrastructure to ensure Internet connectivity, a solid vision at the enterprise level, collaborative networks, attractive cost–benefit performance, and leveraging differentiation strategies. COVID-19 experience demands greater adaptation, resilience, and new forms of management.

During the COVID-19 lockdown, several economic activities were restrained and reopened progressively. Lechuga-Nevárez studied a sample of university entrepreneurs facing this New Normal. A set of traits about entrepreneurship were proposed where they favored ethics, search for opportunities, resilience, and commitment as the most meaningful attributes. The same exercise has been done with the innovation process and digital transformation. On average, they rank effectiveness, efficiency, and innovative culture for the innovation process. Concerning digital transformation, the prelation order was digital skilled human resources and digital leadership. Thus, the New Normal university entrepreneurship can be characterized by behavioral traits first than personal characteristics; the innovation process is geared toward organizational performance and collective attitudes; meanwhile, digital transformation depends on qualified human resources availability and a strategic management approach. There is a high correlation between the three variables, and it can be anticipated that in times of COVID-19 being a university entrepreneur is characterized by an ethical, resilient, and committed behavior in continuous search of opportunities and that it can be facilitated by innovation and digital transformation. The innovation process is characterized by a search for effectiveness and efficiency, in addition to stimulating and promoting an organizational environment conducive to innovation. And that digital transformation requires access to qualified human capital and a strategic approach to benefit from digital resources.

One of the most vulnerable populations to COVID-19's economic, social, and digital divide negative impacts may be the dispersed rural communities. Nonetheless, they must also be one of the most resilient. These communities suffer poverty in different grades as expressed by working poverty (insufficient wage to afford a basic food basket) and social marginalization (lack of access to minimum community services). The health crisis highlighted inequalities like the case study of Lechuga-Nevárez and her colleagues' snapshot. The disease had to be treated in isolation with a lack of health facilities, increasing the home care burden, especially among women. Most of the population dedicated to producing or commercializing primary products suffered an economic shock by the contraction of the economic activity, the supply chain interruption in main local markets, and the lowering of remittances from the US due to its economic slowdown. Rural households are composed of large families, on average seven financial dependents, where half are between 15 and 25 years old, so they have been affected by the pandemic in several ways. Half of them declared to suffer some disruption in their employment condition due to the pandemic, from losing their jobs to ceasing activity, affecting their workday hours and wages, and about a fifth part dropped school. Also, half of them stated to have at least some difficulties covering monthly expenditures. Furthermore, more than three of the fourth parts have access to the Internet via mobile networks. The pandemic forces families to acquire a connectivity device to keep on education and attend to other New Normal needs, such as purchasing, e-commerce, home office, and entertainment.

Undoubtedly, companies worldwide have been progressing in applying digital technologies. Global trade, investment, and technological interdependences have kept a decisive fuel in diffusing digital solutions. In Mexico, multinational enterprises and local businesses integrated into exporting value chains participated in different intensities in digital transformation. An example is a case of firms participating in the value chain of original equipment manufacturers in Mexico's automotive and aeronautical industries, as demonstrated in Casalet's contribution. In most companies surveyed, the vision of digitalization is related more to gradual evolution, improvements, and adaptations, than to a new interactive complex configuration mediated by a platform. Entrepreneurs are concerned about changes and modifications in production processes as well as in the management of the development of new products, services, and business models and, in the second order of importance, in the improvement of efficiency in quality processes, cost savings, and customer relations.

Several actors from the public and private sectors participated in raising awareness about I4.0 in society and industry. Companies obtain information on digital transformation through international conferences and business stays (in locations based in the United States, South Korea, Basque Country in Spain, Germany, and China). Business chambers and state governments in Mexico sponsor these activities where consultants and public research centers also participate. These also provide solutions to SMEs in processing and IT systems oriented to process improvement, data use, and business modeling. The participation of SMEs in digital transformation has been possible through their integration into a production chain linked to the export sector, together with access to digital platforms.

