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Industry 4.0: Costa Rica's State-Of-The-Art in relation to Technology and Value Addition

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Abstract
The main objective of this investigation is to describe the current landscape of Industry 4.0 in Costa Rica. Industry 4.0 is a combination of technologies, such as robotics, big data, the Internet of Things (IoT), and artificial intelligence (AI). Latin America has mostly focused on the development of IoT technology. Costa Rica ranks second in terms of IoT implementation, with a strong focus on environmentally sustainable innovations.
New technologies emerge daily, and the IoT is among these technologies. Thus, after comparing Costa Rica with other countries and regions, there are several areas of opportunity to upscale these revolutionary technologies beyond the IoT. The government of Costa Rica and local businesses should work on a joint roadmap to upskill the population on using these technologies. Additionally, this research provides resources and opportunities for experimentation through design thinking, allowing more innovation creation based on trial and error to find the best solutions to implement to add value.

Keywords
Industry 4.0, technology, value added, Costa Rica.

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1. Introduction

In 2020, the Covid-19 pandemic challenged worldwide economies, processes, and systems. This unexpected situation introduced the opportunity to challenge the status quo by thinking outside the box and redesigning processes and systems to create a new way of doing things. Traditional business models were tested; thus, there is a need to employ more innovative operating mechanisms that are more sustainable and at the same time guarantee competitive advantages.

According to Eakin & Lemos (2006), the IoT and globalization have imposed unprecedented opportunities and challenges in terms of cultural integration and business model operations. For example, Costa Rica, through a joint venture with Coursera, launched a program to strengthen Industry 4.0 skills. The long-term outcome of this training is that it will allow the economy to have skilled people who can rapidly adapt to unforeseen situations. These are one of many efforts Costa Rica is making in terms of Industry 4.0, although it is necessary to compare these developments and implementations across Latin American regions and other countries leading this revolution such as Germany.

This investigation focused on a descriptive analysis of IoT technology as one of the predominant industries, more maturely implemented technology in Costa Rica; and contrasted this against Artificial Intelligence (AI) technology that is nonexistent in Costa Rica. With the current trends and advancements in technology, AI will soon be implemented in the country. The maturity assessment identified the strengths and weaknesses in Costa Rica's current landscape. Opportunity areas should be addressed through multiple years of roadmaps in which the government and local businesses work together to understand, develop and implement these emerging technologies in critical pillars for the country's development, allowing value to be added in the most significant areas.

2. Methodology

Descriptive investigations are those that are designed with the purpose of independently gathering information on a series of related variables and concepts. Descriptive investigations also provide insights into the behavior of variables and concepts. However, they do not necessarily portray direct relationships among variables being studied (Nadler (1967)). Thus, this research is descriptive since its focus is to provide a possible solution to the current landscape of Industry 4.0 technology for Costa Rica and determine how better value could be obtained from this technology to promote sustainable business models and livelihoods.

For all types of research, the methodology that will be used for the study must be established. There are three types of approaches in research processes: qualitative, quantitative, and mixed. Quantitative investigations are those that test hypotheses by applying the [n] data collection format based on mathematical quantification and statistical synthesis to examine theories and explain behavioral patterns (Li et al., 2017).

In contrast, qualitative research aims to analyze and interpret behavioral changes related to the concepts that are under study. However, qualitative studies collect nonnumeric data to interpret

