IEEE Access
Multidisciplinary : Rapid Review : Open Access Journal

Received 18 November 2022, accepted 12 January 2023, date of publication 20 January 2023, date of current version 26 January 2023.

Digital Object Identifier 10.1109/ACCESS.2023.3238384

RESEARCH ARTICLE

Intention to Adopt Industry 4.0 by Organizations in Colombia, Ecuador, Mexico, Panama, and Peru

DIEGO CORDERO[1], KLEBER LUNA ALTAMIRANO[2], JANICE ORDÓÑEZ PARRA[2], AND WILLIAM SARMIENTO ESPINOZA[2]

[1]Green IT Research Group, Administration Academic Unit, Catholic University of Cuenca, Cuenca 010107, Ecuador
[2]Administration Academic Unit, Catholic University of Cuenca, Cuenca 010107, Ecuador

Corresponding author: Diego Cordero (dcordero@ucacue.edu.ec)

This work was supported by the Catholic University of Cuenca.

ABSTRACT This study aims to understand the factors that drive actors belonging to the sector of organizations in Latin America (LA) to adopt Industry 4.0. The proposed model results from the analysis and integration of the technology adoption model (TAM), green information technology adoption model (GITAM), and theory of planned behavior (TPB). To determine the predictive factors for internal organizational actors, the research team surveyed information on organizations belonging to Colombia, Ecuador, Mexico, Panama, and Peru. Information was collected from strategic, tactical, and operational personnel. Data were collected from 499 organizational actors in the productive sector, processed, and analyzed using a structural equation model with the partial least squares technique. The study model explains, first there is an influence of the variables Industry 4.0 perceived ease of use (PEU) and Industry 4.0 perceived utility (PUT) on Industry 4.0 attitude towards use (ATU). Second, there is a positive influence of Industry 4.0 technological context (ICO), Industry 4.0 subjective norm (SNO), Industry 4.0 attitude (ATT), Industry 4.0 attitude towards to use (ATU), and Industry 4.0 attitude behavioral control (BCO) on intention to adopt Industry 4.0 in the organization (IAI). Third, what was not supported is the influence of Industry 4.0 technological context (ICO) on the intention to adopt Industry 4.0 in the organization (IAI). The model results are consistent with those of other studies on technology adoption, and propose a model for Industry 4.0, which is a significant contribution to this study, especially for developing countries.

INDEX TERMS Industry 4.0, organization, adoption model, Latin American.

I. INTRODUCTION

The continuous and accelerated evolution of information and communication technologies (ICT) and their inclusion in industries and organizations has led to the fourth revolution, Industry 4.0 [1]. The first reference to Industry 4.0 was introduced at the Hannover Industrial Technologies Fair in 2011; Industry 4.0 has now become a global scientific and technological program for the development of industries, especially in industrialized countries [2], [3].

Industry 4.0, on the other hand, integrates production operations systems and modern technologies, especially ICT [4]. This wave of change within organizational ecosystems influences the strategies, frameworks, and operating models that must be adapted and integrated [5].

Industry 4.0 enables connection information, objects, and people owing to the convergence of the physical and virtual worlds (cyberspace) in the form of cyber-physical systems (CPS); therefore, it enables the transformation of industries and organizations into intelligent environments [6]. The term CPS was coined in the USA in 2006 [7] because of the growing impact of the interactions between interconnected computer systems and the physical world. However, CPS is a thematic axis, not a discipline [4].

The impact of Industry 4.0 is reflected in various scenarios, such as professional, personal, home, cities, organizations, and systems. The Industry 4.0 paradigm has modified the set of skills required for professionals in the labor field [8], and

The associate editor coordinating the review of this manuscript and approving it for publication was Zhaojun Steven Li.

companies cannot implement state-of-the-art technologies if their workforce does not have the skills to use that new technology [9]. Consequently, educators in education, as in the case of universities, are called upon to adopt curricula to develop new professional skills and meet new market requirements [10].

From a personal point of view, self-improvement, openness to change and conservation values significantly affect the inclination toward leadership in the Industry 4.0 workplace [11]. Due to the massive changes that the implementation of Industry 4.0 implies, the behavior of organizational actors must adhere to certain personal values that are emphasized in new challenges [12].

Through Industry 4.0, the transformation of conventional home appliances into IoT-enabled systems has given rise to smart home systems [13]. This new technology allows appliances to provide benefits such as personalization, energy savings, prediction, defect reduction, and quality improvement [14] through feedback, which is a product of the process of large volumes of data stored in the cloud.

The term smart city is the model of new urbanization based on the application of new-generation technologies of Industry 4.0, for the planning, construction, management, integrated industrialization, computerization, modernization, and sustainable development of cities [15]. The development of a smart city promotes new conditions of life, work, health, education, and accumulation of human capital, and captures financial resources for business development [16], [17].

Within organizations, the Industry 4.0 concept requires innovation, and continuous education not only depends on the skills of the staff but also on organizational culture [18]. It has been detected that a large part of research on Industry 4.0 analyzes technical aspects, without giving greater impetus to the management approach, process organization, corporate strategy, work organization, human resource development, and organizational culture [19].

Implementing Industry 4.0, which implies human interaction with the technical part; Industry 4.0, is a system related to humans (socio) and not related to humans (technical) in search of a certain goal; that is, it is a sociotechnical system [20]. Consequently. Industry 4.0 is subject to the perspective and principles of open systems for adaptability in the face of external disturbances in the environment [21].

This hashes with a new paradigm that transforms the world [22]. However, the most significant impact is expected in the corporate and industrial sectors of manufacturing, management, logistics, and marketing [23], where it is necessary to adopt emerging processes and implement effective data management [24].

Industry 4.0 capabilities bring considerable benefits to companies, such as real-time data analysis, product customization, increased visibility, monitoring and control, dynamic product implementation, and improved production [25], contributing to the optimization of operations and significant reduction of costs and leading times [26].

The manufacturing sector represents approximately 15 % of the world's gross domestic product (GDP) [27] and is one of the most relevant activities for generating wealth. Therefore, some of the most advanced economies seek to improve their productivity and efficiency in industrial production by incorporating Industry 4.0 [28]. Nevertheless, it is necessary to clarify that companies adopt Industry 4.0 in three tracks: laggards, emerging industries, and leaders [29]. Some developed countries, such as Germany and the United States, started implementation in 2011 and are currently prominent leaders; the rest are in the laggard and emerging categories.

Only a few organizations implement Industry 4.0 technologies worldwide, especially in developed countries [30]. LA cone countries are no exception to the development of the manufacturing sector, which represents a significant percentage of GDP [31]. Furthermore, scenarios such as competition, short life cycles, new products, and demand, among others, generate new challenges in the industrial field [32]. For this reason, LA companies are struggling to increase their productivity and competitiveness.

In LA, Mexico is considering the route to implement Industry 4.0 [33], not to mention Brazil; however, there is uncertainty about some factors such as cost, knowledge, culture, and training in universities, among others [34]. The problem is that although, in general, many LA countries have made considerable progress in measuring business innovation [35], no broad international initiative has been taken to measure the state of adoption of Industry 4.0 [36]. So far, there has been little comparative evidence on Industry 4.0 efforts and activities in the LA region.

In LA, there are limited studies on adopting Industry 4.0 to help organization improve their efficiency. Although efforts and initiatives have been implemented in isolation, there should be a reference framework for this industry context that allows relating the variables and indicators that lead to a technology adoption process such as Industry 4.0 [37]. This study examines the adaptation of Industry 4.0 in the organizational context, specifically in the industrial context. An initial starting point is identifying the potential drivers, success factors, and barriers of this technological transformation [38].

Technology transfer is understood as the accessible process of knowledge transfer in an organization [39], while adoption is about how we integrate our processes to bring about significant change. In this research, technology adoption was considered to incorporate operational processes such as production, management, and sales. Enabling flexibility, cost, efficiency, quality, and competitive advantage key benefits for the adoption of Industry 4. 0 [40].

The research proposes a model for Industry 4.0 adoption in organizations in LA country contexts. The following research questions are formulated: What are the factors that influence the organization to decide on the adoption of Industry 4.0? What is the appropriate model to reflect the influence of the factors on the adoption of Industry 4.0? In order to answer the questions posed, a review of the literature related to technology adoption models has been used to integrate constructs of TAM, GITAM, and TPB.

A wide variety of models for the adoption of technology are available in the literature; however, for this research, discrimination has been carried out based on what has been stated by several researchers, who explain that the reason for introducing models for the adoption of technology is to direct the intention of use towards the electronic option. Organizations that are not aware of their influence are able to perceive their use.

As explained, Table 1 is structured, in which five models of technology adoption were analyzed based on five factors, thus asserting the TAM, GITAM, and TPB models. From the point of view of several authors, they have a greater feasibility of use for the type of research proposed. These models seek to explain the relationship between technology acceptance and adoption, demonstrating that the perception of usefulness and ease of use are critical factors in the process of technology adoption and the use of systems, becoming a fundamental resource for organizations achieving optimization and improvement in the different areas of the company through an essential role in achieving competitive advantages in the environment. This was validated by a study by Money and Turner [41].

To support the greater elements of judgment, we explain the models indicated below in more detail. TAM is one of the most important models, with almost 20 years of development, and has become the main model to explain the mechanism of information system adoption. This is strongly supported by the theory of action reasoning, which implies that one can realize one's intention to use without any restrictions if one only intends to act [42].

GITAM defines Green IT four different but interrelated perspectives, positing that technology, organization, environmental contextual variables, dynamic dimensions of Green IT readiness, and strong order drivers of green IT can predict the intent, breadth, and depth of the adoption of green IT [50]. Regulatory requirements and legislative actions are likely to play important roles in the adoption of green policies technologies, and may force some companies to accept a technology even if they do not have a strong intention to do so [43], [44]. The theory of planned behavior (TBP) specifies and proposes that attitudes toward certain behavior, the existence of rules, and companies' perceived control are three key antecedents that determine their intention to perform a certain behavior [45].

Table 1 summarizes the analysis of five models of technology adoption and the reasons for their choice by the authors, where they are compared based on five relevant factors, considering those that meet between four and five of them.

The variables described lead the organizations studied to be more efficient in order to stay in the market, and respond to needs and strategies, through the analysis of these variables it is possible to face the challenge of the current market, which is why it is important that Industry 4. 0 continues to support companies to change their mentality in the offer of their products or services, considering the field of modernity as a new technological tool [57]. These variables contribute to organizations to technological innovation in all departments of companies, the use of IT Information Technology allows the total digitization of production areas with fully automated processes, radically improving internal processes, such as production and administration [58].

TABLE 1. Analysis and choice of models.

Model	Factors					Selection Model
	F1	F2	F3	F4	F5	
TAM [46] - [49]	✓	✓	✓	✓	✓	✓
GITAM [50], [51]	✓	✓		✓	✓	✓
TPB [52] - [54]	✓		✓	✓	✓	✓
TTF Task technology fit model, is a model of user acceptance that relates actual use to tool functionality and task characteristics [55]				✓		X
UTAUT Unified Theory of Acceptance and use of technology explains the intentions of users to use IT and their behavior [56]		✓				X

F1= Age of model
F2= Cost reduction
F3= Adoption of innovation
F4= Conduct and intentions
F5= Acceptance of IT

The factors described lead to the models proposed to be considered by the organizations under study since the use of new technologies supports companies to have a broader panorama, that is, a vision to modernize, leaving aside obsolete technologies. In relation to F1, in recent decades, the TAM has been considered a model of user acceptance of information systems and has been proposed with more extended factors on the acceptance of technology according to technological characteristics, individuals, and organizations [59]. Within F2, it is explained that for the acceptance of the TAM and Green IT models by an individual or company, it addresses personal norms on environmental responsibility and social norms to preserve the environment of the organizations, which are considered important factors, in addition to economic factors such as the reduction of costs through perceived profit [60]

For F3, within companies, current technology models represent the ideal pathway as an important step towards the adoption of technology innovation [108]; Organizations currently face problems in attracting customers, which is caused by the use of existing obsolete technology; for this reason, companies are adopting technology innovation as a tool to provide enriching experiences through technology models such as TAM and Green IT, among others [110];

a positive attitude on the part of senior management of organizations towards change is important to create an organizational environment that is receptive to innovation [61]; senior management commitment and support for innovation are particularly important through the alignment of various factors, where coordination between organizational divisions and problem-solving is essential [62].

Regarding the F4 function, conduct and indirect real conduct are attitudinal factors in the use of technology by companies and investors. The application of technological models for online commerce is considered the most common variable in some theories [137], [140]. The F5 function explains that the acceptance of IT is positively influenced by the perceived usefulness through the size and budget of the company, and the usefulness of the use of IT occurs when organizations think about improving their business management through excellent work performance [119], [128].

Finally, the study is based on an analysis of empirical evidence of the relationship between the main factors described by Abroud et al. [120] in Table 1. Hillmer [63], in his research, deepens the analysis by comparing factors in technology acceptance models, where he explains that existing theories and models have produced useful ideas about the cognitive aspects, affective and behavioral responses of companies towards new technological disruptive.

According to Table 2, the variables were selected based on five factors considered fundamental for their veracity. Variables that meet between three and five factors are considered for the model, otherwise, they are not taken into account.

The factors F1 to F5 underpin the proposed variables because they are directly involved in internal and external processes, such as production and administration in an organization [58], through which it is possible to face the challenge of the current market. Therefore, it is important to implement Industry 4.0 it allows companies and their collaborators to change their minds or beliefs about the offers of their products or services. Within the framework of organizational growth and development [64], considering the field of modernity as a new technological tool [57] that pays tribute to the organizational and environmental technological context, allowing companies to have a broader panorama, leaving obsolete technologies to enter the world of innovative technology [65]; in this way, they will be more efficient through better performance at the work level, framed by good practices of conduct and ethics [95].

Finally, factors F1 to F5 were based on the analyses described by Loo et al. [108], Stieninger et al. [218], and Dalvi-Esfahani et al. [220] in their research, as shown in Table 2. They emphasize that they have contributed substantially to the growth of organizations framed in new technologies together with the environmental aspect with appropriate rules of conduct and ethics, which have contributed to this research.

From GITAM, the proposal considers the contextual variable, which we refer to this variable as Industry 4.0 context.

TABLE 2. Selection of variables.

Model Variables	Factors					Selection
TAM	F1	F2	F3	F4	F5	Model
Perceived ease of use	✓	✓	✓	✓	✓	✓
Perceived utility	✓	✓	✓			✓
Global identity			✓		✓	X
Attitude towards use		✓	✓	✓	✓	✓
GITAM	F1	F2	F3	F4	F5	Model
Context Green IT (Technological)		✓	✓	✓	✓	✓
Intention to Adopt Green IT		✓	✓			X
Green IT Readiness		✓		✓		X
TPB	F1	F2	F3	F4	F5	Model
Attitude	✓		✓	✓	✓	✓
Subjective norm	✓		✓	✓		✓
Attitude behavioral control	✓	✓	✓	✓		✓
Perceived behavioral control			✓	✓		X
Lead-usership			✓			X
Adoption intention	✓	✓	✓	✓	✓	✓

F1= Beliefs
F2= Organizational growth and development
F3= Conduct
F4= Ethics
F5= Technological, organizational and environmental context

From TPB, the proposal considers the variables: attitude, subjective norm, and behavioral control. Moreover, from the TAM model, the following variables are taken into account: perceived ease of use, attitude towards to use, perceived usefulness, and intention to adopt Industry 4.0 in the organization.

The data were collected from organizations in Mexico, Peru, Panama, Colombia, and Ecuador, from 399 organizational actors in industrial sectors, processed and analyzed through a structural equation model using the PLS technique.

In the paper, the subsequent sections that make up this document are organized as follows: section II explains the hypothesis development; section III highlights the research method applied; section IV executes the data analysis and results; followed by their discussion in section V; sections VI and VII consider the research contributions, implications, and conclusions.

II. THEORETICAL BACKGROUND

Industry 4.0 combines technologies for a new technological era, which includes cloud technology [66], the Internet of Things (IoT) [66], [68], big data [66], [67], simulation [69], autonomous robots [68], additive manufacturing and three-dimensional (3d) printing) [67], augmented reality (AR) [67], [68], business intelligence (BI) [68], and cybersecurity [70]. The core technologies of Industry 4.0 and their business applications are explained in the following subsections

A. CLOUD TECHNOLOGY

The cloud is a virtual storage space on the Internet that is not the same as the Internet because the cloud is only a part of the Internet [71]. It has the most powerful computing architecture, allowing large amounts of data collected from systems, devices, equipment, and sensors to be stored on remote servers and has hardware, software, and networked Internet infrastructure. Cloud systems allow access and retrieval of large amounts of data in real-time [72].