Among the obstacles encountered by companies in the digital transformation process, the majority agreed in highlighting the lack of an adequate profile for human resources and deficiencies in connectivity infrastructures. Despite the former, companies have not prospered in designing occupational profiles or exploring alternatives for retraining and upgrading skills in critical fields such as programming, design, cybersecurity, and data science. Mexico needs specialized human resources to develop new products and services related to information management, communication, content creation, and problem-solving. The shortage of capabilities includes big data, cloud computing, and customer interaction platform. One more problem faced by companies is connectivity. The undeveloped broadband and infrastructure represent important limitations to increasing productivity.

In practice, using mature technologies, including non-machine-based ERP management systems, is common. Human inspection and enabling techniques such as enterprise resource planning (ERP) and customer relationship management (CRM) control and monitor production processes and supplier relationships. Both technologies allow greater integration of information and processing across multiple business functions. However, although they are not the most widely used, the most cited technologies are related to big data analytics and cloud computing. Their importance is associated with the interest in developing new products, services, and supplier relationships. The challenge of data analytics is verifying this data's reliability and updating employee skills as technology evolves.

Cloud computing to collect and analyze data in large and growing volumes faces bandwidth constraints.

In Mexico, the absence of public business support strategies has weakened the preparation of companies for digitalization and has stalled the supply of new skills for digital transformation. The lack of a national policy and support programs from the federal government is evident in the low digital readiness of companies.

These firms assert that the advancement of digitalization holds several barriers, among them management strategy, the technological capacity to adapt and improve the use of advanced digital production technologies, and the lack of encouraging actors to integrate technical and social dimensions in a digital ecosystem. Nonetheless, open several opportunities. The continuous growth of data facilitates business model changes, the customization of products, customer experience improvement, flexibilization, coordination and optimization of the chain value, speed and sharpening decision-making, and facilitates exchanges between internal functions and geographically dispersed production units.

18.4 Challenges and Opportunities

The chapters that make up this book raise analyses, discussions, and problems regarding digital transformation and sustainability; from the studies, some limitations and opportunities for digitization can be established, and a series of research experiences are highlighted below.

For their part, Sabando et al. find that in global research on digital transformation, specifically in SMEs (in the context of the pandemic), the main research topics are Business, Management and Accounting, and Computer Science. Germany has the highest participation in scientific production, well above the countries analyzed, followed by Italy, Russia, and the United Kingdom. It should be remembered that Germany is a promoter of industry 4.0. Their investigations have focused on the growth of opportunities offered by digitization.

On the other hand, the study identifies that Latin America is a region with little research, which shows a weakness in identifying specific regional problems. Although the study by Sabando et al. contributes to identifying trends, the lack of research in the region is also evident. Above all, when considering that in Latin America, the largest number of companies are small, with a regularly short lifetime, predominantly with a family organization and during the pandemic, they had a high fatality rate due to the slowdown in economic activity. Given this, the opportunities for all SMEs are unclear, and options are open for regional research, specifically on digital and sustainable transformation.

The previous shows important differences between the regions in terms of digitization. In that direction, as already commented, Lechuga-Nevárez et al. identify the profound impact that the pandemic had on rural communities. The researchers analyze three rural localities in the State of Durango, Mexico, trying to identify the factors that had a socioeconomic impact, making visible how weak rural communities are in the face of health, economic, and other situations. The researchers found that 22% of students had to suspend their studies due to various conditions surrounding the pandemic and 50% of the employed population lost their jobs. Added to this are a series of problems that deepen the precariousness in which they live in rural areas. For example, the income of those who kept their jobs was reduced, health problems, the absence of digital connectivity to carry out various activities, communication (in isolation), employment, and studying. In this regard, the authors identified that informational knowledge and digital tools had a socioeconomic impact due to the expenses incurred in devices/tools and connectivity services such as the Internet, either for the home or under individual connection plans. The precedent sets an example to understand that digitization cannot be carried out with intent alone.