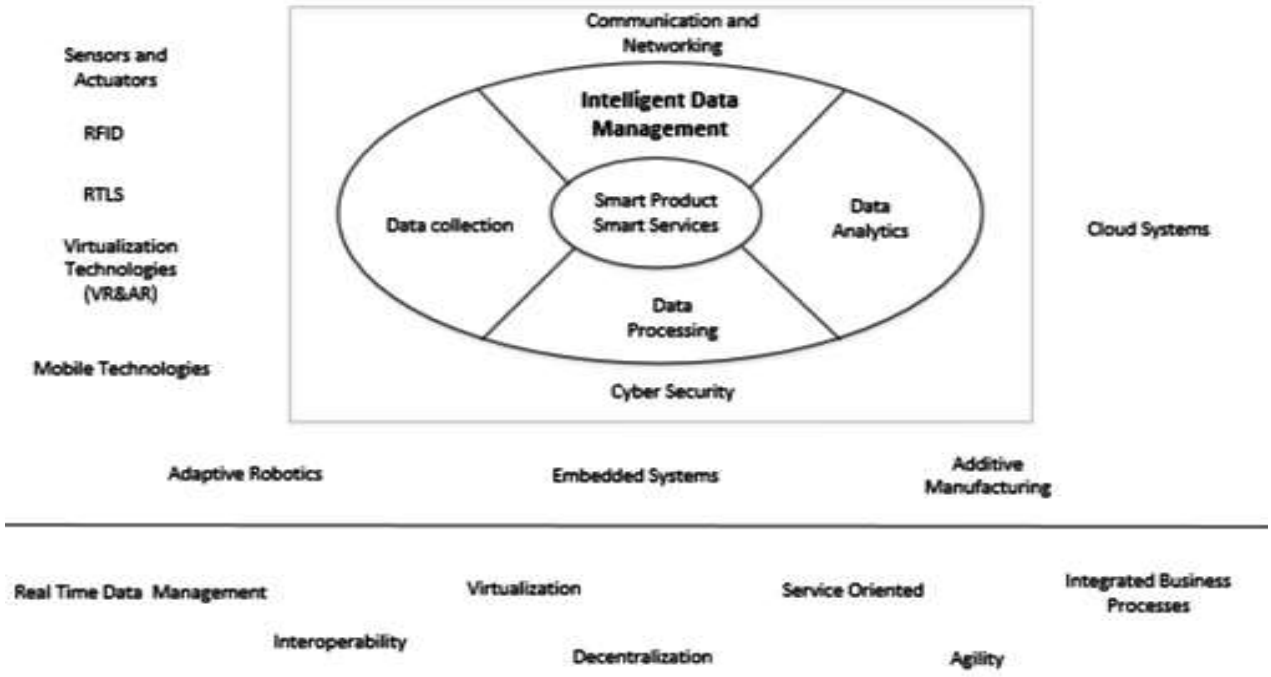
social changes and trends. Finally, the mixed approach is the mixture of both types of research: the qualitative approach and the quantitative approach. For the purposes of this study, a mixed approach will be used. In this way, information and data can be viewed from a more comprehensive point of view (Ritchie et al., 2013).

Due to the nature of the study that was conducted, the type of investigation used here is exploratory. This methodology helps to provide insights into a specific topic under study or a problem. Usually, these topics or problems have very little literature, and exploratory research enables us to set the ground for future research (Fabrigar et al., 1999). In this case, Costa Rica has an unclear perspective regarding Industry 4.0 technology.

3. Conceptual Framework

According to Ustundag & Cevikcan (2018), Industry 4.0 is greatly dependent on the incorporation of active value-creation patterns and systems. This framework also involves a combination of innovative software and systems that interact easily with other economic segments and industry types, ensuring that there is an accessible data transfer and that system performance can be improved based on technological recommendations. In other words, the authors explain that Industry 4.0 integrates production facilities, supply chains and service systems for value added generation.

Figure 1. Supporting technologies of both physical and digital systems



Source: Adapted from Ustundag & Cevikcan (2018), p.19.

There are many technologies that are being covered by Industry 4.0 including the following: big data analytics, autonomous robots (e.g., autonomous driving), the Internet of things, artificial intelligence, 3D printing, virtual reality, and others.

Therefore, an Industry 4.0 framework is needed to guide companies' best practices to adapt to these emerging technologies and obtain the value added in their processes and systems, as demonstrated in Figure 1. The scaling up of these systems is paramount for businesses to enhance their operations in a more sustainable way that affirms their competitive advantages in the market.

Table 1

Existing Industry 4.0 readiness and maturity models

Model Name	Institution/Source	Assessment Approach
IMPULS – Industries 4.0 Readiness (2015)	VDMA, RWTH Aachen, and IW Consult	Assessment in 6 dimensions including 18 items to indicate readiness in 5 levels, and barriers for progressing to the next stage and advice how to overcome them are defined.
Empowered and Implementation Strategy for Industry 4.0 (2016)	Lanza et al.	Assessment of Industry 4.0 maturity as a quick check and part of a process model for realization, gap analyses and toolbox for overcoming maturity-barriers are intended, and no details about items and development process offered.
Industry 4.0/Digital Operations Self Assessment (2016)	Price Waterhouse Coopers	Online self-assessment in 6 dimensions, focus on digital maturity in 4 levels and application as a consulting tool for assessment for a fee is required in 3 of the 6 dimensions, and no details about items and development process offered.
The Connected Enterprise Maturity Model (2014)	Rockwell Automation	Maturity model as part of a five-stage approach to realize Industry 4.0, technology focused assessment in 4 dimensions, and no details about items and development process offered (white paper).
I 4.0 Reifegradmodel (2015)	FH – Oberösterreich	Assessment of maturity in 3 dimensions including 13 items for maturity indication, maturity is assessed in 10 levels, and no details about items and development process offered (development process not finished).