B. THE INTERNET OF THINGS (IoT)

Is a centralized control system that communicates and interacts with different equipment and systems and is the set of sensors, instruments, and autonomous devices connected through the internet to industrial applications [73]. This network allows data collection, analysis, and production optimization, increases efficiency, and reduces manufacturing and service delivery costs [74]. Furthermore, through IoT, a collaboration between enterprises can be enabled by improving functionality and business capabilities [75].

C. BIG DATA

It is a concept that encompasses large volumes of data, both structured and unstructured. This is a complex and large amount of data that none of the traditional data management tools are capable of storing or processing efficiently. Big data uses large volumes of data to improve efficiency and productivity [76]. It helps organizations gather value from large volumes of data to improve efficiency and process performance, customize products, increase flexibility, and enable fast and real-time decision-making [77].

D. SIMULATION

Processing and data collection from big data and cloud systems can be used as a source of a virtual model to analyze all possible scenarios related to product design, development, and production [78]. Simulations are widely used in business modeling to leverage available real-time data and simulate real-world work in a virtual ecosystem [79]. In addition, processes can be tested and optimized through simulations even before implementing changes in a real scenario [69].

E. AUTONOMOUS ROBOTS

Are used in many areas, including manufacturing, logistics, e-commerce, and training [80]. Robots and humans have strengths and limitations, working safely together provides a better-quality product with high precision in less time. The goal of robotics and Industry 4.0 is to improve productivity, generate high-quality products at a low price, and meet customer expectations [81].

F. ADDITIVE MANUFACTURING AND THREE-DIMENSIONAL (3D) PRINTING

Are used to produce objects layer by layer in three dimensions. Functionality in Industry 4.0 is widely used for batch production of scaled and customized products [82]. The quality of materials is vital for efficient additive manufacturing, as some processes can process a more comprehensive range of materials than others [83].

G. AUGMENTED REALITY (AR)

In Industry 4.0, a wide variety of services can be implemented, such as the design of a production line, physical infrastructure, and maintenance schemes, among others, through the use of mobile devices or remote control equipment [84]. AR helps identify and avoid design errors in the early stages of the development process, reduces the number of physical prototypes, saves time and cost for companies [85]; AR is considered a valuable tool for improving and accelerating the development of products and processes in many industrial applications [86]. Although AR is in its early stages; however, in the future, organizations will use it to improve their organizational processes and decision-making [87].

H. BUSINESS INTELLIGENCE (BI)

Involves the provision of technology platforms to collect, store, analyze, and present data obtained from different sources in the organization to support decision-making [88]. In the current competitive environment within the business context, BI has become a vital tool at strategic, tactical, and operational levels. This technology acts as a key and strategic factor for the organization because it provides decision-makers with timely and reliable information to respond to situations that may arise in the company, such as entering new markets, cost analysis, and profitability of a product line [89].

I. CYBERSECURITY

In the context of Industry 4.0, is critical because of the likely increase in security threats [90]. The main elements associated with cybersecurity are the assets involved, system vulnerabilities, cyber threats, and risks within industrial contexts, where physical systems are connected through the Internet. The successful implementation of cybersecurity measures consists mainly of the prevention of internal and external attacks in industries, but in an integrated manner [91].

The main characteristics of Industry 4.0 are collaboration and system integration, both horizontal and vertical [92]. In horizontal integration, ICT are used to exchange information between different actors within a network [93], whereas, in vertical integration, ICT are integrated at different hierarchical levels of the organization covering control, production, operations, and management [94].

The main drivers and barriers to adopting the Industry 4.0 paradigm come from the literature review and are located within several dimensions: organizational, technical, and ethical strategies [95].

Regarding technology adoption, some frameworks consider aspects related to adopting new technologies [96]; these factors are fundamental since they enable investment decisions to be made [97]. For Sperber [98], adopting new technologies is a function of managers' awareness, organizational culture, and problems that encourage risk. The literature also identifies antecedents such as sector, size of the organization, level of complexity, and availability of scarce resources for technology adoption [99].

TAM, it is one of the most popular models cited in research on user acceptance of technology [100]. TAM aims to predict user acceptance and highlight drawbacks before users interact with the system [101]. In fact, for TAM, the acceptance of any technology is fundamentally affected by the user's perception of the use and usefulness of the technology [102]; as it contains two primary constructs that identify it: perceived ease of perceived usefulness and perceived ease of use, which are used in numerous contexts [103].

In GITAM, there are dimensions called Green IT enablers (drivers), which could influence the adoption process of Green IT. Therefore, it is necessary to resort to the theory of motivation to identify these enablers [104].

TPB, emphasizes the importance of attitudinal components in behavior prediction and explanation [105]. Several authors believe that using the TPB as a framework can describe much of the intention and future behavior in the study of environmental behavior [106]. In contrast, Yuriev et al. [107], Loo et al. [108], TPB has limitations in predicting human behavior. Therefore, it is advisable to incorporate more variables according to the context analyzed, demonstrating the flexibility of PTB to adapt.

III. HYPOTHESIS DEVELOPMENT

The research hypothesis is a logical relationship between two or more variables expressed in a statement. The research hypotheses are presented in the following sections. To do this, each of the variables from literal A to H is studied, and the relationship between the variables is justified based on theory. A hypothesis was proposed at the end of each literal.

A. INDUSTRY 4.0 PERCEIVED EASE OF USE (PEU)

In organizations, the current technological system is one of the essential measures to consider the ease of use of new technology [109]. An organization's technological competence is related to its personnel's technical competence through development and training, leading to the ease of use or adoption of new technologies. According to Ramdani at al. [110], the management of organizations can intervene positively in the use of new technologies by expressing a broad vision and fortifying value through the company.

Companies currently face problems in attracting customers, the cause of which is the use of existing technology. Therefore, organizations are looking for new technologies that provide enriching experiences for the market [111]. The opportunities offered by the increasing use of technology in the business world are changing the competitiveness of organizations in the market [112]. On the other hand, for Ghobakhloo et al. [113] only some organizations with sufficient economic resources will have the facility to use the new technology of their choice.

With the increasing ease of technology, materials, energy, essential knowledge, and other factors to develop them will inevitably grow at the same rate [114], [115]. Industry 4.0 is currently known as Industry 4.0, for the ease of digitization in production processes within an organization [116]. For Hofmann and Rüsch [117], the ease of use of the term Industry 4.0, is aligned to describe the concept of digitization of the company, fully automated production processes integrated through a supply chain, which will allow the reduction of labor through cost minimization.

Davis [46] and Abroud et al. [118] explain that perceived ease of use is understood as the degree to which a person assumes that the use of a system would involve less mental and physical effort. Therefore, the organization perceives it as user friendly, giving rise to a favorable attitude towards use. In addition, individuals and companies that demonstrate their identity also have positive intentions regarding the ease of use of technology [119].

An investor's perception of the ease of use of, for example, an online stock trading system could generate a positive attitude towards the use of this system [120]. The technology introduced in banking through web services has degrees of perception of great innovation based on its ease of use [121], [122]. Fichman [123] explained technical characteristics such as relative advantage, complexity, compatibility, observability, and probability. This originates from the ease of use of technology adoption.

Fichman [123], Doh et al. [125], Gupta et al. [126], and Pernici et al. [127], have current views on the feasibi- lity of using technology to improve the efficiency and sustainability of organizations. Industry 4.0 could contribute to the ease of optimal use of technology to efficiently manage organizational activities with reasonable degrees of sustainability [128]. Therefore, the hypothesis contains the following postulate, H1: Industry 4.0 perceived ease of use (PEU) has a positive impact on Industry 4.0 attitude towards to use (ATU).

B. INDUSTRY 4.0 PERCEIVED UTILITY (PUT)

According to Kim et al. [129], technology acceptance is positively influenced by perceived usefulness across organizational size and budget. Perceived usefulness occurs when investors believe that using an Internet trading platform improves their job performance. By contrast, Chan and Lu [130] explain that when it comes to online stock trading, perceived usefulness is defined as the extent to which an investor can use Internet technology to his or her advantage, leaving aside the traditional actions of trading platforms. Thus, it is essential to note that some research has confirmed the importance of perceived usefulness in influencing investors' attitudes toward stock trading [131], [132].

Some studies consider attitude to mediate the direct relationship between perceived usefulness and intention to adopt an online securities trading platform [118]. According to Deci and Ryan [133], attitude is an intrinsic motivation towards adoption, resulting from perceived enjoyment or usefulness in adopting the new technology. Furthermore, Wallace and Sheetz [134] explained that research models exist to evaluate the adoption of software measures, meaning that the effects of perceived usefulness and ease of use are of great importance for designing and developing practical measurement programs that can lead to higher-quality software.

The validity and reliability of perceived usefulness and perceived ease of use variables in TAM have been supported by several investigations, including [135], [136]. Olsson et al. [137], explain that the increase in the growth of augmented reality (AR) applications can be attributed to perceived usefulness and positive consumer experience. Despite the increase in the use of AR technology in the industry, the expected response change in the adoption of AR in a company's value chain may be inadequate. For Gefen and Straub [138], several investigations have determined that attitude toward the use of a self-reported technology system indicates that perceived usefulness plays an important role in determining future effects.

Moore and Benbasa [139] indicated that many studies have attempted to understand the predictors of perceived usefulness related to technology and information adoption. However, some researchers interpret perceived usefulness as multidimensional and may be conceptually too broad to be applied in practice. Regression analyses suggested that perceived ease of use may be a causal antecedent of perceived usefulness. Thus, ease of use operates through usefulness [116]. Hall and Fenton [140] explained that attitude towards using software measures is linked to organizational goals, addressing beyond evaluations focused on superficial characteristics as a measurement scale. Therefore, the hypothesis is as follows: H2. Industry 4.0 perceived utility (PUT) has a positive impact on Industry 4.0 attitude towards to use (ATU).

C. INDUSTRY 4.0 ATTITUDE TOWARDS TO USE (ATU)

Attitudes towards the use of technology by investors through online trading are the most common variables among some theories, considering an estimation of direct behavioral intention and actual indirect behavior [141], [142]. Some researchers have provided significant evidence on the effect of the attitude towards use by investors whose direction is the intention to use technology as a support for online trading [143], [144]. For Ming-Chi [145], an investor has a positive attitude toward using technological tools, such as the internet for stock trading to accept this technology to trade stocks that are favorable. According Taylor and Todd [146], a person has a positive attitude towards using a given technological tool when this goes in a positive direction towards the use that subject will make of the technology.

Alden at al. [147] explained how information and communication technology is expanding rapidly and widely throughout the world, and the attitudes of businesses and customers towards this technology market are becoming increasingly globalized. As those who plan to turn to computers more frequently, the global community is more likely to adopt usage attitudes toward new technologies and advanced products [46]. According to Chen and Huang [148], companies and individuals tend to adopt attitudes toward using new technologies to express their identities, even when unsatisfied with a technological innovation that requires improvement, which means that potential customers or consumers have a more assertive global identity and a broad view of new technology as a way to build a psychological connection with the global community.

Primary users are more enthusiastic about their attitudes towards using new products. They can overcome any problem with new technologies [149]. Chen and Huang [148] showed that a consumer's intention to adopt home robot products is influenced by their usage attitude toward the technology, considering costs and benefits, and their usefulness. In developed and technologically advanced countries, AR technology's adoption and usage attitudes for e-commerce are in advanced stages [150]. In contrast, for Kumar et al. [151], despite the positive attitude toward using the technology, the adoption of AR by e-commerce organizations is still marginal.

Cheng, et al. [152] obtained similar findings when they evaluated the effects of perceived web security on attitudes towards internet banking and trust, usefulness, and perceived security. Other studies have considered internet banking using TAM; internet banking is relevant because research efforts confirm that accuracy, security, network speed, ease of use, user involvement, and convenience are critical to the attitudes toward internet banking adoption [153]. In contrast, Fenton and Neil [154] asserted that using TAM in software measures, in the technological context, accepts that easier-to-use measures are more likely to be adopted. Our model includes ease of use and is consistent with TAM. We model it as a construct and sub-dimension of perceived usefulness [132]. Therefore, the hypothesis contains the following postulate. H3. Industry 4.0 attitude towards to use (ATU) has a positive impact on intention to adopt industry 4.0 in the organization (IAI).

D. INDUSTRY 4.0 TECHNOLOGICAL CONTEXT (ICO)

Industry 4.0 focuses on creating smart factories [38] using emerging technologies such as big data, analytics, the internet of things, virtual reality, additive manufacturing, and cloud computing [155]. It also focuses on the implementation of robotic systems to obtain CPS [38], [156] and a human component interface that leads to manufacturing systems with economic, environmental, and socially sustainable approaches [157] that contribute to the different sectors of a country. Thus, it is known as the fourth industrial revolution framed in the digital revolution [158], [159] and its contribution to industrial production [96] which is emerging from the improvement of networks, contributes to all areas within organizations.

The strength of Industry 4.0 which is directly related to the emergence of digital manufacturing [160], refers to intelligent networks between industry units, mobility in processes, and flexibility in operations [5], thus achieving integration between internal and external customers, suppliers, and above all in the adoption of innovative business models that allow for greater profitability [161], [162]. Since in recent years, factors such as increasing national and international competition, market volatility, product demand, and unforeseen situations such as the global pandemic have presented serious challenges for companies and their life cycles, the need to improve the quality of their products and services has become more critical than ever.

On the other hand, the rapid technological progress has increased the number of potential businesses with greater opportunities and new trends [163] such as digitalization, internet of things, internet of services, and CPS increasingly relevant [164]. Thus, Industry 4.0, has gained significant importance in companies worldwide [165]. Implementing Industry 4.0, technologies in a manufacturing environment indicate that recognizing digital opportunities, especially in manufacturing products and processes, requires deep collaboration with innovation to internalize firm and sector-specific inadequacies and create reciprocal security among stakeholders [166]. Therefore, the hypothesis contains the following postulate: H4. Industry 4.0 technological context (ICO) has a positive impact on the intention to adopt industry 4.0 in the organization (IAI).

E. INDUSTRY 4.0 ATTITUDE BEHAVIORAL CONTROL (BCO)

Technologies and their accelerated advancement over the years, together with innovation, do not leave the intention of consumer behavior towards the use of technologies unnoticed [137]. With the application of the TPB model, the effects of usefulness and ease of use on intention were mediated by attitude. Therefore, it is essential to analyze the effects of these antecedents on behavioral intentions. Cortés et al. [167], as well as Onar et al. [159], found that self-identity can increase predictive validity, considering individual differences, personality traits, and characteristics of users in organizations, which will determine the attitude and intentions of technology adoption [168]. Another aspect to consider, according to Bisoyi and Das [169], is that user leadership greatly influences the adoption behavior of new products.

The scope and implications of technological initiatives worldwide are still difficult to quantify [170], [171]. However, Industry 4.0 optimizes production and transformation systems, shortens the development cycle of new products, reduces manufacturing costs, and allows fully integrated and automated production processes [167], [172]. Furthermore, these will provide information that can be accessed globally in real time through the internet and various mobile devices, thus facilitating the creation of cooperation and collaboration networks [173], positively changing the attitude of the members of the organization, and most importantly, reaching timely decision-making and having greater control of activities over time.

People's satisfaction or behavior towards existing systems and the shift from centralized to decentralized production supported by new technologies have become a challenge for organizations. As emphasized by Mittal et al. [174], resistance to change was an important aspect that hindered the success of integrated manufacturing by processors in the 1990's [175]. The Rejection simultaneously with the motivation for change emanates from two circumstances: lack of skills or satisfaction with the existing system [176]. Therefore, the motivation and socialization of the benefits of the application of information technologies should be focused on improving the performance and behavioral attitude of the organization's members and making it satisfactory.

According to Ajzen and Fishbein [177], an attitude towards behavior is an evaluative judgment of marked hanges in an object. It is conceived as a predisposition learned to respond positively or negatively to an object [152] attitudes are shaped by the repertoire of dogmas relative to an object [178]. This Attitude can be determined by emotional factors, previous experiences, or preceding information from the environment, which defines whether the behavior will be executed [179]. Opinions are conceived as consequences of performing a particular behavior [180].

Therefore, the hypothesis is as follows: H5. Industry 4.0 attitude behavioral control (BCO) has a positive impact on intention to adopt industry 4.0 in the organization (IAI).

F. INDUSTRY 4.0 SUBJECTIVE NORM (SNO)

The subjective norm represents the influence exerted by society in general and by the individuals that the person considers necessary to him [181]; i.e., it accumulates the regulated beliefs of the particular subject at the moment of setting his behavior [182]. On the other hand, it is believed that behavior is made explicit by behavioral intention and that this, in turn, is manifested through attitudes towards behavior and the subjective norm [174]. The two elements, in turn, are manifested on normative bases insofar as they represent retained information about objects.