Larios-Hernández explained that digital transformation is a way to achieve sustainability, mainly because it causes decentralized organizational processes, leading to efficiencies. However, the direction that digital transformation takes in some organizations tends to favor the interests and priorities of managers (referring to the classic economic problems of selfishness and free rider), who regularly promote schemes where they can maintain control (centralized) of the organization, compromising sustainability. The author insists that although digitization enhances the efficiency of information flows (technical element), it is not enough to implement the digital transformation and has repercussions on sustainability. The organization must understand the decision scenarios and that the transformation generates long-term value for the interested parties, mentions Larios-Hernández. In the words of the author, digitization by itself will not save the environment. An understanding of the goals of organizations and societies is required. Along these lines, a limitation faced by digitization is its promotion without an extended version of conflicts, the nature of organizations, and human behavior.

The starting point for any analysis of social problems is information, and its absence is not only a barrier to the characterization of the different issues it also limits decision-making to solve them. In this direction, Zea analyzes the various sources of information (surveys) in Mexico that could provide a reference to the state of SMEs in terms of digitization and COVID. From exploring these surveys, Zea finds that using ICTs is focused on administrative activities and support for entrepreneurship, which can promote skills development. However, they lack information and indicators that allow knowing the use of digital media and social networks, as well as the impact of ICTs in the organizational management of SMEs. The research shows the absence of instruments that delve into the state of SMEs concerning current problems, which became relevant in the face of the pandemic. The absence of information is a major limitation for decision-making regarding digitization.

In this sense, the studies show some challenges for the economy. The case of the survey by Martínez, based on the analysis of a multinational automotive company in Mexico, identifies the challenges of implementing Industry 4.0 technologies within companies (an industry with digitization processes as one of its foundations). In this regard, Martínez set up three challenges to solve to implement industry 4.0. Technological infrastructure, mainly the company, must protect its information by defining cybersecurity protocols. When the main raw material of these processes is data/information, processes must be in place that protects its flow inside and outside the firm. The labor market still does not have the necessary profile to implement digitization. Profitable projects within the planning of the investment and return aspects are required. Thus, they can be implemented and, above all, be convenient for the companies. In this sense, the research allows us to think about specific tasks so that Industry 4.0 sees the light, such as justified investments, guidelines to train human resources, and the integration framework for specialized providers (for example, information security and material infrastructure), among others.

Along the same lines, Sahoo's study examines in detail the measures (in digitization terms) that companies in the tourism sector could take to gain a competitive advantage in an environment such as the current one, of which the following stand out: following up on the experience mobility through different applications; use of bots, mainly using interaction to extract more detailed information from experiences but also where customer doubts can be resolved; intelligent kiosks, where users can access tourist information; and contactless transactions, digital technologies have increased the number of transactions without direct intermediation with people, which tends to facilitate transactions for users and increase the monetary flow. Likewise, the study identifies the main users of digital technologies being people within the age group between 20 and 40 years old, for which a substantial increase in the use of digital services is expected in the short term. Following the tourism line, Toscano et al. stressed the importance of government participation in creating technological infrastructure and that the tourism sector can take advantage of digitization.

The studies that make up this project have not only been limited to identifying the state of digitization and sustainability, its limitations, and challenges. They also describe how the challenges that achieved the transformation and disruption brought by the pandemic have been overcome. Villasana-Arreguín, through a literature review, identified the resilience strategies and the capacities adopted to face the pandemic. The assessment allowed the author to identify the main capabilities used by companies, such as adaptability, agility, collaboration, decreased vulnerability, diversification, dynamic capabilities, flexibility, innovation, knowledge and learning abilities, and the reconfiguration of organizational resources, emphasizing that the solution it is not only technical and that the organization needs to implement strategies beyond the devices.