Source: Adapted from Schumacher et al. (2016).

The efficiency and effectiveness of supporting technologies applied to scale up IoT will depend on the maturity model used, as shown in Table 1. According to Schumacher et al. (2016), maturity models are frequently applied as an innovative instrument to provide theories and measure the level of maturity in an organization. Additionally, they can also be used to establish sequential processes in relation to specific targets and objectives.

Based on research by (Apuy, 2019), Costa Rica has 450 companies that generate 970 jobs related to Industry 4.0 technologies. The most relevant areas of participation are cloud computing, big data, the Internet of things, artificial intelligence, and robotic process automation.

Additionally, Industry 4.0 technologies can be explained as follows, according to Javaid et al. (2020):

- **Artificial intelligence:** AI is an application, such as machine learning, computer vision and natural language processing, that can instruct computers to use models based on big data for recognizing, explaining, and predicting the pattern.
- **Internet of Things:** The Internet of Things comprises data collection, transfer, analytics, and storage. Data collection is performed with the help of sensors incorporated in mobile phones, robots, etc. Then, the collected data are sent to the central cloud server for analytics and decision making.
- **Virtual reality:** Virtual reality is a digital technology that provides a simulated experience that is almost the same or different from the working world.
- **Cloud computing:** Cloud computing is a digital technology that involves the delivery of computer system resources, such as servers, storage, databases, networking, and intelligence, over the Internet.
- **Autonomous robot:** An autonomous robot can be used to conduct tasks without the influence of any external agency.
- **Biosensors:** Biosensors are used for the conversion of biological signals into electrical signals. Some of the essential types of biosensors are optical, thermal, piezoelectric, and electrochemical biosensors.