Ajzen and Fishbein [177] considered that attitude and subjective norms do not have the same weight in predicting behavior, depending on the person and the situation, as they can have very different results on behavioral intention. [183]. According to research by Chen and Huang [148], subjective norms weaken the effect of attitude on adoption intentions [157]. Therefore, word-of-mouth and coercion from collaborators could be vital communication tools to convince consumers to adopt technologies in their homes and businesses [184].

The following hypothesis is proposed: H6. Industry 4.0 subjective norm (SNO) has a positive impact on the intention to adopt industry 4.0 in the organization (IAI).

G. INDUSTRY 4.0 ATTITUDE (ATT)

Many extended and competing models have been formulated using TAM and information technology (IT) acceptance research. For example, Kim et al. [185] emphasized that attitude toward technology use fully mediates the effects of salient beliefs on behavioral intention when the attitude is strong, while it partially mediates when attitude is weak. A similar idea can be found in Iyer et al. [186], who argued that some authors accepted virtual learning environments in China, while others added standard TAM constructs with an attitude towards system use. This idea constitutes an extension of that proposed by Sampat et al. [187], who refers to TAM as a model describing an individual's acceptance of information technology.

According to cognitive dissonance theory, individuals who like consistency in their beliefs (dogmas, papers, and performance) when there is a lack of agreement will change their attitude to resolve dissonance [188]. On the other hand, attitude is considered a critical antecedent of technology use and adoption. Two hedonic and utilitarian attitudes were examined to determine how they influenced satisfaction with technology. The former may not lead to use but influence satisfaction, whereas utilitarianism leads to use and satisfaction [189]. This view is supported by Sampat and Sabat [190], who state that perceived usefulness and perceived ease of use have a positive effect on attitude leading to continued intention and satisfaction with continued intention to use e-Government services; however, attitude and satisfaction, together with perceived usefulness and self-efficacy, can support users' intention.

Wang et al. [191] established that leaders' attitude mediate agricultural information technology (AIT), technological factors and intention to adopt. However, to our knowledge, no scholars have tested the mediating effect of executives' attitudes on technology adoption in an organizational context. Additionally, attitudinal and motivational states are essential for predicting innovation. There are examples of innovation models derived from motivational models [192]. Attitude refers to a person favorably or unfavorably feeling toward the adopting a specific technology. However, it is not the only factor that determines usage because it is influenced by system performance which leads to the intention to use and adopt the technology. The attitude to use and intention to accept are endogenous factors that previous studies have shown to have an effect on the presence of attitude toward the intention to use new technologies. Several studies support that attitude affects intention to use. Reference [193] similarly, perceived ease of social network use is positively related to attitude towards social network use [187].

In this context, there is a model called the binary choice model that understands how attitudes influence the decision to purchase. It studies the adoption at the individual level according to the antecedents of hedonic and utilitarian attitudes, and is used to determine adoption and usage behavior [189].

Therefore, the hypothesis is as follows H7. Industry 4.0 attitude (ATT) has a positive impact on intention to adopt industry 4.0 in the organization (IAI).

H. INTENTION TO ADOPT INDUSTRY 4.0 IN THE ORGANIZATION (IAI)

Industry 4.0 has driven analytical capabilities in the company over the last decade through innovation in all areas of the organization, business models, and the ability of organizations to become an element of competitive advantage in almost all sectors [194], [195]. For Arnold et al. [162], Bauer et al. [196], the main characteristics related to Industry 4.0, such as real-time capacity, interoperability, vertical and horizontal integration of productive systems through ICT systems, are considered the current challenges that organizations must face to remain competitive in the market, owing to the growing demand and the demand of customers in relation to product and service innovation.

Discussion and initiatives point to digital transformation in organizations. Thus, Germany was the first country to introduce digitization of Industry 4.0. However, term expanded worldwide, so the United States of America focused on smart manufacturing through the adoption of Industry 4.0 in almost all organizations, followed by smart Japan and Korea [6], [65]. Therefore, the authors, Fleisch, et al. [197] and Iivari et al. [198], explain that technology directed to digital industries is becoming very relevant for traditional companies as sales increase. Consequently, the adoption of Industry 4.0 driving organizations to change their mentality to improve their products and services.

Companies within the technology world are highly competitive in having a better position in adopting Industry 4.0, therefore, are more prepared for Industry 4.0 [199]. By contrast, Nguyen and Luu [200] found that the perception of a better customer relationship has a significant effect on the adoption of Industry 4.0, and that efforts by organizations aimed to increase the perceptions of factors on the adoption of Industry 4.0. The relevance of technology contributes to its success, which is defined as the effective use of Industry 4.0.

For Neugebauer et al. [201], Industry 4.0 technology should be a priority in the new manufacturing era, calling it smart factory or smart manufacturing. The vision of Industry 4.0 is real-time digitization with added value. Therefore, it is considered to be the most revolutionary and evolutionary. On the other hand, for Nick and Pongrácz [202], Dassisti et al. [203], Industry 4.0 is supported by nine pillars, these being: advanced manufacturing; additive manufacturing; augmented reality; simulation; horizontal and vertical integration; industrial internet; cloud; cybersecurity; and big data analysis; however, the challenge that organizations face is to understand their processes, procedures and philosophy, in order to take advantage of the potential of technology, as some theorists always ask, with Industry 4.0 ''how do we get from where we are now to where we want to be?

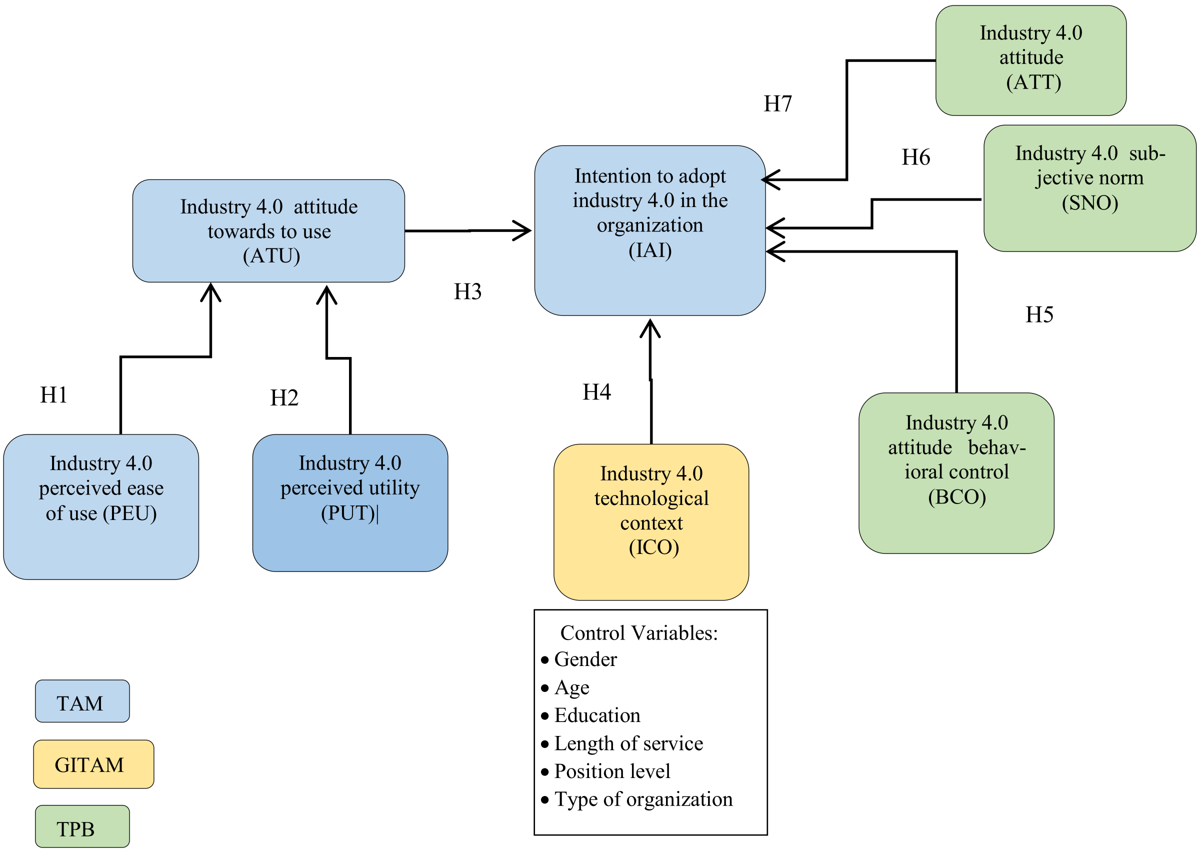

FIGURE 1. Research model and hypothesis.

Figure 1 shows the proposed model for intention to adopt Industry 4.0 in organization based on seven hypothesis. The models from which the variables were taken are also shown, according to the color of the boxes.

IV. RESEARCH METHODOLOGY

A. INSTRUMENT

To develop the questionnaire, indicators were generated through a review of the theoretical framework (see Appendix A). Items referring to demographic information about the organization and informants were also inserted, and all items of the instrument were evaluated on a scale from 0 to 4, with the following parameters: disagree entirely, partially disagree, neither agree nor disagree, partially agree, and completely agree.

Initial feedback was provided by 10 experts who refined the instrument. Based on this, the questions were consolidated to maintain consistency in the responses of the informants. The profile of the experts is explained in the Table 3, where they appear, academic degree, type of work carried out, positions, university, and country.

B. POPULATION AND SAMPLE

The characteristics of the proposed model were used to determine the sample, that is, eight constructs and four constructs that point to the dependent variable. According to the Partial Least Square (PLS) model, the sample size for the model is calculated by multiplying ten by the last number, that is, 10 x 4 = 40. Despite this, the 80% power analysis [204] is applied, requiring in the end: 40 + 32 = 72 cases.

Data were captured between November 2021 and February 2022 and an online questionnaire was administered using Google Docs. The survey link was sent by email, and after four months, 499 refined surveys were completed. The study involved stakeholders from organizations in LA countries in the following proportions: Colombia 25.25%, Ecuador 23.05%, Mexico 22.04%, Peru 20.24%, and Panama 9.42%.

The sectors of manufacturing, education, commerce, services and others, support the advancement and development of a state, include organizations with the capacity to absorb Information Technologies. These new technologies are enabling ever higher levels of production efficiency [205], they are intermediate measures, for consumer surplus and economic growth [206]. Companies choose development strategies that lead to the achievement of economic objectives. In this sense, these sectors are those whose needs are framed by the adoption of quality technology, in order to be more competitive and thus contribute to the progress of their countries.

TABLE 3. Expert profile.

Academic Degree Name	University - Country - Position	Line of research
PhD, Expert in Evolutionary Computing; Computer EngineerFigure 1	Research Professor at Shinshu University, Japan.	Artificial intelligence; Evolutionary Computing; Technology Adoption
PhD, in Computer Science; Computer engineer	Research Professor at the Universitat de les Illes Balears (UIB), Spain. IEEE Senior Member,	Performance Engineering; Green IT and IT Governance; Technology Adoption
PhD, in Information Technologies; Computer engineer	Research Professor at the Universitat de les Illes Balears (UIB), Spain. President of Women in Engineering of the IEEE Spain Section	Cloud computing; Virtual machine; Data center
PhD of Science and Technology, Computer engineer	Research Professor at Yachat Tech University, Ecuador	Artificial intelligence; Evolutionary computing
PhD, of Business Administration; Economist	Research Professor at University of Cuenca, Ecuador	Innovation in organizations; Entrepreneurship; Organizational culture
PhD in Psychology	Research Professor at the Catholic University of Cuenca, Ecuador	Cognitive behavior; Organizational psychology
PhD in electronics Electronic Engineer	Research Professor at the Catholic University of Cuenca, Ecuador	Industry 4.0; Robotics
PhD in Administration Sciences	Research Professor at ESPE University, Ecuador	Organizational culture; Change management
PhD in Administration Sciences; Computer engineer	Research Professor at the National Autonomous University of Mexico (UNAM), Mexico	Digital transformation; Business intelligence;
PhD in Information Systems	Faculty Director of the Residential Program of the Master of Science in Business Analytics. Williamsburg, Virginia, United States	Business Analytics Big Data

C. DEMOGRAFIC DATE

Table 4, illustrates the demographic composition of the respondents. As explained in the previous paragraph, the research focused on some Latin American countries, whose demographic information was extremely important for the strengthening of the study, where factors such as the number of employees, exceeding 300, of the qualities in their greatest number are male, each of them having a relevant position within the market; another important factor is their level of higher education, highlighting this as a priority for organizational efficiency; finally, it is shown that most of the registered companies have little seniority with staff ranging from 35 to 55 years. These factors are essential to strengthen research, as these organizations are friendly with the use of modern technology.

V. DATA ANALYSIS AND RESULTS

The model was measured using the PLS technique in Smart PLS 3.3.3. The model is analyzed in two parts: the measurement model and the structural model [207], and is useful when there are limitations in the sample size [208].

A. MEASURE MODEL

Cronbach's alpha, composite reliability, average variance extracted (AVE), and discriminant validity were determined. The measurement model results are shown in Figure 2. The Cronbach's alpha of the indicators, except for ICO4, is greater than 0.7; this implies, according to Carmines and Zeller [209], that they are valid. Table 5 contains the detailed values of the loadings for each indicator where ICO4 should be revised, eliminated or restructured in the text of the question

The reliability of the constructs was analyzed using composite reliability and Cronbach's alpha. A value higher than 0.7 is acceptable [210]; in Table 6, the constructs have a satisfactory level of internal consistency reliability, with values higher than 0.7. The convergent validity of each construct was analyzed with the value of the average variance extracted (AVE); if the value is greater than 0.5, it is acceptable according to Fornell and Larcker [211]; in Table 6, the AVE value was greater than 0.5 for all constructs.

Discriminant validity analysis was performed based on Fornell and Larcker [211], which determines whether the value of the square root of the mean extracted variance is greater than the interconstruct correlations. For the present model, although for most of the constructs the square root of AVE is greater than the correlation between them, this condition is not 100% fulfilled in all cases.

For example, it is below the constructs of ATT and ICO. Therefore, it cannot be concluded that the model meets the discriminant validity criterion and that the latent variables are differentiated (see Table 7). However, to strengthen the discriminant validity analysis, a cross-loading check is also performed, which validates that each indicator is correlated with its latent variable rather than with others. Therefore, it was not necessary to reconsider the adequacy of the model, as shown in Table 8.

TABLE 4. Informant demographic profile.

Category	Frequency	Percentage
Country		
Colombia	126	25.25%
Ecuador	115	23.05%
Mexico	110	22.04%
Peru	101	20.24%
Panama	47	9.42%
Sector		
Manufacture	203	40.68%
Education	170	34.07%
Commerce	42	8.42%
Services	28	5.61%
Other	56	11.22%
Number of Employees		
< 10	15	3.01%
11-50	77	15.43%
51-100	77	15.43%
101-300	99	19.84%
> 300	231	46.29%
Gender		
Male	287	57.52%
Female	212	42.48%
Age		
< 25	31	6.21%
25-35	58	11.62%
35-45	175	35.07%
45-55	179	35.87%
> 55	56	11.22%
Years in the Organization		
<5	31	6.21%
5- 10	232	46.49%
11-15	33	6.61%
16-20	119	23.85%
> 20	84	16.83%
Position level		
Strategic	161	32.26%
Tactical	182	36.47%
Operational	156	31.26%
Education level		
Primary	0	0.00%
Secondary	46	9.22%
Undergraduate	224	44.89%
Graduate	229	45.89%

The measurement model is validated after analyzing its parameters, implying that the instrument is statistically valid and reliable and that the theory is supported [212].

B. STRUCTURAL MODEL

The structural model was assessed based on the weight and magnitude of the relationships between different variables using the R^2 index, f^2 effect, standardized path coefficients β, and bootstrapping analysis. R^2 determines the predictive power of the model; values greater than 0.67, 0.33, and 0.19, denoted as substantial, moderate, and weak, respectively, are considered feasible [205]. Table 9 lists values that ensured the percentage of construct variability, thereby confirming the predictive characteristics of the model. On the other hand, f^2 identifies the impact on a dependent construct of a variable, if $f^2 > 0.35$, it implies large size; $0.15 < f^2 \leq 0.35$ implies medium effect and $0.02 < f^2 \leq 0.15$, represents small effect size (see Table 10).

TABLE 5. Loads for each indicator.