These works identify the main problems faced by both digitalization and sustainability. However, there are several unfinished issues to consider that should be contemplated; it is worth mentioning at least two, the world economic crisis and the financing problems. One of them is the financial turmoil developed countries face, and the various current technological developments have not been enough to counteract the economic slowdown that deepened during the pandemic. In addition to low growth rates, two phenomena are added: the fall in the profitability rate of the economy, such as the low productivity already reported by supranational institutions (OCDE), and the barriers that technological development faces for digitization and sustainability. Furthermore, money is getting expensive with Central Banks moving the interest rate upward to cope with the recession. How is investment encouraged in a scenario of few incentives for the investor? How is financing encouraged to carry out investments with certainty? These questions mark a beta that needs to be explored and deepened in countries where the economy's lethargy tends to hit the hardest (because they are vulnerable) and risky investments are scarce due to their dispersed market and without a critical mass that would promote technological diffusion.

18.5 The Dimension of a Technological Revolution

There is no doubt that the subject of the book is on the frontier, which permeates all areas of the daily life of any social class and any economy. The theme is on the border because it could mark the beginning of a new technological revolution that is going through a discussion that has lasted half a century, basically addressing environmental problems, health, and infrastructure, in which digitization plays a preponderant role. Thinking each of these problems will be decisive in this new revolution tells us that it will be necessary to identify the key industries in the medium and long term, know their trends, and the actions to take into account to solve current social problems. Regarding sectors, the task is to locate some driving branches (those already known as new) or those that produce universal inputs in this technological revolution, which can range from some already well-known (for example, semiconductors) to new but have been maturing (like the data). Also, the user industries within this revolutionary transformation will have to be elucidated, such as environmental, health, and urban development technologies that require more efficient processes found in digitalization. On the other hand, it will be necessary to identify the essential infrastructure in the revolution, such as cloud technology and greater speed in information transfer for all new developments, for example, in the case of platforms.

Although identifying the key industries in this revolution will serve to know the sectoral trends, it is insufficient due to social problems. The participation of social organizations is becoming increasingly necessary, not only because it must be inclusive but also because the involvement of different social agents will facilitate the early identification of both problems and solutions. In addition, it is impossible to “reverse” the population to participate in the proposal and build solutions. For a long time, firms have maintained the greatest participation in “offering” solutions; however, many of these solutions today are part of the problem, as they only have their gaze and do not incorporate that of the population.

Governments cannot stop participating in the formulation of solutions. It is a serious risk to continue proposing policies in which the government is only an observer and does not seriously regulate the sustainability problems, which encompass the ecological, employment, and the economy. It is not just about the government going digital, promoting digital technologies, or developing infrastructure. The government must involve social actors such as academia, firms, civil organizations, and sectors to propose solutions. The pandemic has shown that leaving everything to the market is not a unique solution. The direction of the different governments and the technological developments were required as a result of the coordination that they maintained.

18.6 The Solutions Are Not Only Technological

Thinking from a technological revolution dimension and a systemic point of view requires placing technology as a means but not as the solution itself. Although the extensive technological developments in the book show us the scope they could cause, technology is not a tabula rasa. Technology is determined by a direction (although it does not imply that it cannot be redirected) and social specificity. The technologies that involve digitalization seem to be the answer to the demands of sustainability. However, future analyses should apply digital technologies' limitations and consider the ethical, economic, social, environmental, and geographical elements on which these technologies are designed, produced, and consumed. The different works of the book have shown the transversality required to take these approaches into account. For diverse problems, there cannot be a merely technical or technological solution.

The final point is that the digitization process has not yet presented an inflection or decline in its life cycle, mainly because it has been sustained because, during the last decades, there has been a snowball in technological developments. These have fed back the growth of digital technologies and the deepening of the digitization of the economy. Due to the above, it can be seen that the digital transformation will still take place in the medium term. From this, the digital transformation is not new and will not end soon, so it is necessary to continue delving into the subject.