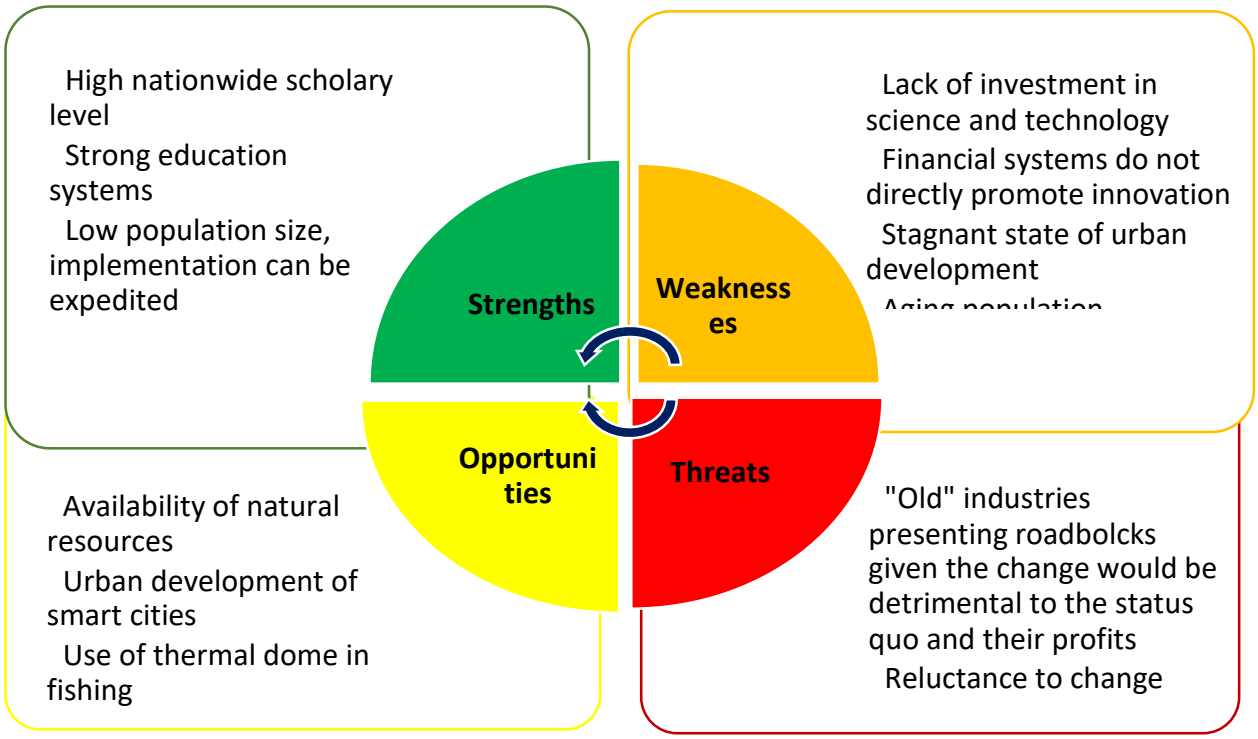
4. Results

4.1 SWOT analysis for Industry 4.0 development in Costa Rica

Costa Rica, like most other developing countries, presents a series of strengths, weaknesses, opportunities and threats regarding the implementation and development of Industry 4.0, as demonstrated in Figure 2. However, it is ideal to convert weaknesses to strengths and threats to opportunities. This will enable Costa Rica to leverage industry 4.0 more, in addition to massive investments and favorable government policies that promote the sustainable development of technologies.

Figure 2

SWOT analysis for Industry 4.0 development in Costa Rica



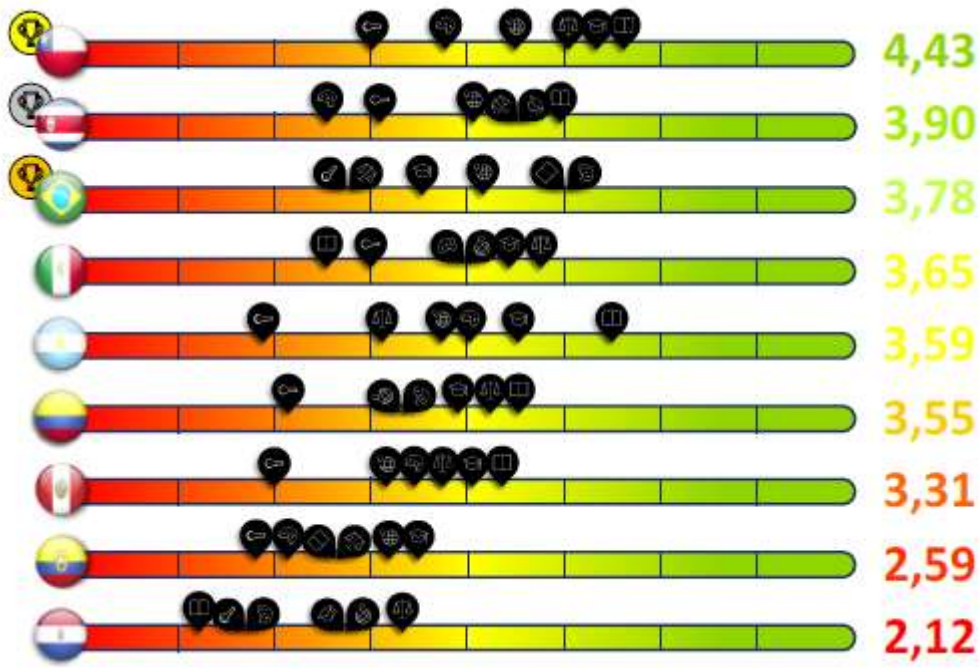
Source: Own elaboration.

4.2 Descriptive Analysis - IoT in Costa Rica

Since 2018, the Deloitte company and the Center for Telecommunications Studies of Latin America have conducted a study in the region to determine the implementation of the IoT for the business sector in Latin America. The results of the study indicate that Costa Rica is the second best positioned country in Latin America for the implementation of solutions based on the IoT. Chile is positioned as number one in the region, as demonstrated in Figure 3. In addition, the main risk detected by the study is the existence of a weakness in the capacity to innovate (Mendoza P. & Cuellar, 2020 and Deloitte, 2018).

Figure 3

Degree of IoT adoption in Latin American countries



Source: Adapted from Deloitte (2018).

The IoT should be an enhancer for business development that will allow the growth and optimization of processes, ensuring the continuity of operations and profitability during the current financial and political instability. It is also important to train the population in IoT in addition to incentivizing small businesses to implement innovative technologies in their business models. However, for the country to improve itself from the 4th Industrial Revolution and sustainable development, new forms of work must be developed and implemented through new skills profiles, new business and service models, and new technological and organizational culture models.

Nevertheless, small-scale fishing is not a segment that has to be separate from technology. Those engaged in small-scale fishing have been impacted by the economic consequences of the global pandemic, and therefore investments in technology to optimize fishing are necessary. It is through the implementation of thermal dome fishing technologies that fishermen's incomes have been sufficient for their families.