	IAI	ATT	ATU	BCO	ICO	PEU	PUT	SNO
AIA1	0.924							
AIA2	0.959							
AIA3	0.890							
AIA4	0.888							
AIA5	0.927							
ATT1		0.762						
ATT2		0.973						
ATT3		0.946						
ATT4		0.968						
ATU1			0.772					
ATU2			0.899					
ATU3			0.888					
ATU4			0.797					
BCO1				0.819				
BCO2				0.887				
BCO3				0.770				
BCO4				0.735				
ICO1					0.935			
ICO2					0.884			
ICO3					0.950			
ICO4					0.086			
ICO5					0.933			
PEU1						0.882		
PEU2						0.860		
PEU3						0.834		
PEU4						0.884		
PEU5						0.713		
PUT1							0.900	
PUT2							0.732	
PUT3							0.920	
SNO1								0.744
SNO2								0.837
SNO3								0.831
SNO4								0.932

f^2 can be seen as an indicator for which the latent variable predictor has a small, medium, or large effect at the structural level and quantifies the proportion of variance of the dependent variable that is explained by the set of predictor variables [213].

Table 10 highlights that Industry 4.0 perceived utility (PUT) has a significant effect on Industry 4.0 attitude towards to use (ATU), while Industry 4.0 perceived ease of use (PEU), has a medium effect. On the other hand, the constructs Industry 4.0 attitude (ATT), Industry 4.0 attitude towards to use

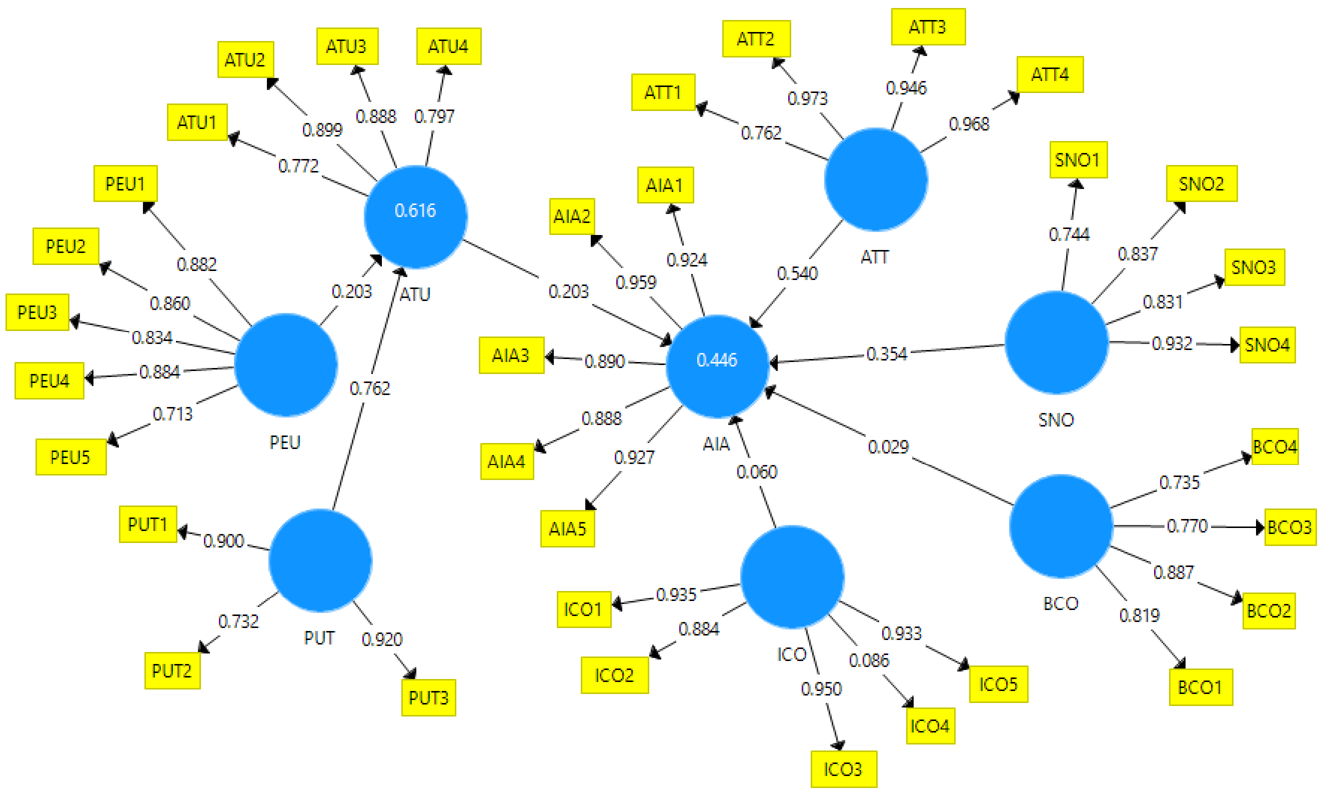

FIGURE 2. Measure model results.

(ATU), Industry 4.0 attitude behavioral control (BCO), Industry 4.0 technological context (ICO), and Industry 4.0 subjective norm (SNO) have a small effect on intention to adopt industry 4.0 in the organization (IAI). The fact that the five variables have a low impact on the IAI variable is related to the context of the informants, as they are organizations that belong to a group of developing countries where inconveniences and challenges are perceived in the implementation of the industry.

C. HYPOTHESIS TESTING

Concerning the standardized path coefficients β, whose objective is to measure the relevance of path relationships, those that reach at least a value of 0.2 are considered significant [214]. Unfortunately, in Table 11, which contains the path coefficients between the variables, two values (0.029 and 0.060) do not exceed the minimum value of 0.2, which is why the model should be reorganized from a structural point of view.

Bootstrapping analysis is a resampling procedure that treats an observed sample as representative a population. Figure 3 shows the bootstrap values of the model. In addition, this analysis allows the testing of hypotheses by calculating the standard error of the parameters and the Student's t-values; in this area, the indicators whose Student's t-values are greater than 1.96 are considered significant [215]. Table 11 shows the relationships between the model's

TABLE 6. Reliability and convergent validity of constructs.

	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
ATT	0.934	0.954	0.840
ATU	0.861	0.906	0.707
BCO	0.825	0.880	0.648
IAI	0.953	0.964	0.843
ICO	0.842	0.902	0.687
PEU	0.897	0.921	0.701
PUT	0.818	0.890	0.731
SNO	0.858	0.904	0.703

constructs through standardized beta paths, standard error, Student's t-value, significance level, and acceptance or rejection of the hypothesis.

The study tested the following hypotheses: Hypothesis one suggests that Industry 4.0 perceived ease of use (PEU), has a positive impact on Industry 4.0 attitude towards to use (ATU). Table 11 highlights the positive and median influences of PEU on ATU (β = 0.203, t-value = 3.168, p <0.01), supporting this hypothesis.

Hypothesis two suggests that Industry 4.0 perceived utility (PUT) has a positive impact on Industry 4.0 attitude towards

TABLE 7. Fornell-Larcker's criterion test.

	ATT	ATU	BCO	IAI	ICO	PEU	PUT	SNO
ATT	0.917							
ATU	0.728	0.841						
BCO	-0.799	-0.596	0.805					
IAI	0.652	0.405	-0.523	0.918				
ICO	0.783	0.672	-0.702	0.506	0.829			
PEU	0.030	-0.187	-0.122	0.167	0.149	0.837		
PUT	-0.876	-0.758	0.666	-0.655	-0.683	-0.021	0.855	
SNO	0.932	0.770	-0.802	0.627	0.849	0.013	-0.839	0.838

to use (ATU). Table 11 highlights the positive and significant influence of PUT on ATU ($\beta = 0.762$, t-value = 22.380, p <0.001), thus, supporting this hypothesis.

Hypothesis three suggests that Industry 4.0 attitude towards to use (ATU) have a positive impact on intention to adopt Industry 4.0 in the organization (IAI). Table 11 highlights a positive and significant influence of PUT on ATU ($\beta = 0.203$, t-value = 4.496, p <0.001), thus, supporting this hypothesis.

Hypothesis four suggests that Industry 4.0 technological context (ICO) has a positive impact on intention to adopt Industry 4.0 in the organization (IAI). Table 11 highlights a positive and lower significance influence of ICO on IAI ($\beta = 0.060$, t-value = 2.006, p <0.05), the hypothesis is supported.

Hypothesis five suggests that Industry 4.0 attitude behavioral control (BCO) has not a positive impact on intention to adopt Industry 4.0 in the organization (IAI). Table 11 highlights the negative influence of BCO on IAI ($\beta = 0.029$, t-value = 0.928). Therefore, this hypothesis is not supported.

Hypothesis six suggests that Industry 4.0 subjective norm (SNO) has a positive impact on the intention to adopt Industry 4.0 in the organization (IAI). Table 11 highlights a positive and significant influence of SNO on IAI ($\beta = 0.354$, t-value = 6.608, p <0.001); thus, this hypothesis is accepted.

Hypothesis seven suggests that Industry 4.0 attitude (ATT) has a positive impact on the intention to adopt Industry 4.0 in the organization (IAI). Table 11 highlights a positive and significant influence of ATT on IAI ($\beta = 0.540$, t-value = 8.725, p <0.001), the hypothesis is supported

VI. DISCUSSION

H1: The model analysis demonstrates the positive influence and impact of PEU on ATU. Ease of use goes hand in hand with the attitude towards use. Many companies are currently on the way to the search for new technologies in order to be more competitive in the market. Some organizations' economic factors do not impede positive attitudes towards green IT. It is important to note that the ease of use of Industry 4.0 aligns with companies' objectives in LA. This allows digitization production processes with fully automated processes, thus reducing labor and costs within organizations [81]. The ease of use of Industry 4.0, through the efficient incorporation of technology, allows companies to maintain their attitude towards this use, thus allowing them to efficiently manage organizational activities, leading to more competitiveness and sustainability in the national, LA, and global markets [126].

H2: This study highlights the positive and significant influence of PUT on ATU. Therefore, companies currently perceive the adoption of technology as a perceived utility, in the sense that companies make use of cutting-edge technology, leaving aside without taking into consideration traditional technologies; thus, they regain the importance importance of the application of Industry 4.0 for organizational processes, directly influencing investors attitudes towards stock trading [129], [130]. Therefore, it is essential to emphasize that companies' objectives are currently oriented towards using software that supports better organizational management. In short, the perceived usefulness of Industry 4.0 influences the attitude toward use when an investor or company believes that using the Internet trading platform improves work performance [118].

H3: The research shows that ATU directly influences IAI. IT is essential to highlight the importance of organization's positive attitude towards the use of modern technological tools to improve processes at the enterprise level, favoring the intention to accept this technology to be more efficient in the market. Some studies show the critical effect of the attitude towards the use by organizations and investors whose intention is to use technology as a support for online commerce [142], [143], [144]. Current information systems and communications are expanding rapidly worldwide. The attitudes of use by companies, investors, and customers towards this new technological market, are becoming increasingly globalized, so those who plan to address computers more frequently are more likely to maintain the intention to adopt new technologies and advanced products such as Industry 4.0 in organizations worldwide [46], [147].

H4: Predominates a positive influence and has lower significance for ICO than for IAI. This coupled with the dizzying technological progress that has motivated the birth of new businesses with more significant opportunities and modern trends [163] such as digitization, the Internet of Things, the Internet of Services, and CPS [164] has become increasingly timely, which is why Industry 4.0 has gained significant importance in organizations worldwide. [165]. This is why it is known as the fourth industrial revolution framed in the

TABLE 8. Cross-loadings.

	IAI	ATT	ATU	BCO	ICO	PEU	PUT	SNO
AIA1	0.924	0.681	0.551	-0.535	0.536	0.024	-0.673	0.671
AIA2	0.959	0.682	0.426	-0.559	0.556	0.158	-0.682	0.666
AIA3	0.890	0.505	0.212	-0.378	0.407	0.233	-0.530	0.443
AIA4	0.888	0.533	0.291	-0.432	0.374	0.166	-0.489	0.518
AIA5	0.927	0.558	0.327	-0.467	0.420	0.214	-0.601	0.540
ATT1	0.449	0.762	0.462	-0.626	0.702	0.075	-0.588	0.654
ATT2	0.645	0.973	0.739	-0.777	0.749	-0.010	-0.873	0.936
ATT3	0.589	0.946	0.646	-0.699	0.644	0.022	-0.798	0.830
ATT4	0.678	0.968	0.773	-0.812	0.784	0.036	-0.908	0.957
ATU1	0.394	0.533	0.772	-0.364	0.452	-0.169	-0.576	0.541
ATU2	0.401	0.696	0.899	-0.536	0.624	-0.150	-0.734	0.747
ATU3	0.358	0.640	0.888	-0.564	0.619	-0.129	-0.654	0.672
ATU4	0.178	0.564	0.797	-0.545	0.562	-0.191	-0.566	0.614
BCO1	-0.329	-0.554	-0.389	0.819	-0.542	-0.188	0.361	-0.564
BCO2	-0.477	-0.713	-0.512	0.887	-0.602	-0.112	0.584	-0.695
BCO3	-0.518	-0.730	-0.560	0.770	-0.629	-0.043	0.664	-0.741
BCO4	-0.256	-0.478	-0.394	0.735	-0.417	-0.071	0.433	-0.491
ICO1	0.448	0.677	0.654	-0.637	0.935	0.171	-0.588	0.776
ICO2	0.359	0.572	0.550	-0.516	0.884	0.170	-0.565	0.625
ICO3	0.577	0.874	0.707	-0.784	0.950	0.125	-0.722	0.932
ICO4	0.016	0.069	0.056	-0.038	0.086	-0.014	-0.081	0.064
ICO5	0.446	0.713	0.549	-0.606	0.933	0.097	-0.625	0.749
PEU1	0.091	-0.007	-0.171	-0.020	0.080	0.882	0.008	-0.042
PEU2	0.163	0.025	-0.088	-0.095	0.137	0.860	-0.095	-0.002
PEU3	0.227	0.048	-0.035	-0.084	0.116	0.834	-0.121	0.009
PEU4	0.132	-0.008	-0.186	-0.101	0.048	0.884	0.047	0.004
PEU5	0.165	0.088	-0.168	-0.193	0.249	0.713	-0.053	0.079
PUT1	-0.539	-0.716	-0.671	0.470	-0.643	-0.042	0.900	-0.700
PUT2	-0.447	-0.572	-0.425	0.437	-0.205	0.098	0.732	-0.466
PUT3	-0.663	-0.906	-0.778	0.752	-0.766	-0.062	0.920	-0.900
SNO1	0.423	0.641	0.482	-0.455	0.466	0.014	-0.574	0.744
SNO2	0.471	0.799	0.871	-0.631	0.664	-0.165	-0.736	0.837
SNO3	0.600	0.790	0.535	-0.761	0.706	0.036	-0.762	0.831
SNO4	0.577	0.874	0.707	-0.784	0.920	0.125	-0.722	0.932

TABLE 9. R^2 of dependent variables.

	R Square	R Square Adjusted	Level
ATU	0.616	0.614	Moderate
IAI	0.446	0.441	Moderate

digital revolution [158], [159] and especially its contribution to industrial production [93], which is born from the improvement of networks, contributing to all areas within organizations. The strength of Industry 4.0 is directly related to the emergence of digital manufacturing [160].

H5: Table 11 highlights the negative influence of BCO on IAI. Ricci et al. [166] argued that attitude towards behavior is conceived as a learned predisposition to respond positively or negatively to an object [152]. This is why behavioral control towards Industry 4.0 is shaped by the repertoire of beliefs relative to the object, which does not influence the intention

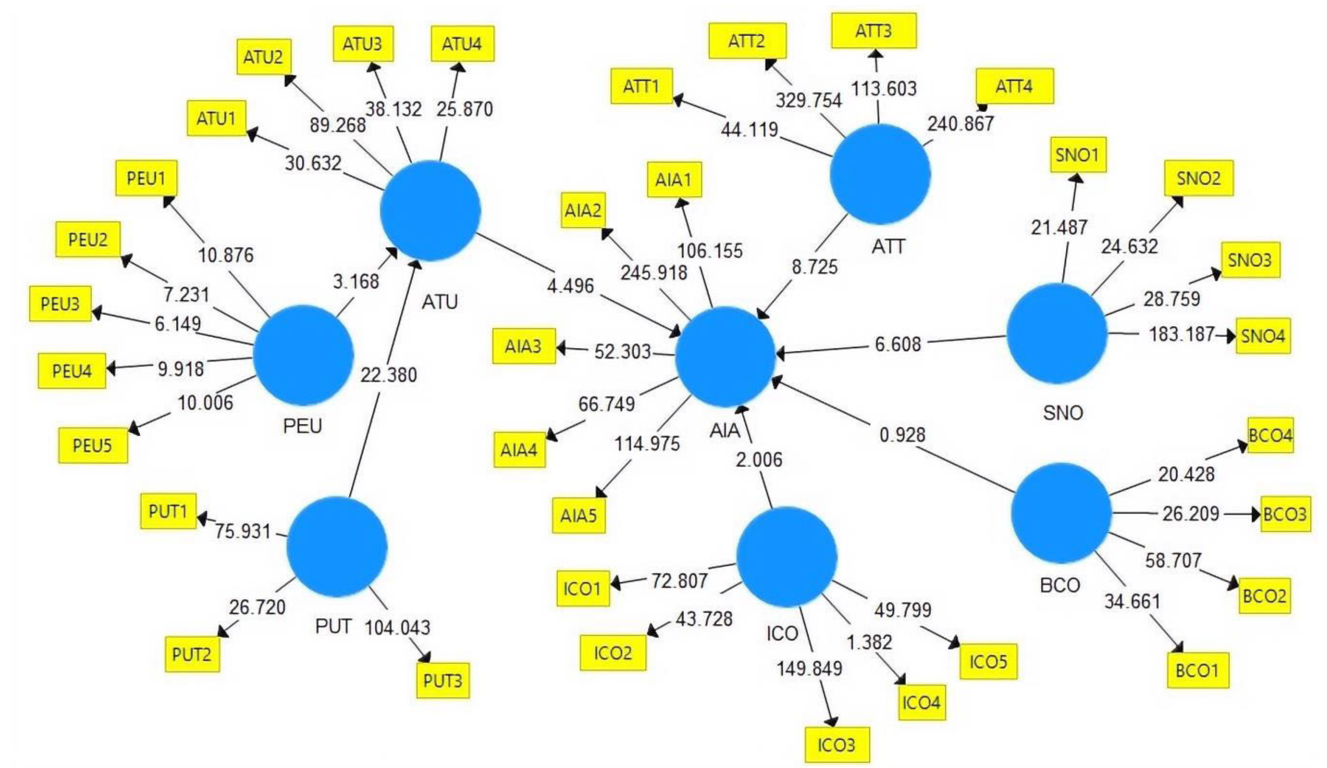

FIGURE 3. Bootstrapping results.