The book is one of the different institutional efforts RIDIT has made in the last couple of years regarding the problem that intersects sustainability—digital transformation—(taking into account the pandemic). Other efforts in this direction include holding talks like the one with professors from the Berlin Business and Law School in early 2022. In this conversation, the advances in digital transformation in

Germany were raised, but they also spoke about the challenges that arise in this matter. From a Latin American point of view, anyone could have an image that frontier developments are maintained in Germany, and everything works perfectly. However, the researchers raised the challenges that Germany presents as a society and government (mainly when considering the differences between countries/regions and firms). Even in the main promoter country of industry 4.0, researchers perceive themselves as limited compared to other countries. They underline that the specific actions regarding digitization are different even within the cities. In Berlin's downtown area, one can think of a Smart City (access to the energy network, etc.), but in other neighborhoods, the situation is very different or non-existent. This is because each neighborhood government makes different decisions. In addition to this, it was suggested that digitization and sustainability as a model of entrepreneurship have greater openness in other countries, such as those in developing countries; with this, it is observed on the one hand that there is not a homogeneous acceptance of both in the importance of the sustainability, and on the other, even recognizing that it is imperative to take action on the matter that digitization is the only way.

The researchers highlight the importance of taking interculturality into account for applying policies for digital transformation when considering cultural differences. Actions on interculturality will only be successful if they are inclusive. Otherwise, advances in digitalization and sustainability will not have the expected benefits. It has also been suggested that in some sectors, mainly academics, there is a certain reluctance to interact mediated by digital technology. The researchers stated that digital technology access was facilitated (you can connect with people from anywhere). However, it does not mean that it is easier to interact and that this is completely accepted by society. This is a limitation for creating intercultural capacities, mainly because there is a state of comfort when the connection is made digitally, different when the link is made in person. In this sense, new problems appear with interculturality as digitization develops.

Additionally, a round table was held organized by the RIDIT and the International Entrepreneurship Lab Smart Money. The latter is a digital platform that mainly encourages entrepreneurship and innovation through forming support networks and deploys a collaborative online intercultural/international learning experience. The round table discussed digital business accompaniment and multiculturalism of innovation and entrepreneurship, where successful experiences were also presented. The platform is an example of the power of digital transformation, which it has taken advantage of to link students, teachers, and managers through technologies before the pandemic and the new Normality. In this sense, digital capacities were generated to promote entrepreneurship during the pandemic, which could be used. As mentioned above, digitization during the pandemic has shown not only the use of digital technologies to communicate but also a certain reluctance to continue doing so. However, the platform offers the possibility of successful, mature experiences in which learning and entrepreneurship could take place during digital transformation. The truth is that even with its limitations, the trend toward an increasingly digital economy is an adaptation by the different agents that include industry, academia, government, etc.

The RIDIT held its 11th international conference, this time in online mode, on February 24 and 25, 2022. It was the University of Guanajuato (Mexico), the institution that hosted the event. As mentioned earlier, the conference's core was Digital and Sustainable Transformation and Innovation on a Post-COVID World. The themes that made up the event were organized into six panels with topics such as manufacturing, intellectual property, services, health, and the new Normality. Each panel considers at least three presentations, covering the issues of digitization and sustainability in patents, tourism, health, monetary aspects, and public policies. The conference incorporated researchers from Mexico, Colombia, Ecuador, Argentina, India, Spain, and Germany. Most of the researchers belong to universities and research centers that, for years, have carried out research focused on innovation and that seek academic discussion and development proposals.

The conference left, as a result, many ideas that help guide the work of teachers, researchers, and business people, in addition to paying for current debates. It should be noted that it was emphasized that technological development could not be defined in isolation or only technically. For this, it was established that it is necessary to incorporate elements of a social, economic, cultural, and organizational nature to change toward a course where sustainability is guaranteed.