Furthermore, thermal dome fishing technology was developed by students from "Tecnológico de Costa Rica" University who developed a project related to the IoT, the Narwix project. The project consists of the creation of devices called Diglos, which will allow the transmission of data between them and act as Wi-Fi routers for underwater activities, including research or aquaculture. The network can be public and accessible to those who require it (Tec Emprede Lab, 2019). These

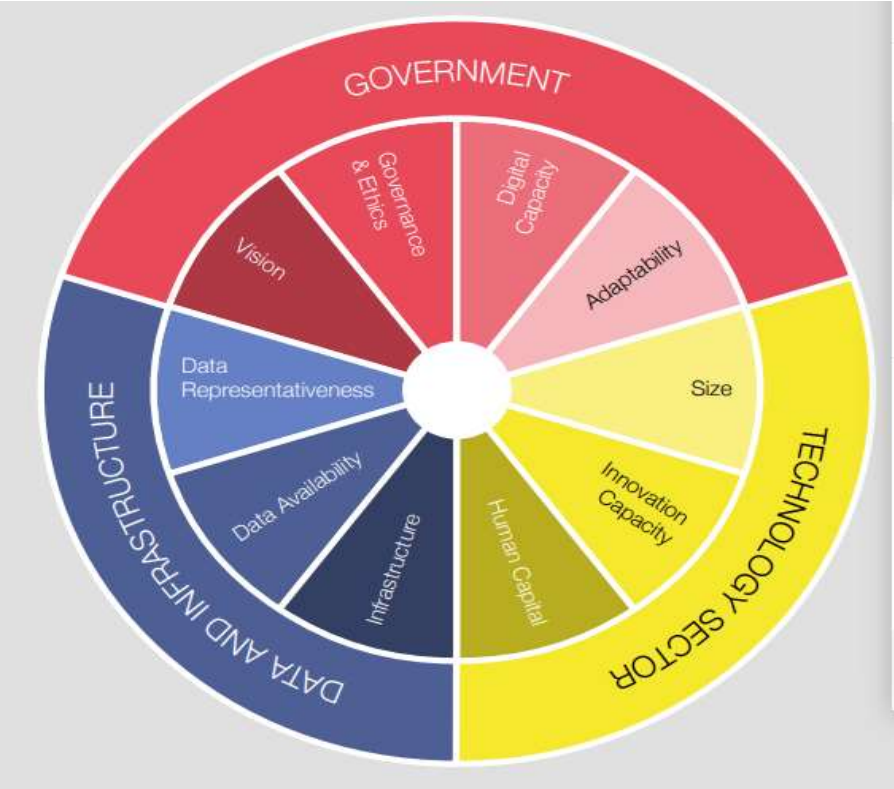
devices allow data to be transmitted in real time and can even remotely turn on equipment, collect and monitor data supplied by sensors and maintain communication between equipment located at sea and equipment located on land.

4.3 Comparative Analysis - AI Readiness

In October 2020, Oxford Insights published the AI Readiness Index, which ranked Costa Rica 78 of 172. Costa Rica is part of the lowest-scoring regions on average. The goal of the AI Readiness Index is to answer the question of how governments can position themselves to take advantage of this AI-powered transformation. According to Eleanor et al. (2020), this index should be used to compare the current state of government AI readiness in countries and regions across the globe, and the process is as shown in Figure 4.

Figure 4

Pillars and dimensions of the Government AI Readiness Index



Source: Adapted from Eleanor et al. (2020).