TABLE 10. Effect Size f^2.

	ATU	Category	IAI	Category
ATT			0.065	Small
ATU			0.030	Small
BCO			0.031	Small
IAI				
ICO			0.032	Small
PEU	0.108	Medium		
PUT	1.512	Large		
SNO			0.040	Small

to adopt new technologies in organizations [187] which emotional principles, past experiences can relate, or through preceding information from the environment that specifies whether the behavior will be executed or not. [179] Therefore, opinions are conceived as consequences of performing a particular behavior [180]. Chen and Huang [148] determined that self-identity can increase predictive validity by considering individual differences, personality traits, and characteristics of organizational users. These will determine the attitude and intentions of adoption of Industry 4.0 in the organization [157]; another aspect to consider, according to Bisoyi and Das [169], is that user leadership greatly influences the adoption behavior of new products.

H6: Table 11 highlights the positive and significant influence of SNO on IAI. Thus, the subjective norm represents the predominance exerted by society in general, which the individual considers vital for him [181]; that is, it accumulates the regulated beliefs of the particular subject at the moment of setting his course of action. [182] On the other hand, it is believed that behavior is made explicit by behavioral intention and that this, in turn, is manifested by attitudes towards behavior and the subjective norm [174]. These two elements, in turn, are manifested by normative bases because they represent the information retained about the objects. Ajzen and Fishbein [177] considered that attitude and subjective norms do not have the same weight in predicting behavior, depending on the person and situation, since they can have very different results in behavioral intention. [183] According to research by [162], subjective norms weaken the effect of attitude on adoption intentions [182] therefore, word-of-mouth and coercion from collaborators could be strong communication tools to convince consumers to adopt technologies in their homes and organizations [197].

H7: Table 11 highlights the positive and significant influence of ATT on IAI. Wang et al. [191] determine that managers' attitudes have a mediating effect on AIT, technological components, and intention to adopt. However, the mediating effect of firm managers' attitudes on technology adoption in an organizational context has not yet been tested. Since attitudinal and motivational states play an essential role in the prediction of innovation, there is an influence on the

TABLE 11. Summary of results for structural model.

	B	Standard Error	t - student	p values	Significant Level	Results
H1: PEU -> ATU	0.203	0.064	3.168	0.002	**	Accepted
H2: PUT -> ATU	0.762	0.034	22.380	0.000	***	Accepted
H3: ATU -> IAI	0.203	0.045	4.496	0.000	***	Accepted
H4: ICO -> IAI	0.060	0.030	2.006	0.045	*	Accepted
H5: BCO -> IAI	0.029	0.031	0.928	0.354		Rejected
H6: SNO -> IAI	0.354	0.054	6.608	0.000	***	Accepted
H7: ATT -> IAI	0.540	0.062	8.725	0.000	***	Accepted

*** *p<0.001*; ** *p< 0.01*; * *p< 0.05*

adoption of Industry 4.0 as modern and efficient technology for internal processes at the enterprise level. [192]. Attitude refers to a person or organization's optimistic or negative feelings towards adopting a specific technology. However, it is not the only factor that determines usage as it is influenced by the system performance that leads to the intention to use and adopt technology. Attitude and intention to accept are the endogenous factors; previous studies have shown the effect of Attitude related to the influence of the adoption of new technologies and claim that Attitude has a positive effect on the intention to adopt Industry 4.0 in the organization [193]. Similarly, perceived ease of use of social networking through current technology is positively related to attitude [187]. In short, the attitude toward the use of cutting-edge technology companies worldwide is influenced by the efficiency it provides in administrative and productive processes aimed at the quality, competitiveness, and sustainability of organizations.

VII. RESEARCH CONTRIBUTIONS AND IMPLICATIONS

A. THEORETICAL CONTRIBUTION

The work demonstrated that the proposed model is consistent with the data. There is theoretical evidence of the results by identifying the variables that influence the intention of organizational actors to adopt Industry 4.0, as well as the fundamental role played by the integrating role of GITAM, TPB and TAM. The positive relevance of the influence of Industry 4.0 perceived ease of use (PEU) and Industry 4.0 perceived utility (PUT) on Industry 4.0 attitude towards to use (ATU); of Industry 4.0 technological context (ICO), Industry 4.0 subjective norm (SNO), ''industry 4.0 attitude (ATT)'', and Industry 4.0 attitude (ATU) on intention to adopt industry 4.0 in the organization (IAI) was determined. What could not be validated is the influence of the Industry 4.0 technological context (ICO) on intention to adopt industry 4.0 in the organization (IAI). The results of the model are consistent with those of other researchers on technology adoption; proposing a model for intention to adopt Industry 4.0 is a significant contribution of the work, especially for developing countries.

B. PRACTICAL CONTRIBUTION

Organizations worldwide, especially in LA, are currently focused on acquiring knowledge through the digitalization of the company, which will radically improve internal processes such as production and administration, leading reduced costs and, in turn, high standards of quality and efficiency, a goal pursued by every business person. Industry 4.0 is being inserted into this modern world, whose purpose is to offer cutting-edge technology to the industry manufacturing and services sectors. The opportunities provided by technology within the world of organizations are leading to more productive, competitive, and sustainable development in the current market, increasing regional, national, and international development. This study contributes to organizational actors in determining the critical factors in adopting Industry 4.0 and the support for sound decision-making in this regard.

C. RESEARCH LIMITATIONS

Information was collected from 499 organizational actors of the productive sector belonging to strategic, tactical, and operational levels in Colombia, Ecuador, Mexico, Panama, and Peru, where limitations were detected, such as the capacity to expand to a greater number of countries due to logistical difficulties and contact with the informants. For the authors, the fact that the information was collected through virtual channels can be considered a limitation to a certain extent because it prevented a personalized approach to resolving concerns about the indicators on the part of the respondents. However, the lack of research on adopting Industry 4.0 in LA did not contribute to the feedback results.

D. CONTRIBUTIONS TO THE SDGS

The Sustainable Development Goals (SDGs) of the United Nations 2030 Agenda aim to ensure a more sustainable future for all nations; the 17 SDGs form an action plan designed to help nations achieve a more sustainable future. The research proposed in the context of the 17 SDGs, contributes with central and substantial contributions to SDG-7 ''Industry, Innovation and Infrastructure'', and indirectly to SDG-11

TABLE 12. Survey for intention to adopt industry 4.0.

No	Proposal	Original (Adapted from)	Reference
Industry 4.0 perceived ease of use (PEU)			
No	Proposal	Original (Adapted from)	Reference
PEU1	The use of Industry 4.0 will reduce my work effort in the organization.	The amount of user effort required in order to accomplish tasks using the technology	[216]
PEU2	The degree of technical competence of the personnel for the use of Industry 4.0 in the organization facilitates its implementation.	Training or experience with the technology, including relevant accumulated knowledge facilitates its implementation.	[216]
PEU3	The degree of technical competence of the personnel for the use of Industry 4.0 in the organization implies effort and complexity.	Lack of training and the capacity of ICT (information and communication technologies) personnel generates problems in their jobs.	[217]
PEU4	There is a reduction in the labor force covered by Industry 4.0.	The use of technology reduces the problems related to collaboration and coordination.	[220]
PEU5	The inclusion of Industry 4.0 facilitates organizational activities in different areas.	The application of cloud storage services is useful for the accomplishment of tasks.	[218]
Industry 4.0 perceived utility (PUT)			
No	Proposal	Original (Adapted from)	Reference
PUT1	Industry 4.0 will improve my job performance in the organization.	Using that Application X improves my performance in my job.	[208]
PUT2	Investment returns are expected based on the use of Industry 4.0.	The Monetary Cost-Benefit Assessment Based on Industry 4.0	[220]
PUT3	The Industry 4.0-based organization will improve its performance.	Lack of digital culture Technological	[24]
Industry 4.0 attitude towards to use (ATU)			
No	Proposal	Original (Adapted from)	Reference
ATU1	Organization maintains positive action to use Industry 4.0	Overall, using cloud storage on business is negative-positive	[218]
ATU2	Satisfaction with organizational technological innovation through Industry 4.0	Cloud storage solutions are considered innovative in an organization.	[218]
ATU3	Confidence, usefulness and perceived security with new technology through Industry 4.0	Detailed contractual agreements with the cloud storage provider (e.g. SLAs) contribute to an improved perception of data security and safety	[218]
ATU4	Strategic alignment of the organization with new technologies through Industry 4.0	Lack of alignment, experience, vision, and digital strategy in the organization	[24]
Industry 4.0 technological context (ICO)			
No	Proposal	Original (Adapted from)	Reference
ICO1	Knowledge of the implications of Industry 4.0 in the organization.	There is infrastructure and relevant knowledge for support processes	[216]
ICO2	Technical knowledge of Industry 4.0 outside the organization.	There is Accessibility to Technology	[216]
ICO3	Technical knowledge of Industry 4.0 towards the inside of the organization	There is openness to change, assignment of responsibility	[218]
ICO4	Integration of current technological platforms towards Industry 4.0	There is awareness of the consequences when integrating technological platforms	[218]
ICO5	Competences to adopt / implement new business models based on Industry 4.0	Overcoming resistance to technological change	[24]
Industry 4.0 attitude behavioral control (BCO)			
No	Proposal	Original (Adapted from)	Reference
BCO1	Maintains contact with organizations and actors that use Industry 4.0 in their processes.	Adoption of technology solutions leads to stakeholder relationships.	[218]
BCO2	They would use Industry 4.0 technology because they refer to its usefulness.	It is important to use new value offers through technology to improve competitiveness and use	[24]
BCO3	Confidence in their ability to make use of Industry 4.0 in the organization	Confidence in technology in the organization.	[218]
BCO4	Skills and knowledge, assuming that Industry 4.0 is determined by the presence of factors that may facilitate or impede the performance of their behavior in the organization	I have the resources, skills, knowledge, and ability to make use of a domestic robot and facilitate the performance	[138]
Industry 4.0 subjective norm (SNO)			
No	Proposal	Original (Adapted from)	Reference
SNO1	People who influence my behavior in the organization think that I should be a user of new technologies that contemplate Industry 4.0	People who influence my behavior think that I should use a domestic robot.	[148]
SNO2	The people who are important to me within the organization think that I should be a user of new technologies that contemplate Industry 4.0.	People who are important to me think that I should use a domestic robot.	[148]
SNO3	The experiences of other people and organizations interfere with my decision to be a user of new technologies that contemplate Industry 4.0.	Improved data security, experience, and business play a role in the decision process towards adopting cloud storage.	[218]
SNO4	The organization influences my job action to work in Industry 4.0	It is important to reduce monotonous work and promote new business models based on technology	[24]

TABLE 12. *(Continued.)* **Survey for intention to adopt industry 4.0.**

No	Proposal	Original (Adapted from)	Reference
Industry 4.0 attitude (ATT)			
ATT1	I am personally motivated to participate in processes that contemplate the use of Industry 4.0.	I feel positive and motivated about using domestic robots	[148]
ATT2	The organization is concerned about including new technologies in its processes that contemplate Industry 4.0.	Technological opportunities and market prospects are important in the organization	[217]
ATT3	The organization is concerned about improving its efficiency based on the inclusion of Industry 4.0.	The organization seeks greater efficiency, quality and agility through Industry 4.0	[24]
ATT4	The organization experiences pressure from the industry sector to implement Industry 4.0.	The adoption of technological solutions is influenced by the industry sector	[218]
Intention to adopt industry 4.0 in the organization (IAI)			
No	Proposal	Original (Adapted from)	Reference
IAI1	Actions to implement Industry 4.0 by the organization in the medium term	Within the next five years, will you invest in or develop the implementation of future manufacturing systems?	[40]
IAI2	Executive-level decision to implement Industry 4.0 in the medium term.	Managers tend to adopt new technological products before other people.	[148]
IAI3	Industry 4.0 support and induction of technology suppliers.	The trustfulness of the cloud storage provider is a crucial factor within the adoption decision process.	[218]
IAI4	Infrastructure, procedures and processes to enable Industry 4.0	Technological infrastructure to support the processes is important	[216]
IAI5	Investment and budgets allocated for new technologies contemplated by Industry 4.0.	Financial limitations and cost reduction are considered by the organization.	[24]

''Sustainable cities and communities'', to SDG-13 ''Climate action '' and SDG-7 of ''Clean and affordable energy''

E. FUTURE PROJECTS

Future studies on Industry 4.0 adoption should consider other potential technology adoption drivers. It is possible to include additional internal variables in the proposed model, such as organizational culture, the beliefs and values of organizational actors, innovation, and knowledge management. It is also feasible to consider the adoption of Industry 4.0, that is, inter-institutional Industry 4.0, among organizations as the scope of this study. Another variable that can be analyzed is the outsourcing of Industry 4.0, which is based on the principal-agent theory. The proposed model can be applied in organizational environments of different natures and geographical latitudes, and to validate the indicated topic, it is necessary to develop new research processes.

It is expected that this research will be a reference for future studies, which will allow companies in different LA countries to incorporate Industry 4.0 as state-of-the-art technology, especially in information and communication, thus improving both internal and external processes of the organizations, and continuing to position the business sector of goods and services within the global market.

VIII. CONCLUSION

The research validated the generation of a model for the adoption intention of Industry 4.0 in the context of LA organizations; the main research questions have been answered. The model complies with the parameters that validate the measurement model, implying that it is reliable and that the instrument applied is statistically valid. These indicators significantly contribute to the latent variables. However, the model validated six of the seven hypotheses from a structural perspective. In addition, the number of hypotheses fulfilled depends on the context in which the model is applied. It may be that in another organizational environment or region, a greater or lesser number of hypotheses may be supported.

The selection of variables in the TAM, GITAM, and TPB models will lead to the intention to adopt Industry 4.0 within the organizations studied, allowing them to be more efficient through quality production and management, leveraging them to face competitive challenges within the market.

Organizations at the Latin American level maintain a positive attitude towards the adoption of Industry 4.0, from the point of view of the attitude and behavior of their employees, business utility, and the technological context in which they operate.

The intention to adopt Industry 4.0, expressed by organizations, is a necessity and will affect commitment to technological updating, changes in worker attitude, commitment, and leadership at the strategic, tactical, and operational levels.

This work contributes to the lack of knowledge about technology adoption strategies, especially in Industry 4.0, within organizations in developing countries, where there is a lack of knowledge on how to do it. Overcoming this gap will allow the organization to be more efficient and profitable.

APPENDIX A

See Table 12.

ACKNOWLEDGMENT

The authors express sincere gratitude to the Catholic University of Cuenca for logistical support.

REFERENCES

[1] L. S. Dalenogare, G. B. Benitez, N. F. Ayala, and A. G. Frank, ''The expected contribution of industry 4.0 technologies for industrial performance,'' *Int. J. Prod. Econ.*, vol. 204, pp. 383–394, Oct. 2018, doi: 10.1016/j.ijpe.2018.08.019.