Noteworthy, the conference clarified that there are many gaps in research and knowledge building and creating academic, business, and mixed networks. This is to propose strategies based on the use of frontier knowledge and new digitization technologies and meet the objectives of sustainable development to improve the quality of life of people and guarantee economic sustainability and the preservation of natural resources. The conference had the opportunity to unite both the basic and the applied part of the research because the nature of the problems to be faced has required going one step further, reaching action (once the phenomenon has been characterized), and trying to solve the social issues. The problem is complex, full of multiple determinations that feed each other, which can be synthesized in digitization and sustainability.

18.7 The Biggest Challenge Is a Systemic View

COVID-19 shows there is a long way to sustainable development. The gaps, inequalities, behaviors, trends, contradictions, and worsening conditions have been underlined throughout the reading of the chapters of this book. Nonetheless, a big picture of the situation is suitable for foreseeing the future. Some conditions are especially important to engage with digital transformation and address it toward sustainability. Multilevel schemata must be drafted to get a systemic view.

Since a purpose intent is needed to link sustainable transformation to digital transformation, strategic management is a convenient point of departure. For small businesses and entrepreneurs, a continuous adaptation of strategies has been a constant since COVID-19 restrictions, and literature on resilience and capabilities does gather changes in management systems and business models. In an environment where data is continuously growing, changes in production processes, new product and service development, business models, and customer experience improvements are expected. Thus, embracing Industry 4.0 with a sustainable orientation may be facilitated by the recent experience of resilience and the related dynamic capabilities acquired, developed, or strengthen throughout this trajectory.

Knowledge management should be highlighted among the dynamic capabilities, such as adaptability, collaboration, and learning. When organizations do not process information and knowledge systematically, they cannot understand a given situation and resist change. Their role in resilience is the first-order capability because of their usefulness in alerting or becoming aware of trends and drivers of change. These capabilities precede sustainable business models and digital readiness as they help to be mindful of socio-environmental constraints. Acquiring and processing large amounts of knowledge about the manufacturing environment and value chains is desirable for successfully adopting an Industry 4.0 strategy.

As a national capability, it may permit looking at promissory collaboration areas, assessing current infrastructure and opportunities, evaluating skills shortages, bridging knowledge creators and users, enabling public and private agreements, and addressing regulations to develop, adopt and adapt new technologies. Therefore, this capability may be at the center of a national policy to align the national innovation system toward digital and sustainable transformation.

Another function of knowledge management is to transfer and combine knowledge. As digital transformation demands the readaptation of traditional businesses, it is a great challenge to combine traditional skills and techniques with digital technologies in a particular context while respecting sustainability. One way to achieve this commitment is to respect jobs and skills by facilitating connectivity and access. Empower decentralization and enable stakeholder participation and aggregation. A good example of this can be, in the primary sector, the case of precision beekeeping that is collected in this book.

A good knowledge management practice can consider a harmonious combination of knowledge, experiences, values, contextual information, and expert opinions. Ethics, resilience, and commitment are some values and behaviors to consider to take advantage of digital transformation. Following this idea, the solution to embracing digital transformation is not only technological; management must be open to the influence of the socio-organizational environment. Along with a strategic vision to reconfigure resources and achieve effectiveness and efficiency in all intended changes, a collective attitude toward innovation must be promoted to pursue flexibility and agility. It may be advisable to develop ambidexterity in using and acquiring knowledge. A highly motivated workforce is capital for retraining and integrating new skilled digital talent and using local knowledge provided by external sources such as universities and research centers. It is worth noting that the current population aware and willing to use digital technologies and applications are young people. Millennials and centennials are critical for staff recruitment, motivation, and customer engagement.