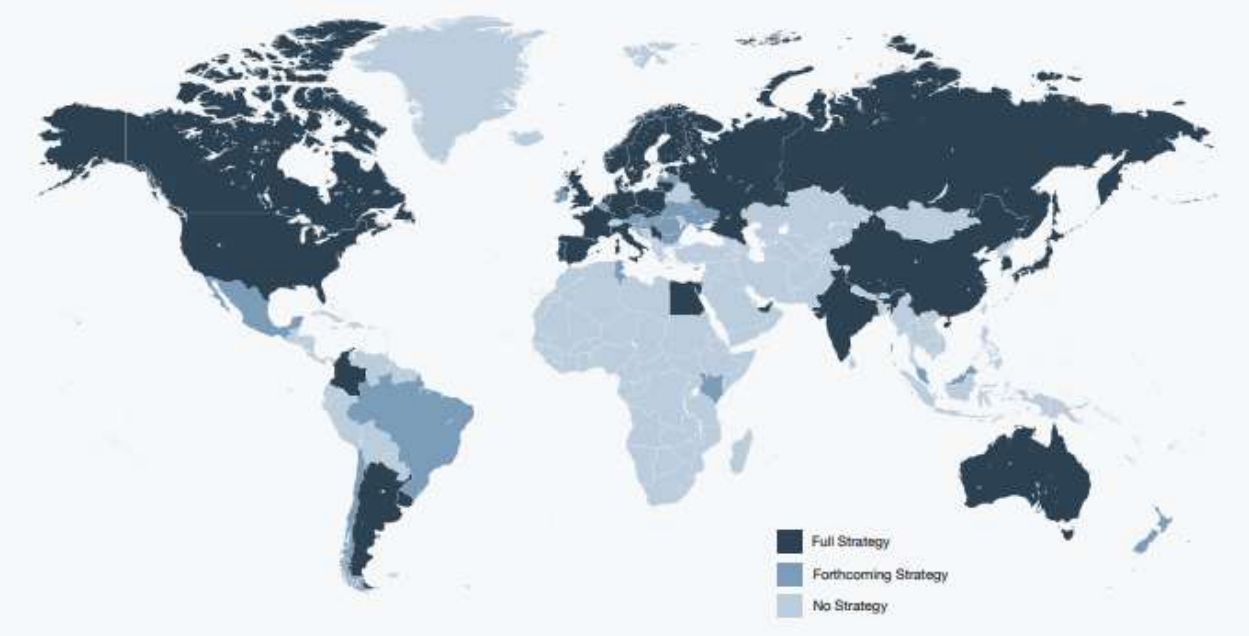
5. Discussion

Based on Oxford Insights by Eleanor et al. (2020), the United States of America is ranked the highest; and the remainder of top-five ranking is European countries including the UK, Finland, Germany and Sweden. This also shows that Western Europe and North America have advanced technologies and AI implementation not only in their business models but also as a way of life.

Regarding the United States, one of the findings is that Silicon Valley is making the difference by constantly innovating with cutting edge technology. In addition, the study of Oxford Insights attributes the good results for Western Europe to the high concentration of national AI strategies, supported by the European Union, as shown in Figure 5.

Figure 5

National AI Strategies in the 2020 Government AI Readiness Index



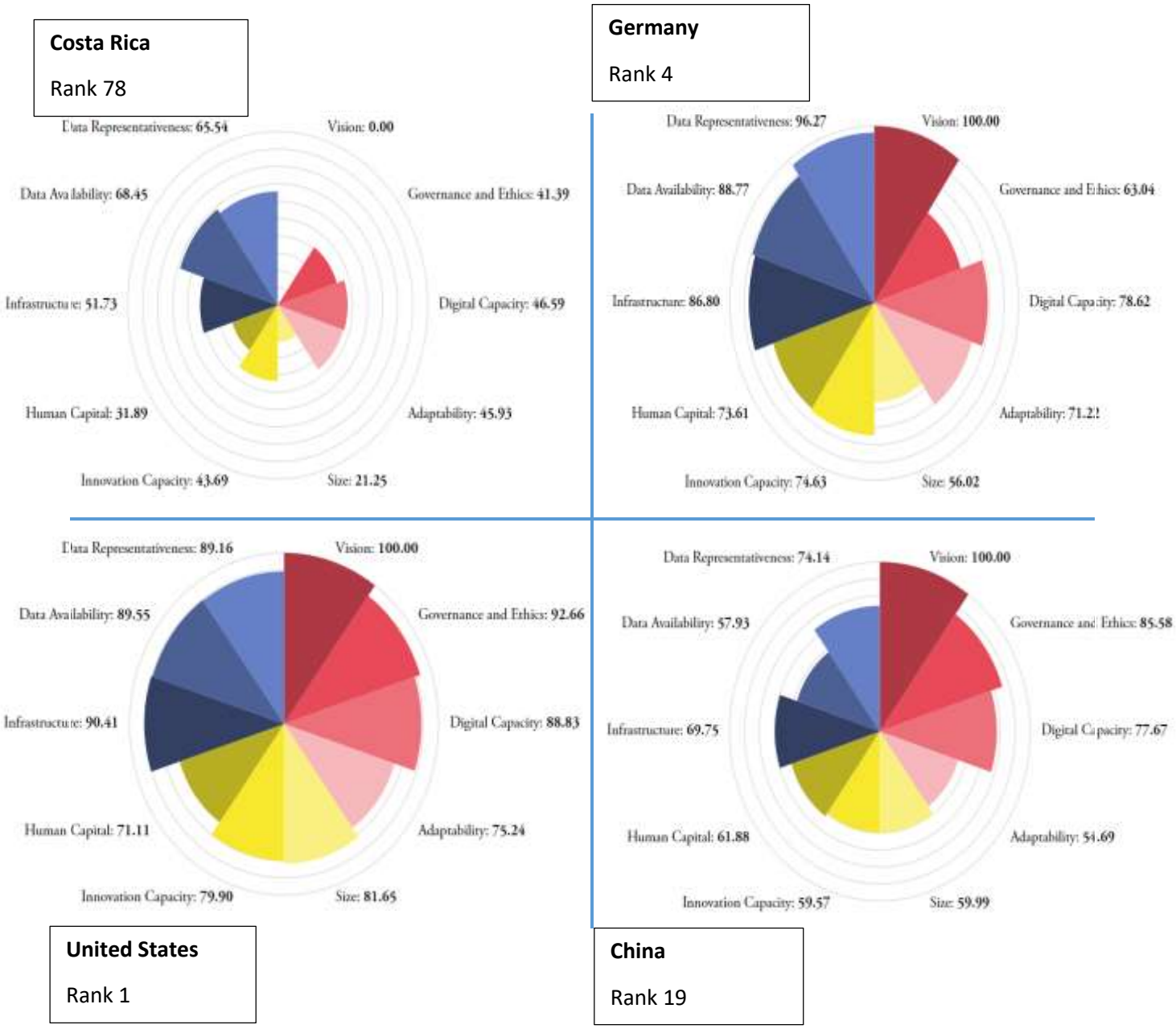
Source: Adapted from Eleanor et al. (2020).