[2] V. Majstorović and R. Y. Z. M. Mišković, "Industry 4.0 in Serbia-state of development," *Serbian J. Manage.*, vol. 1, nos. 5–14, p. 17, 2022, doi: 10.5937/sjm17-36626.

[3] N. Y. R. A. El-Sayed, "Industry 4.0: An empirical study to identify the critical challenges of implementing industry 4.0 for manufacturing firms across Germany, Nordic, and Gulf region," Tech. Rep., 2022.

[4] L. Wang, M. Törngren, and M. Onori, "Current status and advancement of cyber-physical systems in manufacturing," *J. Manuf. Syst.*, vol. 37, pp. 517–527, Oct. 2015, doi: 10.1016/j.jmsy.2015.04.008.

[5] L. Barreto, A. Amaral, and T. Pereira, "Industry 4.0 implications in logistics: An overview," *Proc. Manuf.*, vol. 13, pp. 1245–1252, Jan. 2017, doi: 10.1016/j.promfg.2017.09.045.

[6] K. D. Thoben, S. Wiesner, and T. Wuest, "'Industrie 4.0' and smart manufacturing—A review of research issues and application examples," *Int. J. Automat. Technol.*, vol. 11, no. 1, pp. 4–16, 2017, doi: 10.20965/ijat.2017.p0004.

[7] E. A. Lee, "Cyber-physical systems-are computing foundations adequate," in *Proc. Position Paper NSF Workshop Cyber-Phys. Syst., Res. Motivat., Techn. Roadmap*, vol. 2, 2006, pp. 1–9.

[8] C. Sallati, J. D. A. Bertazzi, and K. Schützer, "Professional skills in the product development process: The contribution of learning environments to professional skills in the industry 4.0 scenario," *Proc. CIRP*, vol. 84, pp. 203–208, Jan. 2019.

[9] *Upskilling Pathways: New Learning Opportunities for Adults*, European Commission, Brussels, Belgium, 2017.

[10] A. Florea, "Digital design skills for factories of the future," in *Proc. MATEC Web Conf.*, vol. 290, 2019, p. 14002, doi: 10.1051/matecconf/201929014002.

[11] R. Črešnar and Z. Nedelko, "Understanding future leaders: How are personal values of generations Y and Z tailored to leadership in industry 4.0?" *Sustainability*, vol. 12, no. 11, p. 4417, May 2020, doi: 10.3390/su12114417.

[12] W. Lam, C. Lee, M. S. Taylor, and H. H. Zhao, "Does proactive personality matter in leadership transitions? Effects of proactive personality on new leader identification and responses to new leaders and their change agendas," *Acad. Manage. J.*, vol. 61, no. 1, pp. 245–263, Feb. 2018, doi: 10.5465/amj.2014.0503.

[13] F. Cui, L. Ma, G. Hou, Z. Pang, Y. Hou, and L. Li, "Development of smart nursing Homes using systems engineering methodologies in industry 4.0," *Enterprise Inf. Syst.*, vol. 14, no. 4, pp. 463–479, Apr. 2020, doi: 10.1080/17517575.2018.1536929.

[14] S. Singaravel, J. Suykens, and P. Geyer, "Deep-learning neural-network architectures and methods: Using component-based models in building-design energy prediction," *Adv. Eng. Inform.*, vol. 38, pp. 81–90, Oct. 2018, doi: 10.1016/j.aei.2018.06.004.

[15] A. Safiullin, L. Krasnyuk, and Z. Kapelyuk, "Integration of industry 4.0 technologies for 'smart cities' development," *IOP Conf. Ser., Mater. Sci. Eng.*, vol. 497, no. 1, 2019, Art. no. 012089.

[16] A. Chauhan, S. K. Jakhar, and C. Chauhan, "The interplay of circular economy with industry 4.0 enabled smart city drivers of healthcare waste disposal," *J. Cleaner Prod.*, vol. 279, Jan. 2021, Art. no. 123854, doi: 10.1016/j.jclepro.2020.123854.

[17] M. Postranecky and M. Svitek, "Smart city near to 4.0—An adoption of industry 4.0 conceptual model," in *Proc. Smart City Symp. Prague (SCSP)*, May 2017, pp. 1–5, doi: 10.1109/SCSP.2017.7973870.

[18] H. Mohelska and M. Sokolova, "Management approaches for industry 4.0—The organizational culture perspective," *Technol. Econ. Develop. Economy*, vol. 24, no. 6, pp. 2225–2240, Nov. 2018.

[19] K. Fettig, T. Gacic, A. Koskal, A. Kuhn, and F. Stuber, "Impact of industry 4.0 on organizational structures," in *Proc. IEEE Int. Conf. Eng., Technol. Innov. (ICE/ITMC)*, Jun. 2018, pp. 1–8, doi: 10.1109/ICE.2018.8436284.

[20] M. Sony and S. Naik, "Industry 4.0 integration with socio-technical systems theory: A systematic review and proposed theoretical model," *Technol. Soc.*, vol. 61, May 2020, Art. no. 101248, doi: 10.1016/j.techsoc.2020.101248.

[21] J. Avis, "Socio-technical imaginary of the fourth industrial revolution and its implications for vocational education and training: A literature review," *J. Vocational Educ. Training*, vol. 70, no. 3, pp. 337–363, 2018.

[22] D. Bandyopadhyay and J. Sen, "Internet of Things: Applications and challenges in technology and standardization," *Wireless Pers. Commun.*, vol. 58, no. 1, pp. 49–69, 2011, doi: 10.1007/s11277-011-0288-5.

[23] L. M. Fonseca, "Industry 4.0 and the digital society: Concepts, dimensions and envisioned benefit," in *Proc. Int. Conf. Bus. Excellence*, 2018, vol. 12, no. 1, pp. 386–397, doi: 10.2478/picbe-2018-0034.

[24] A. Ghadge, M. E. Kara, H. Moradlou, and M. Goswami, "The impact of industry 4.0 implementation on supply chains," *J. Manuf. Technol. Manage.*, vol. 31, pp. 1–26, Mar. 2020, doi: 10.1016/j.protcy.2013.12.242.

[25] G. L. Tortorella, A. M. C. Vergara, J. A. Garza-Reyes, and R. Sawhney, "Organizational learning paths based upon industry 4.0 adoption: An empirical study with Brazilian manufacturers," *Int. J. Prod. Econ.*, vol. 219, pp. 284–294, Jan. 2020, doi: 10.1016/j.ijpe.2019.06.023.

[26] A. Telukdarie, E. Buhulaiga, S. Bag, S. Gupta, and Z. Luo, "Industry 4.0 implementation for multinationals," *Process Saf. Environ. Protection*, vol. 118, pp. 316–329, Aug. 2018, doi: 10.1016/j.psep.2018.06.030.

[27] *World Development Indicators 2015*, WorldBank, Washington, DC, USA, 2015.

[28] J. Posada, I. Toro, D. Barandiaran, and D. Oyarzun, "Visual computing as a key enabling technology for industrie 4.0 and industrial internet," *Comput. Graph. Appl.*, vol. 35, no. 2, pp. 26–40, 2015.

[29] I. Arbulu, V. Lath, M. Mancini, A. Patel, and O. Tonby, *Industry 4.0: Reinvigorating ASEAN Manufacturing for the Future*. Singapore: McKinsey, 2018.

[30] D. Li, Å. Fast-Berglund, and D. Paulin, "Current and future industry 4.0 capabilities for information and knowledge sharing," *Int. J. Adv. Manuf. Technol.*, vol. 105, no. 9, pp. 3951–3963, Dec. 2019, doi: 10.1007/s00170-019-03942-5.

[31] J. E. S. Castro, P. N. P. Pérez, and G. Sánchez Pérez, "Concentración de la industria manufacturera en Colombia, 2001–2010: Una aproximación a partir del índice de Herfindahl–Hirschman," *Diálogos de saberes*, no. 40, pp. 115–138, Jun. 2014.

[32] S. Bag, S. Gupta, and S. Kumar, "Industry 4.0 adoption and 10R advance manufacturing capabilities for sustainable development," *Int. J. Prod. Econ.*, vol. 231, Jan. 2021, Art. no. 107844, doi: 10.1016/j.ijpe.2020.107844.

[33] *Crafting the Future: A Roadmap for Industry 4.0 in Mexico*, Ministry of Economy, Colonia Condesa, Mexico, 2016.

[34] *Industry 4.0: A New Challenge for Brazilian Industry*, National Confederation of Industry of Brazil, Asa Norte, Brazil, 2016.

[35] G. Crespi and F. Peirano, "Measuring innovation in Latin America: What we did, where we are and what we want to do," in *Proc. Conf. Micro Evidence Innov. Developing Countries*, 2007, pp. 1–10.

[36] C. Guillard and M. Salazar, "The experience in innovation surveys of selected Latin American countries," American Development Bank, Washington, DC, USA, Tech. Rep., IDB-DP-530, 2017.

[37] A. A. Hernandez, "Understanding motivation factors in green IT adoption: An empirical evidence from philippine SMEs," *Int. J. Asian Bus. Inf. Manage.*, vol. 9, no. 4, pp. 21–35, Oct. 2018, doi: 10.4018/IJABIM.2018100102.

[38] S. S. Kamble, A. Gunasekaran, and R. Sharma, "Analysis of the driving and dependence power of barriers to adopt industry 4.0 in Indian manufacturing industry," *Comput. Ind.*, vol. 101, pp. 107–119, Oct. 2018, doi: 10.1016/j.compind.2018.06.004.

[39] V. L. da Silva, J. L. Kovaleski, and R. N. Pagani, "Technology transfer in the supply chain oriented to industry 4.0: A literature review," *Technol. Anal. Strategic Manage.*, vol. 31, no. 5, pp. 546–562, May 2019, doi: 10.1080/09537325.2018.1524135.

[40] T. Masood and P. Sonntag, "Industry 4.0: Adoption challenges and benefits for SMEs," *Comput. Ind.*, vol. 121, Oct. 2020, Art. no. 103261, doi: 10.1016/j.compind.2020.103261.

[41] W. Money and A. Turner, "Application of the technology acceptance model to a knowledge management system," in *Proc. 37th Annu. Hawaii Int. Conf. Syst. Sci.*, 2004, pp. 1–9, doi: 10.1109/HICSS.2004.1265573.

[42] Y. Li, J. Qi, and H. Shu, "Review of relationships among variables in TAM," *Tsinghua Sci. Technol.*, vol. 13, no. 3, pp. 273–278, Jun. 2008.

[43] E. G. Olson, "Creating an enterprise-level 'green' strategy," *J. Bus. Strategy*, vol. 29, no. 2, pp. 22–30, Feb. 2008.

[44] P. del Río González, "Analysing the factors influencing clean technology adoption: A study of the Spanish pulp and paper industry," *Bus. Strategy Environ.*, vol. 14, no. 1, pp. 20–37, Jan. 2005.

[45] R. Bagozzi, "The legacy of the technology acceptance model and a proposal for a paradigm shift," *J. Assoc. Inf. Syst.*, vol. 8, no. 4, pp. 244–254, Apr. 2007.

[46] F. D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology," *MIS Quart.*, vol. 13, no. 3, pp. 319–340, 1989, doi: 10.2307/249008.

[47] F. D. Davis, "User acceptance of information technology: System characteristics, user perceptions and behavioral impacts," *Int. J. ManMach. Stud.*, vol. 38, no. 3, pp. 475–487, 1993, doi: 10.1006/imms.1993.1022.

[48] M. G. Morris and A. Dillon, "How user perceptions influence software use," *IEEE Softw.*, vol. 14, no. 4, pp. 58–65, Jul. 1997, doi: 10.1109/52.595956.

[49] P. Roberts and R. Henderson, "Information technology acceptance in a sample of government employees: A test of the technology acceptance model," *Interacting Comput.*, vol. 12, no. 5, pp. 427–443, 2000, doi: 10.1016/S0953-5438(98)00068-X.

[50] A. Molla, "GITAM: A model for the adoption of green IT," in *Proc. 19th Australas. Conf. Inf. Syst. Christchurch*, vol. 64, no. 64, pp. 658–668, 2008.

[51] S. K. Srivastava, "Green supply-chain management: A state-of-the-art literature review," *Int. J. Manage. Rev.*, vol. 9, no. 1, pp. 53–80, Mar. 2007, doi: 10.1111/j.1468-2370.2007.00202.x.

[52] S. Asadi, A. Hussin, and H. Dahlan, "Theoretical model for green information technology adoption," *ARPN J. Eng. Appl. Sci.*, vol. 10, no. 23, pp. 17720–17729, 2015.

[53] M. C. Onwezen, G. Antonides, and J. Bartels, "The norm activation model: An exploration of the functions of anticipated pride and guilt in pro-environmental behaviour," *J. Econ. Psychol.*, vol. 39, pp. 141–153, Dec. 2013.

[54] J. Park and S. Ha, "Understanding consumer recycling behavior: Combining the theory of planned behavior and the norm activation model," *Family Consum. Sci. Res. J.*, vol. 42, no. 3, pp. 278–291, Mar. 2014.

[55] I. Klopping and E. McKinney, "Extending the technology acceptance model and the task-technology fit model to consumer e-commerce," *Inf. Technol. Learn. Perform. J.*, vol. 22, no. 1, pp. 1–10, 2004.

[56] V. Venkatesh, J. Thong, and X. Xu, "Unified theory of acceptance and use of technology: A synthesis and the road ahead," *J. Assoc. Inf. Syst.*, vol. 17, no. 5, pp. 328–376, May 2016.

[57] J. Xu and W. Lu, "Developing a human-organization-technology fit model for information technology adoption in organizations," *Technol. Soc.*, vol. 70, Aug. 2022, Art. no. 102010, doi: 10.1016/j.techsoc.2022.102010.

[58] F. Yuliaty, "Employee empowering through information technology and creativity in organizations," *Int. J. Econ. Perspect.*, vol. 11, no. 3, pp. 54–59, 2017.

[59] R. Glass and S. Li, "Social influence and instant messaging adoption," *J. Comput. Inf. Syst.*, vol. 51, no. 2, pp. 24–30, 2010.

[60] C. Yoon, "Extending the TAM for green IT: A normative perspective," *Comput. Hum. Behav.*, vol. 83, pp. 129–139, Jun. 2018.

[61] F. Bano, "Quality of ERP implementation: Case study of select Indian organizations," *Int. Proc. Econ. Develop. Res.*, vol. 75, no. 9, pp. 36–39, 2014.

[62] I. Sila, "Factors affecting the adoption of B2B e-commerce technologies," *Electron. Commerce Res.*, vol. 13, no. 2, pp. 199–236, May 2013.

[63] U. Hillmer, "Existing theories considering technology adoption," in *Technology Acceptance in Mechatronics*, 2009, pp. 9–28.

[64] A. B. L. de Sousa Jabbour, C. J. C. Jabbour, M. G. Filho, and D. Roubaud, "Industry 4.0 and the circular economy: A proposed research agenda and original roadmap for sustainable operations," *Ann. Oper. Res.*, vol. 270, nos. 1–2, pp. 273–286, Nov. 2018, doi: 10.1007/s10479-018-2772-8.

[65] M. Hermann, T. Pentek, and B. Otto, "Design principles for industrie 4.0 scenarios," in *Proc. 49th Hawaii Int. Conf. Syst. Sci. (HICSS)*, Jan. 2016, pp. 3928–3937, doi: 10.1109/HICSS.2016.488.

[66] T. Zheng, M. Ardolino, A. Bacchetti, and M. Perona, "The applications of industry 4.0 technologies in manufacturing context: A systematic literature review," *Int. J. Prod. Res.*, vol. 59, no. 6, pp. 1922–1954, Mar. 2021, doi: 10.1080/00207543.2020.1824085.

[67] M. Medojevic, P. D. Villar, I. Cosic, A. Rikalovic, and N. Sremcev, "Energy management in industry 4.0 ecosystem: A review on possibilities and concerns," *Ann. DAAAM Proc.*, vol. 29, pp. 1–14, Jan. 2018, doi: 10.2507/29th.daaam.proceedings.097.

[68] T. L. Olsen and B. Tomlin, "Industry 4.0: Opportunities and challenges for operations management," *Manuf. Service Oper. Manage.*, vol. 22, no. 1, pp. 113–122, Jan. 2020, doi: 10.1287/msom.2019.0796.

[69] W. de Paula Ferreira, F. Armellini, and L. A. De Santa-Eulalia, "Simulation in industry 4.0: A state-of-the-art review," *Comput. Ind. Eng.*, vol. 149, Nov. 2020, Art. no. 106868, doi: 10.1016/j.cie.2020.106868.

[70] A. Corallo, M. Lazoi, and M. Lezzi, "Cybersecurity in the context of industry 4.0: A structured classification of critical assets and business impacts," *Comput. Ind.*, vol. 114, Jan. 2020, Art. no. 103165, doi: 10.1016/j.compind.2019.103165.