Emerging and developing countries have a population distribution in a transition to varying degrees, from progressive to stationary. As the economically active population is a demographic bonus, governments can allocate the extra resources to social investment, healthcare, poverty alleviation, inclusion, and the preservation of natural resources. Improving connectivity and planning investment in infrastructure in a green way can be a powerful tool to address problems with precision and cross-cutting scope. Furthermore, it can be a promising way to improve the quality of life and face the Sustainable Development Goals.

Pandemic and recovery are leaving vast amounts of data behind thanks to the increasing use of social media and social networks. Knowledge management capabilities must progress toward developing data analytics capabilities to take advantage of it. There are many opportunities to improve and take advantage of data analytics. While data are the inputs for process improvement and business modeling, they also enable entrepreneurship opportunities, digital acceleration, and business model change. In addition, they produce a great impact on society and the economy. Therefore, it is worth understanding data analytics skills in a cognitive and skills context as in business and social environments.

As a cognitive area, data is a Science and enclose a group of disciplines like Statistics, Data Mining, Automate Learning, and Predictive Analysis. So extracting knowledge and understanding data convey methods, processes, and systems. Two key technologies are to recollect and analyze data: Cloud computing and Big Data. The first is constrained by bandwidth connection and the latter by data reliability and security. These are highly valuable technologies in business because they help develop new products and services and manage supplier relationships. To protect inflows and external flow information, companies must establish cybersecurity protocols. Thus, critical areas for developing human resources are programming, design, cybersecurity, content creation, and soft skills like problem-solving. The knowledge of these fields may be acquired in external sources like universities and research centers but also by learning by doing or by interacting in the production chains with partners or accessed through digital platforms. These exchanges may be the stepping-stones toward a digital ecosystem.

Another driver of change is customer orientation and customer behaviors. They provide data on their needs and consumption habits as they engage in social media and networks. COVID-19 disrupted social behavior and consumption habits. Even when disclosed a low readiness, its effect was to accelerate ICTs' adoption and increase the use of apps on media platforms and social networks. Accessing a connectivity device was critical to keep on with the New Normal life. People get acquittance for telework, on-live transactions and communication, distance learning, and streaming. As the population deepens its engagement with digital technologies and devices, stronger stress is put on energy consumption and natural resources and waste, the rebound effect. As COVID-19 pandemic contention measures advance, the recession broadens and divests purchasing power, destroys jobs, and alters precarious employment so much more families have difficulties covering monthly expenditures. This combination presents a disruptive landscape for businesses; efficiency and effectiveness may not be the sole driver of their strategies; environmental and societal care must steward their strategic planning and operational concerns.

So data must reach not only the production processes, new product development management, or the business models they must seek on the customer relationship. Currently, the ERP and CRM technologies enable tracing data related to customers. In B2B, the customer interaction platform is critical to provide agility and flexibility to processes and exchanges for the value chain, reaching outperforming coordination. In B2C and services industries, customer service is changing through data, enabling product customization and customer experience improvement. A paradigmatic example must be tourism, where destinations and suppliers keep changing as tourists modify their behaviors. Some areas experiencing these changes may be mobility, information, payments, and attention through digital technologies such as bots, robots, touchless kiosks, cashless payments, and biometric security. Also, communication and promotion are changing as people engage in social media. Even small businesses are changing their marketing strategies by combining outbound with inbound strategies. They communicate with potential customers through email marketing strategies and engage them through social networks despite a lack of capabilities to manage customer interaction platforms. Another marketing answers to the changes are in the product strategies to bet on new products, improvements, and quality. In pricing, they are proposing to lower prices and cashless payments. In placement, they provide contactless solutions within access and home delivery platforms. For these COVID-19 times, age has retaken a capital role for segmentation and proven functional in predicting behavior due to its high determination of digital habits and acquaintance with digital solutions. Finally, data management improves customer satisfaction and is useful for retaining the customer base.