One of the largest surprises resulting from this study is China, which ranked 19th. The Oxford Insights explained that this result is because the research index measured the capacities and aiding features necessary for a government to position itself for AI operations. However, the methodology used does not measure the actual operations. China has prioritized its operations by enacting its "Next, Generation Artificial Intelligence Development Plan". Consequently, China is investing heavily in its capacity compared to the rest of other countries with high scores for readiness. However, it has not yet utilized its optimal readiness for capacity changes (Eleanor et al., 2020).

Based on the national AI strategies, Costa Rica was identified as a country with no strategy at the national level, which means that between the government, local industries, and others, there is no common roadmap to build AI technology together. This finding is supported by a zero score in the "vision" dimension. Costa Rica requires innovative measures to prepare its economy and readiness, especially in terms of vision and human capital investments, as shown in Figure 6.

Figure 6

Comparison analysis AI Readiness

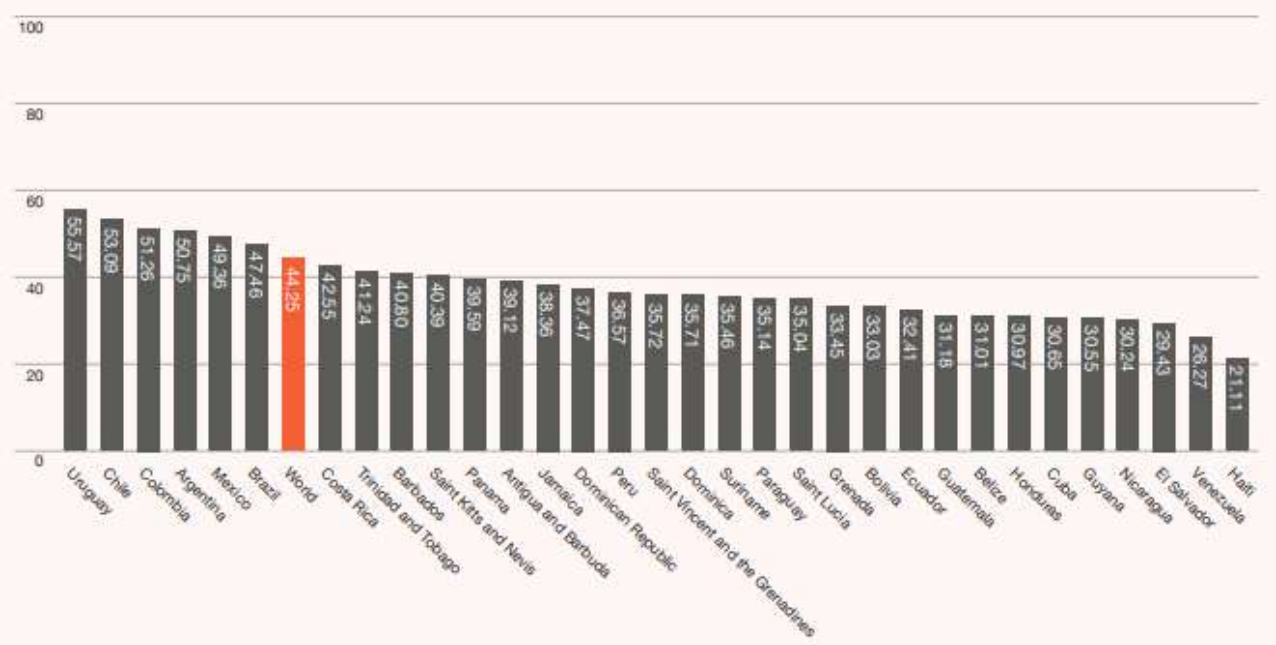


Source: Adapted from Oxford Insights by Eleanor et al. (2020).

The greatest strength for Costa Rica is in terms of data representatives and data availability, where Costa Rica does not lead but obtained a good score in comparison with countries such as the United States, Germany, and China. However, this good position in these dimensions is not helpful due to the large gap in other dimensions such as infrastructure, human capital, adaptability, and others. Another important fact is that compared to Latin America and the Caribbean region, Costa Rica ranks number 7, but we are below the average worldwide, as shown in Figure 7.

Figure 7

Latin America and Caribbean Index Scored



Source: Adapted from (Eleanor et al., 2020)

6. Conclusions

As a result of analyzing the current landscape in CR, technology and value addition, Industry 4.0 is a necessary initiative. Most of the implementations are led by entrepreneurs, and every day increasingly more entrepreneurs demand the development of these technologies.

Although the availability of data and technology does not guarantee the ability to exploit available current infrastructure, government assistance is required to train the population and aid in technology issues to identify and adopt best practices.

The viability of technology implementation projects depends on investment opportunities and feasibility. Costa Rica does not guarantee or provide specific technology investment programs to entrepreneurs, and most initiatives are led by local companies.

It is advisable for entrepreneurs to understand the real needs of certain sectors (such as small-scale fishermen) to work on a comprehensive solution. This will not only improve productivity but also foster the development of an inclusive economy because small-scale fishermen are not included in most national development strategies. High investment and emphasis is directed towards tourism as a prime national economic activity.

7. Recommendations