[71] P. Srivastava and R. Khan, "A review paper on cloud computing," *Int. J. Adv. Res. Comput. Sci. Softw. Eng.*, vol. 8, no. 6, pp. 17–20, 2018.

[72] E. Oztemel and S. Gursev, "Literature review of industry 4.0 and related technologies," *J. Intell. Manuf.*, vol. 31, no. 1, pp. 127–182, Jan. 2020, doi: 10.1007/s10845-018-1433-8.

[73] J. Hou and B. Li, "The evolutionary game for collaborative innovation of the IoT industry under government leadership in China: An IoT infrastructure perspective," *Sustainability*, vol. 12, no. 9, p. 3648, May 2020, doi: 10.3390/su12093648.

[74] S. Aheleroff, X. Xu, Y. Lu, M. Aristizabal, J. P. Velásquez, B. Joa, and Y. Valencia, "IoT-enabled smart appliances under industry 4.0: A case study," *Adv. Eng. Informat.*, vol. 43, Jan. 2020, Art. no. 101043, doi: 10.1016/j.aei.2020.101043.

[75] A. Khanna and S. Kaur, "Internet of Things (IoT), applications and challenges: A comprehensive review," *Wireless Pers. Commun.*, vol. 114, no. 2, pp. 1687–1762, Sep. 2020, doi: 10.1007/s11277-020-07446-4.

[76] T. Nguyen, R. G. Gosine, and P. Warrian, "A systematic review of big data analytics for oil and gas industry 4.0," *IEEE Access*, vol. 8, pp. 61183–61201, 2020, doi: 10.1109/ACCESS.2020.2979678.

[77] C. Li, Y. Chen, and Y. Shang, "A review of industrial big data for decision making in intelligent manufacturing," *Eng. Sci. Technol., Int. J.*, vol. 29, May 2022, Art. no. 101021, doi: 10.1016/j.jestch.2021.06.001.

[78] R. Y. Zhong, X. Xu, E. Klotz, and S. T. Newman, "Intelligent manufacturing in the context of industry 4.0: A review," *Engineering*, vol. 3, no. 5, pp. 616–630, 2017, doi: 10.1016/J.ENG.2017.05.015.

[79] S. Gorecki, J. Possik, G. Zacharewicz, Y. Ducq, and N. Perry, "Business models for distributed-simulation orchestration and risk management," *Information*, vol. 12, no. 2, p. 71, Feb. 2021, doi: 10.3390/info12020071.

[80] G. Fragapane, D. Ivanov, M. Peron, F. Sgarbossa, and J. O. Strandhage, "Increasing flexibility and productivity in industry 4.0 production networks with autonomous mobile robots and smart intralogistics," *Ann. Oper. Res.*, vol. 2020, pp. 1–19, Feb. 2020, doi: 10.1007/s10479-020-03526-7.

[81] R. Goel and P. Gupta, "Robotics and industry 4.0," in *A Roadmap to Industry 4.0: Smart Production, Sharp Business and Sustainable Development*. Cham, Switzerland: Springer, 2020, pp. 157–169, doi: 10.1007/978-3-030-14544-6_9.

[82] H. L. Wei, T. Mukherjee, W. Zhang, J. S. Zuback, G. L. Knapp, A. De, and T. DebRoy, "Mechanistic models for additive manufacturing of metallic components," *Prog. Mater. Sci.*, vol. 116, Feb. 2021, Art. no. 100703, doi: 10.1016/j.pmatsci.2020.100703.

[83] I. Gibson, D. Rosen, B. Stucker, and M. Khorasani, "Materials for additive manufacturing," in *Additive Manufacturing Technologies*. Cham, Switzerland: Springer, 2021, pp. 379–428, doi: 10.1007/978-3-030-56127-7_14.

[84] K. Lavingia and S. Tanwar, "Augmented reality and industry 4.0," in *A Roadmap to Industry 4.0: Smart Production, Sharp Business and Sustainable Development*, 2020, pp. 143–155, doi: 10.1007/978-3-030-14544-6_8.

[85] A. Elshafey, C. C. Saar, E. B. Aminudin, M. Gheisari, and A. Usmani, "Technology acceptance model for augmented reality and building information modeling integration in the construction industry," *J. Inf. Technol. Construct.*, vol. 25, pp. 161–172, Mar. 2020, doi: 10.36680/j.itcon.2020.010.

[86] Y. Chen, Q. Wang, H. Chen, X. Song, H. Tang, and M. Tian, "An overview of augmented reality technology," *J. Phys., Conf. Ser.*, vol. 1237, no. 2, 2019, Art. no. 022082.

[87] M. Mekni and A. Lemieux, "Augmented reality: Applications, challenges and future trends," *Appl. Comput. Appl. Comput. Sci.*, vol. 20, pp. 205–214, Apr. 2014.

[88] D. Arnott, F. Lizama, and Y. Song, "Patterns of business intelligence systems use in organizations," *Decis. Support Syst.*, vol. 97, pp. 58–68, May 2017, doi: 10.1016/j.dss.2017.03.005.

[89] M. I. Nofal and Z. M. Yusof, "Integration of business intelligence and enterprise resource planning within organizations," *Proc. Technol.*, vol. 11, pp. 658–665, Jan. 2013, doi: 10.1016/j.protcy.2013.12.242.

[90] A. Ghadge, N. Caldwell, and R. Wilding, "Managing cyber risk in supply chains: A review and research agenda," *Supply Chain Manage.*, vol. 25, no. 2, pp. 223–240, 2019, doi: 10.1016/j.protcy.2013.12.242.

[91] M. Lezzi, M. Lazoi, and A. Corallo, "Cybersecurity for industry 4.0 in the current literature: A reference framework," *Comput. Ind.*, vol. 103, pp. 97–110, Dec. 2018, doi: 10.1016/j.compind.2018.09.004.

[92] M. Pérez-Lara, J. A. Saucedo-Martínez, J. A. Marmolejo-Saucedo, T. E. Salais-Fierro, and P. Vasant, "Vertical and horizontal integration systems in industry 4.0," *Wireless Netw.*, vol. 26, no. 7, pp. 4767–4775, Oct. 2020, doi: 10.1007/s11276-018-1873-2.

[93] K. Chukalov, "Horizontal and vertical integration, as a requirement for cyber-physical systems in the context of industry 4.0," *Industry*, vol. 2, no. 4, pp. 155–157, 2017.

[94] C. T. B. Garrocho, M. C. Silva, C. M. S. Ferreira, C. F. M. D. C. Cavalcanti, and R. A. R. Oliveira, "Real-time systems implications in the blockchain-based vertical integration of industry 4.0," *Computer*, vol. 53, no. 9, pp. 46–55, Sep. 2020, doi: 10.1109/MC.2020.3002686.

[95] S. Luthra and S. K. Mangla, "Evaluating challenges to industry 4.0 initiatives for supply chain sustainability in emerging economies," *Process Saf. Environ. Protection*, vol. 117, pp. 168–179, Jul. 2018, doi: 10.1016/j.psep.2018.04.018.

[96] S. Koul and A. Eydgahi, "A systematic review of technology adoption frameworks and their applications," *J. Technol. Manage. Innov.*, vol. 12, no. 4, pp. 106–113, 2017.

[97] S.-W. Chuang, T. Luor, and H.-P. Lu, "Assessment of institutions, scholars, and contributions on agile software development (2001–2012)," *J. Syst. Softw.*, vol. 93, pp. 84–101, Jul. 2014, doi: 10.1016/j.jss.2014.03.006.

[98] S. Sperber, "The top managerial influence on innovation: Development of a comprehensive framework," in *Digitalization, Digital Transformation and Sustainability in the Global Economy*. Cham, Switzerland: Springer, 2021, pp. 93–113.

[99] W. Orlikowski, "CASE as organizational change," *Manage. Inf. Syst. Quart.*, vol. 17, no. 3, pp. 309–340, 1993.

[100] P. C. Lai, "The literature review of technology adoption models and theories for the novelty technology," *J. Inf. Syst. Technol. Manage.*, vol. 14, no. 1, pp. 21–38, 2017, doi: 10.4301/s1807-17752017000100002.

[101] A. Umar, "Extending the technology acceptance model to account for social influence, trust and integration for pervasive computing environment: A case study in university industry," *Amer. J. Econ. Bus. Admin.*, vol. 3, no. 3, pp. 552–559, Dec. 2011.

[102] A. Dillon and M. G. Morris, "User acceptance of new information technology: Theories and models," *Annu. Rev. Inf. Sci. Technol.*, vol. 14, no. 4, pp. 3–32, 1996.

[103] S. Koul and A. Eydgahi, "Utilizing technology acceptance model (TAM) for driverless car technology adoption," *J. Technol. Manage. Innov.*, vol. 13, no. 4, pp. 37–46, Dec. 2018, doi: 10.4067/S0718-27242018000400037.

[104] P. J. DiMaggio and W. Powell, "The iron cage revisited: Institutional isomorphism and collective rationality in organizational behaviour," *Amer. Sociol. Rev.*, vol. 48, pp. 147–160, Apr. 1983.

[105] I. Ajzen, "The theory of planned behavior," *Org. Behav. Hum. Decis. Process.*, vol. 50, no. 2, pp. 179–211, 1991, doi: 10.1016/0749-5978(91)90020-T.

[106] S. Bamberg and P. Schmidt, "Incentives, morality, or habit? Predicting students' car use for university routes with the models of Ajzen, Schwartz, and Triandis," *Environ. Behav.*, vol. 35, no. 2, pp. 264–285, Mar. 2003, doi: 10.1177/0013916502250134.

[107] A. Yuriev, M. Dahmen, P. Paillé, O. Boiral, and L. Guillaumie, "Pro-environmental behaviors through the lens of the theory of planned behavior: A scoping review," *Resour., Conservation Recycling*, vol. 155, Apr. 2020, Art. no. 104660, doi: 10.1016/j.resconrec.2019.104660.

[108] W. H. Loo, P. H. Yeow, and U. C. Eze, "Responsible consumption behaviour: A framework for acquisition, use and disposal of computers," in *Proc. PACIS*, 2013, p. 278.

[109] S. Chandra and K. Karippur, "Exploring factors influencing organizational adoption of augmented reality in e-commerce: Empirical analysis using technology-organization-environment model," *J. Electron. Commerce Res.*, vol. 19, no. 3, pp. 237–265, 2018.

[110] B. Ramdani, P. Kawalek, and O. Lorenzo, "Predicting SMEs' adoption of enterprise systems," *J. Enterprise Inf. Manage.*, vol. 22, no. 1/2, pp. 10–24, Feb. 2009, doi: 10.1108/17410390910922796.

[111] K. Kallweit, P. Spreer, and W. Toporowski, "Why do customers use self-service information technologies in retail? The mediating effect of perceived service quality," *J. Retailing Consum. Services*, vol. 21, no. 3, pp. 268–276, May 2014.

[112] K. Dery, I. M. Sebastian, and N. van der Meulen, "The digital workplace is key to digital innovation," *MIS Quart. Executive*, vol. 16, no. 2, pp. 1–10, 2017.

[113] M. Ghobakhloo, M. Sabouri, T. Hong, and N. Zulkifli, "Information technology adoption in small and medium-sized enterprises; an appraisal of two decades literature," *Interdiscipl. J. Res. Bus.*, vol. 1, no. 7, pp. 53–80, 2011.

[114] D. Guster, C. Hemminger, and S. Krzenski, "Using virtualization to reduce data center infrastructure and promote green computing," *Int. J. Bus. Res.*, vol. 9, no. 6, pp. 33–139, 2009.

[115] D. Niyato, S. Chaisiri, and L. B. Sung, "Optimal power management for server farm to support green computing," in *Proc. 9th IEEE/ACM Int. Symp. Cluster Comput. Grid*, Mar. 2009, pp. 84–91, doi: 10.1109/CCGRID.2009.89.

[116] J. Smit, S. Kreutzer, C. Moeller, and M. Carlberg, "Industry 4.0 a study for the European parliament," *Eur. Parliament*, vol. 15, pp. 189–202, Jan. 2016.

[117] E. Hofmann and M. Rüsch, "Industry 4.0 and the current status as well as future prospects on logistics," *Comput. Ind.*, vol. 89, pp. 23–34, Aug. 2017, doi: 10.1109/CCGRID.2009.89.

[118] A. Abroud, Y. Choong, and S. Muthaiyah, "Preparation of measurement tools of the effective factors for the acceptance of online stock trading," *Eur. J. Econ., Finance Administ. Sci.*, vol. 4, no. 19, pp. 34–51, 2010.

[119] S. A. Westjohn, M. J. Arnold, P. Magnusson, S. Zdravkovic, and J. X. Zhou, "Technology readiness and usage: A global-identity perspective," *J. Acad. Marketing Sci.*, vol. 37, no. 3, pp. 250–265, Sep. 2009, doi: 10.1007/s11747-008-0130-0.

[120] A. Abroud, Y. V. Choong, S. Muthaiyah, and D. Y. G. Fie, "Adopting e-finance: Decomposing the technology acceptance model for investors," *Service Bus.*, vol. 9, no. 1, pp. 161–182, Mar. 2015, doi: 10.1007/s11628-013-0214-x.

[121] S. Liao, Y. P. Shao, H. Wang, and A. Chen, "The adoption of virtual banking: An empirical study," *Int. J. Inf. Manage.*, vol. 19, no. 1, pp. 63–74, 1999, doi: 10.1016/S0268-4012(98)00047-4.

[122] P. Y. K. Chau and V. S. K. Lai, "An empirical investigation of the determinants of user acceptance of internet banking," *J. Organizational Comput. Electron. Commerce*, vol. 13, no. 2, pp. 123–145, Jun. 2003, doi: 10.1207/S15327744JOCE1302_3.

[123] R. G. Fichman, "Going beyond the dominant paradigm for information technology innovation research: Emerging concepts and methods," *J. Assoc. Inf. Syst.*, vol. 5, no. 8, p. 11, 2004, doi: 10.17705/1jais.00054.

[124] T. A. Jenkin, J. Webster, and L. McShane, "An agenda for 'green' information technology and systems research," *Inf. Org.*, vol. 21, no. 1, pp. 17–40, Jan. 2011, doi: 10.1016/j.infoandorg.2010.09.003.

[125] I. H. Doh, Y. J. Kim, J. S. Park, E. Kim, J. Choi, D. Lee, and S. H. Noh, "Towards greener data centers with storage class memory: Minimizing idle power waste through coarse-grain management in fine-grain scale," in *Proc. 7th ACM Int. Conf. Comput. Frontiers*, May 2010, pp. 309–318, doi: 10.1145/1787275.1787340.

[126] S. K. S. Gupta, R. R. Gilbert, A. Banerjee, Z. Abbasi, T. Mukherjee, and G. Varsamopoulos, "GDCSim: A tool for analyzing green data center design and resource management techniques," in *Proc. Int. Green Comput. Conf. Workshops*, Jul. 2011, pp. 1–8, doi: 10.1109/IGCC.2011.6008612.

[127] B. Pernici, M. Aiello, J. V. Brocke, B. Donnellan, E. Gelenbe, and M. Kretsis, "What IS can do for environmental sustainability: A report from CAiSE'11 panel on green and sustainable IS," *Commun. Assoc. Inf. Syst.*, vol. 30, no. 1, pp. 275–292, 2012, doi: 10.17705/1CAIS.03018.

[128] D. Sedera, S. Lokuge, and B. Tushi, "Multi-disciplinary green IT archival analysis: A pathway for future studies," *Commun. Assoc. Inf. Syst.*, vol. 41, no. 1, pp. 674–733, 2017, doi: 10.17705/1CAIS.04128.

[129] D.-Y. Kim, S. Jang, and A. M. Morrison, "Factors affecting organizational information technology acceptance: A comparison of convention and visitor bureaus and meeting planners in the United States," *J. Conv. Event Tourism*, vol. 12, no. 1, pp. 1–24, Feb. 2011.

[130] S.-C. Chan and M.-T. Lu, "Understanding internet banking adoption and use behavior: A Hong Kong perspective," *J. Global Inf. Manage.*, vol. 12, no. 3, pp. 21–43, Jul. 2004, doi: 10.4018/jgim.2004070102.

[131] M. Gopi and T. Ramayah, "Applicability of theory of planned behavior in predicting intention to trade online: Some evidence from a developing country," *Int. J. Emerg. Markets*, vol. 2, no. 4, pp. 348–360, Oct. 2007, doi: 10.1108/17468800710824509.

[132] T. Ramayah, K. Rouibah, M. Gopi, and G. J. Rangel, "A decomposed theory of reasoned action to explain intention to use internet stock trading among Malaysian investors," *Comput. Hum. Behav.*, vol. 25, no. 6, pp. 1222–1230, 2009, doi: 10.1016/j.chb.2009.06.007.