At the national level, understanding the value of data must be translated into the continuous effort to provide precise data on ICT infrastructure and usage to develop new indicators to trace social network usage and society advances in the digital economy. Noteworthies are the international agencies of United Nations attempts and the national statistic offices worldwide framing index, indicators, and models for tracking the social progress of the digital transformation. The New Normal is to retake our lives with intermittent contention measures. This intermittence does provoke uncertainty in financial investment, business success, and social behavior. It seems that change is the Normality, as our needs have been evolving in education, health, work, commerce, leisure, and socialization, among other activities mediated by digital technologies. Predicting performance and outcomes is impossible, but some indicators should prove useful.

In this holistic framework, there must be a place for innovation. It is an input, activity, and result. It is part of a Sustainable Development Goal (with industrialization and resilient infrastructure). It is essential to understand digital and sustainable transformation as it is a capability for its implementation. Also, it is considered a driver to overcome an adverse experience. During the COVID-19 outbreak, an unusual number of SMEs engage in innovation in response to this situation. Innovation is fundamental to the business value proposal as it affects the business process, business model, and sustainable innovation. It may be looked at in the operations and production improvement, the supply chain reconfiguration process, or the adoption of sustainable practices. It may participate in organizational, technical, or commercial changes. It is related to digital technology and impulse sustainability from digital transformation, and it may be an input and an outcome of digital technology usage. As a sustainable innovation, it affects the triple bottom line at the corporate level, while in the social economy, it acts on climate change, food security, and poverty alleviation. In the business and digital ecosystems, open and social innovation strengthens networking and reconfigures partnerships. In the New Normal, the innovation process in entrepreneurship is oriented toward efficiency, effectiveness, and innovative culture. Even the State could address innovation through an authoritarian innovation and obligate a technology to be adopted. Such innovation may reduce costs, increase inclusion and generate new competition rules.

In the case of digital technologies, it may grant a convenient infrastructure and assure technology access and security issues. Innovation is a strategic approach toward Industry 4.0 and sustainable transformation.

As a final comment, at this project's beginning, several questions about how COVID-19 has impulsed the digital and sustainable transformation have been posed. In this book, we may respond to a few; for example, in the cases herein presented, digitization and sustainable innovation have been responding to some Sustainable Development Goals, but they fall short of coping with them. The book's main focus is socioeconomic impacts, and they were expected to provide an institutional trouble-shooting view. The publication highlights the capabilities related to the double transformation but not the management practices. The expectation was that several contributions might be anchored on digital technologies and entrepreneurship practice.

Nevertheless, some include literature reviews and interviews that shed light on the importance of cloud computing and big data analytics as ERP and CRM systems. Furthermore, deters and determinants of adoption are both technological and organizational, as demonstrated in the automotive, aeronautical, banking, tourism, and apicultural cases presented in this work. This volume suggested significant issues government and businesses must assess to keep pace with worldwide accelerating post-pandemic trends. The chapters may reflect how regions understand the double transformation, including the primary, secondary, and tertiary sectors. Latin America and, to some extent, South Asia may show the following. The primary is more oriented toward sustainable innovation, harnessing the digital in combination with traditional knowledge. The secondary sector impulse is on retrofitting manufacturing and upskilling human resources in search of some sustainable results restrained to the economic dimension. The third is combining digital and circular solutions within the customers' habits changes and responding to government regulations. Small businesses are in a transitional phase, mainly digitalizing their communications and applying an appealing change to their offer to perform efficiently and effectively.

There is still little research on the digital and sustainable transformation accelerated by the COVID-19 health and economic crisis. This statement holds true for research globally, within regions, countries, and sectors.

The progression of gaps and their widening needs to be documented and possible solutions generated. International collaboration has proven to be a viable way to develop solutions acceleratedly, particularly when the viability of human life is at stake. This publication is a start but also a challenge to continue to reflect and act on the dual transformation of society, digital and sustainable, from a systemic perspective.

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S. Estrada (ed.), *Digital and Sustainable Transformations in a Post-COVID World*, https://doi.org/10.1007/978-3-031-16677-8