The strategic plan for Costa Rica to take advantage and maximize the topic of Industry 4.0 needs to be multitiered and comprehensive. There is a distinct need for all interested parties to collaborate and work jointly in developing the proper environment for which all the aspects of Industry 4.0 can develop and help foster growth.

It is important that Costa Rica takes advantage of its strengths such as the educational attainment of their population and the strong education system. These two aspects specifically should be a cornerstone for their plan. Upskilling the existing workforce, be it workers with technical degrees or coursework, would have great benefits for the development of technology in the country and more so to the innovation and improvement of current operations in the country by using Industry 4.0 topics such as the IoT.

Upskilling or reskilling the existing workforce for technologic improvement has benefits for all parties. The workforce receives relevant and useful training and skills; the companies in the country are able to have a more skilled workforce for their development and operations; and the country will benefit given the higher skilled workforce, more industrial activity, more technological advancement, etc.

In addition to building on their strengths, as previously mentioned, it is important not only that existing economic activities and sectors are not pushed aside and forgotten but also that they should be given the tools necessary for them to improve their conditions and maximize their performance.

There are several sectors that would benefit greatly from Industry 4.0. For example, the fishing industry in Costa Rica is mostly comprised of small artisanal fishermen. However, if these fishermen were given tools such as satellite imaging identification of hotspots, meteorological warning systems, and sonar radars, among other tools, they would be able to improve their operations in the short term and be able to compete with foreign fishing operations in the long term. This would allow them to expand their operations and attain increased revenue, which would most surely trickle down to improve the entire economic activity in coastal cities and the population. As this example noted, there are several sectors and populations that, if included in the plan and given the tools to develop and grow, will bring collective gains for Costa Rica's society and economy. All of this will help the country achieve sustainable development, specifically with factors on reducing inequality, decent work and growing the economy, and responsible consumption.

In parallel with the industrial components of the suggested actions for Industry 4.0 development and deployment in Costa Rica is the societal development side. There should be comprehensive

urban development to help with the economic situation of the entire population. For example, topics on smart cities, lower fossil fuel use, sustainable adequate transport, no at-risk population, and fiber optics, among others, are topics that the government should have in mind as essential for the improvement and development of the country. In addition, when we mention the country, it means the entire country not just the greater metropolitan area. There are possibilities to design and develop development hubs across the country, each one centered and taking advantage of each location's strengths.

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