[133] E. L. Deci and R. M. Ryan, "The 'what' and 'why' of goal pursuits: Human needs and the self-determination of behavior," *Psychol. Inquiry*, vol. 11, no. 4, pp. 227–268, Oct. 2000, doi: 10.1207/S15327965PLI1104_01.

[134] L. G. Wallace and S. D. Sheetz, "The adoption of software measures: A technology acceptance model (TAM) perspective," *Inf. Manag.*, vol. 51, no. 2, pp. 249–259, 2014, doi: 10.1016/j.im.2013.12.003.

[135] D. A. Adams, R. R. Nelson, and P. A. Todd, "Perceived usefulness, ease of use, and usage of information technology: A replication," *MIS Quart.*, vol. 16, no. 2, pp. 227–247, Jun. 1992, doi: 10.2307/249577.

[136] A. R. Hendrickson, P. D. Massey, and T. P. Cronan, "On the test-retest reliability of perceived usefulness and perceived ease of use scales," *MIS Quart.*, vol. 17, no. 2, pp. 227–230, 1993, doi: 10.2307/249803.

[137] T. Olsson, E. Lagerstam, T. Kärkkäinen, and K. Väänänen-Vainio-Mattila, "Expected user experience of mobile augmented reality services: A user study in the context of shopping centres," *Pers. Ubiquitous Comput.*, vol. 17, no. 2, pp. 287–304, Feb. 2013, doi: 10.1007/s00779-011-0494-x.

[138] D. Gefen, D. University, D. Straub, and G. State University, "The relative importance of perceived ease of use in IS adoption: A study of e-commerce adoption," *J. Assoc. Inf. Syst.*, vol. 1, no. 1, pp. 1–30, Oct. 2000.

[139] G. C. Moore and I. Benbasat, "Development of an instrument to measure the perceptions of adopting an information technology innovation," *Inf. Syst. Res.*, vol. 2, no. 3, pp. 192–222, 1991, doi: 10.1287/isre.2.3.192.

[140] T. Hall and N. Fenton, "Implementing effective software metrics programs," *IEEE Softw.*, vol. 14, no. 2, pp. 55–65, Mar. 1997, doi: 10.1109/52.582975.

[141] I. Ajzen, "Nature and operation of attitudes," *Annu. Rev. Psychol.*, vol. 52, no. 2, pp. 27–58, 2001, doi: 10.1016/0749-5978(91)90020-T.

[142] M. Fan, A. Whinston, S. Srinivasan, and J. Stallaert, "Electronic commerce and the revolution in financial markets," Thomson Learning, Boston, MA, USA, Tech. Rep., 2002.

[143] J. Park, "Understanding consumer intention to shop online dissertation," Univ. Missouri, Columbia, MO, USA, Tech. Rep., 2003.

[144] S. Kim, "Factors influencing customers' use of electronic commerce in stock trading: An empirical study in Korea," in *Proc. Pacific Asia Conf. Inf. Syst.*, no. 3, 2001, pp. 30–44.

[145] M.-C. Lee, "Predicting and explaining the adoption of online trading: An empirical study in Taiwan," *Decis. Support Syst.*, vol. 47, no. 2, pp. 133–142, May 2009, doi: 10.1016/j.dss.2009.02.003.

[146] S. Taylor and P. A. Todd, "Understanding information technology usage: A test of competing models," *Inf. Syst. Res.*, vol. 6, no. 2, pp. 144–176, Jun. 1995, doi: 10.1287/isre.6.2.144.

[147] D. L. Alden, J.-B.-E. M. Steenkamp, and R. Batra, "Consumer attitudes toward marketplace globalization: Structure, antecedents and consequences," *Int. J. Res. Marketing*, vol. 23, no. 3, pp. 227–239, Sep. 2006, doi: 10.1016/j.ijresmar.2006.01.010.

[148] N.-H. Chen and S. C.-T. Huang, "Domestic technology adoption: Comparison of innovation adoption models and moderators: Domestic technology adoption," *Hum. Factors Ergonom. Manuf. Service Industries*, vol. 26, no. 2, pp. 177–190, Mar. 2016, doi: 10.1002/hfm.20621.

[149] M. Ozer, "The roles of product lead-users and product experts in new product evaluation," *Res. Policy*, vol. 38, no. 8, pp. 1340–1349, Oct. 2009, doi: 10.1016/j.respol.2009.07.001.

[150] M. F. S. Tutunea, "Augmented reality-state of knowledge, use and experimentation," *USV Ann. Econ. Public Admin.*, vol. 13, no. 2, pp. 215–227, 2013.

[151] K. N. Kumar, S. Chandra, S. Bharati, and S. Manava, "Factors influencing adoption of augmented reality technology for e-commerce," in *Proc. Pacific Asia Conf. Inf. Syst., Assoc. Inf. Syst.*, 2016, pp. 1–9.

[152] T. C. E. Cheng, D. Y. C. Lam, and A. C. L. Yeung, "Adoption of internet banking: An empirical study in Hong Kong," *Decision Support Syst.*, vol. 42, no. 3, pp. 1558–1572, 2006, doi: doi:10.1016/j.dss.2006.01.002.

[153] Z. Liao and M. T. Cheung, "Internet-based e-banking and consumer attitudes: An empirical study," *Inf. Manage.*, vol. 39, no. 4, pp. 63–74, 2002, doi: 10.1016/S0378-7206(01)00097-0.

[154] N. Fenton and M. Neil, "Software metrics: Successes, failures and new directions," *J. Syst. Softw.*, vol. 47, nos. 2–3, pp. 149–157, 1999, doi: 10.1016/S0164-1212(99)00035-7.

[155] I. Lee and K. Lee, "The Internet of Things (IoT): Applications, investments, and challenges for enterprises," *Bus. Horizons*, vol. 58, no. 4, pp. 431–440, 2015, doi: 10.1016/j.bushor.2015.03.008.

[156] R. Schmidt, M. Möhring, R. Härting, and C. Reichste, "Industry 4.0—Potentials for creating smart products: Empirical research results," *Bus. Inf. Syst.*, vol. 208, pp. 16–27, Jan. 2015, doi: 10.1007/978-3-319-19027-3_2.

[157] K. Atashgar and O. A. Zargarabadi, "Monitoring multivariate profile data in plastic parts manufacturing industries: An intelligently data processing," *J. Ind. Inf. Integr.*, vol. 8, pp. 38–48, Dec. 2017, doi: 10.1016/j.jii.2017.06.003.

[158] A. C. Pereira and F. Romero, "A review of the meanings and the implications of the industry 4.0 concept," *Proc. Manuf.*, vol. 13, pp. 1206–1214, Jan. 2017, doi: 10.1016/j.promfg.2017.09.032.

[159] S. Onar, A. Ustundag, and C. Kadaifci, "The changing role of engineering education in industry 4.0 era," in *Industry 4.0: Managing The Digital Transformation*, 2018, vol. 8, no. 1, pp. 151–157, doi: 10.1007/978-3-319-57870-5_8.

[160] B. Tjahjono, C. Esplugues, E. Ares, and G. Pelaez, "What does industry 4.0 mean to supply chain?" *Proc. Manuf.*, vol. 13, pp. 1175–1182, Jan. 2017, doi: 10.1016/j.promfg.2017.09.191.

[161] G. Cruzara, A. Takahashi, E. Sandri, and A. Cherobim, "The impact of digital transformation and industry 4.0 on the aspects of value: Evidence from a meta-synthesis," *Contextus, Revista Contemporânea Economia Gestão*, vol. 18, pp. 10–92, Jan. 2020, doi: 10.19094/contextus.2020.43717.

[162] C. Arnold, D. Kiel, and K.-I. Voigt, "Innovative business models for the industrial Internet of Things," *BHM Berg Hüttenmännische Monatshefte*, vol. 162, no. 9, pp. 371–381, Sep. 2017, doi: 10.1007/s00501-017-0667-7.

[163] H. Fatorachian and H. Kazemi, "A critical investigation of industry 4.0 in manufacturing: Theoretical operationalisation framework," *Prod. Planning Control*, vol. 29, no. 8, pp. 633–644, Jun. 2018, doi: 10.1080/09537287.2018.1424960.

[164] A. Jerman, I. Erenda, and A. Bertoncelj, "The influence of critical factors on business model at a smart factory: A case study," *Bus. Syst. Res. J.*, vol. 10, no. 1, pp. 42–52, Apr. 2019, doi: 10.2478/bsrj-2019-0004.

[165] C. Bischof-dos-Santos and E. Oliveira, "Production engineering competencies in the industry 4.0 context: Perspectives on the Brazilian labor market," *Production*, vol. 30, pp. 1–10, Nov. 2020, doi: 10.1590/0103-6513.20190145.

[166] R. Ricci, D. Battaglia, and P. Neirotti, "External knowledge search, opportunity recognition and industry 4.0 adoption in SMEs," *Int. J. Prod. Econ.*, vol. 240, pp. 1–18, Jan. 2021, doi: 10.1016/j.ijpe.2021.108234.

[167] C. Cortés, J. Landeta, and J. Chacón, "El entorno de la industria 4.0: Implicaciones y perspectivas futuras," *Conciencia Tecnológica*, vol. 54, pp. 33–45, Jan. 2017.

[168] A. Ibrahim, "Understanding the factors affecting the adoption of green computing in the Gulf universities," *Int. J. Adv. Comput. Sci. Appl.*, vol. 9, no. 3, pp. 1–8, 2018.

[169] B. Bisoyi and B. Das, "An approach to en route environmentally sustainable future through green computing," *Smart Comput. Informat.*, vol. 77, pp. 621–629, Jan. 2018, doi: 10.1007/978-981-10-5544-7_61.

[170] J. Wan, S. Tang, Z. Shu, D. Li, S. Wang, M. Imran, and A. V. Vasilakos, "Software-defined industrial Internet of Things in the context of industry 4.0," *IEEE Sensors J.*, vol. 16, no. 20, pp. 7373–7380, May 2016, doi: 10.1109/JSEN.2016.2565621.

[171] M. Prause, "Challenges of industry 4.0 technology adoption for SMEs: The case of Japan," *Sustainability*, vol. 11, no. 20, pp. 2–13, 2019, doi: 10.3390/su11205807.

[172] F. Almada-Lobo, "The industry 4.0 revolution and the future of manufacturing execution systems (MES)," *J. Innov. Manage.*, vol. 3, no. 4, pp. 16–21, Jan. 2016, doi: 10.24840/2183-0606_003.004_0003.

[173] A. Moeuf, R. Pellerin, S. Lamouri, S. Tamayo-Giraldo, and R. Barbaray, "The industrial management of SMEs in the era of industry 4.0," *Int. J. Prod. Res.*, vol. 56, no. 3, pp. 1118–1136, Feb. 2018, doi: 10.1080/00207543.2017.1372647.

[174] S. Mittal, M. A. Khan, D. Romero, and T. Wuest, "A critical review of smart manufacturing & industry 4.0 maturity models: Implications for small and medium-sized enterprises (SMEs)," *J. Manuf. Syst.*, vol. 49, pp. 194–214, Oct. 2018, doi: 10.1016/j.jmsy.2018.10.005.

[175] T. Wagner, C. Herrmann, and S. Thiede, "Industry 4.0 impacts on lean production systems," *Proc. CIRP*, vol. 63, pp. 125–131, Jan. 2017, doi: 10.1016/j.procir.2017.02.041.

[176] K. Akdil, A. Ustundag, and E. Cevikcan, "Maturity and readiness model for industry 4.0 strategy," in *Industry 4.0: Managing The Digital Transformation*. Cham, Switzerland: Springer, 2018, pp. 61–94, doi: 10.1007/978-3-319-57870-5_4.

[177] I. Ajzen and M. Fishbein, "Attitudes and the attitude-behavior relation: Reasoned and automatic processes," *Eur. Rev. Social Psychol.*, vol. 11, no. 1, pp. 1–33, Jan. 2000, doi: 10.1080/14792779943000116.

[178] R. J. G. Romero and A. G. V. Mercado, "Las mipymes tecnológicas peruanas al 2030. Estrategias para su inserción a la industria 4.0," *Nova Scientia*, vol. 10, no. 20, pp. 754–778, May 2018, doi: 10.21640/ns.v10i20.1329.

[179] J. Carrillo, R. Gomis, S. De los Santos, L. Covarrubias, and M. Matus, "Podrán transitar los ingenieros a la industria 4.0? Análisis industrial en Baja California," *Entreciencias, Diálogos Sociedad Conocimiento*, vol. 8, no. 22, pp. 1–33, 2020.

[180] Y. Lu, "Industry 4.0: A survey on technologies, applications and open research issues," *J. Ind. Inf. Integr.*, vol. 6, pp. 1–10, Jun. 2017, doi: 10.1016/j.jii.2017.04.005.

[181] A. Sanders, C. Elangeswaran, and J. Wulfsberg, "Industry 4.0 implies lean manufacturing: Research activities in industry 4.0 function as enablers for lean manufacturing," *J. Ind. Eng. Manage.*, vol. 9, no. 3, pp. 811–833, 2016, doi: 10.3926/jiem.1940.

[182] R. Abraham, J. Schneider, and J. V. Brocke, "Data governance: A conceptual framework, structured review, and research agenda," *Int. J. Inf. Manage.*, vol. 49, pp. 424–438, Dec. 2019, doi: 10.1016/j.ijinfomgt.2019.07.008.

[183] M. N. Zolotov, T. Oliveira, and S. Casteleyn, "E-participation adoption models research in the last 17 years: A weight and meta-analytical review," *Comput. Hum. Behav.*, vol. 81, pp. 350–365, Apr. 2018, doi: 10.1016/j.chb.2017.12.031.

[184] T. Torres-Hernández, I. Barreto, and J. C. Rincón Vásquez, "Creencias y normas subjetivas como predictores de intención de comportamiento proambiental," *Suma Psicológica*, vol. 22, no. 2, pp. 86–92, Jul. 2015, doi: 10.1016/j.sumpsi.2015.09.003.

[185] Y. J. Kim, J. U. Chun, and J. Song, "Investigating the role of attitude in technology acceptance from an attitude strength perspective," *Int. J. Inf. Manage.*, vol. 29, no. 1, pp. 67–77, Feb. 2009, doi: 10.1016/j.ijinfomgt.2008.01.011.

[186] S. Iyer, A. K. Pani, and L. Gurunathan, "User adoption of eHRM—An empirical," *Re-Imagining Diffusion Adoption Inf. Technol. Syst., Continuing Conversation*, vol. 617, pp. 231–248, Jan. 2020, doi: 10.1007/978-3-030-64849-7_21.

[187] B. Sampat, A. Sharma, and B. Prabhakar, "Understanding factors influencing the usage intention of mobile pregnancy applications," in *Proc. Int. Work. Conf. Transf. Diffusion IT*, Dec. 2020, pp. 641–654.

[188] J. Radhakrishnan and M. Chattopadhyay, "Determinants and barriers of artificial," in *Proc. Int. Work. Conf. Transf. Diffusion IT*, 2020, pp. 88–99.

[189] A. Mishra and A. Shukla, "Psychological determinants of consumer's," in *Re-Imagining Diffusion and Adoption of Information Technology and Systems: A Continuing Conversation*, vol. 617, 2020, pp. 274–283.

[190] B. Sampat and K. C. Sabat, "Antecedents to continuance intention to use eGovernment services in India," in *Proc. Int. Work. Conf. Transf. Diffusion IT*, Dec. 2020, pp. 284–291, doi: 10.1007/978-3-030-64849-7_21.

[191] Y.-N. Wang, L. Jin, and H. Mao, "Farmer cooperatives' intention to adopt agricultural information technology—Mediating effects of attitude," *Inf. Syst. Frontiers*, vol. 21, no. 3, pp. 565–580, Jun. 2019, doi: 10.1007/s10796-019-09909-x.

[192] J. L. Pierce and A. L. Delbecq, "Organization structure, individual attitudes and innovation," *Acad. Manage. Rev.*, vol. 2, no. 1, pp. 27–37, Jan. 1977, doi: 10.5465/amr.1977.4409154.

[193] M. Prabaharan and M. Selvalakshmi, "Customers interest in buying an electric car: An analysis of the Indian market," in *Proc. Int. Work. Conf. Transf. Diffusion IT*. Cham, Switzerland: Springer, Dec. 2020, pp. 493–509, doi: 10.1007/978-3-030-64849-7_21.

[194] J. Bleicher and H. Stanley, "Digitization as a catalyst for business model innovation a three-step approach to facilitating economic success," *J. Bus. Manage.*, vol. 12, pp. 62–71, Jan. 2016.

[195] V. Grover and R. Kohli, "Revealing your hand: Caveats in implementing digital business strategy," *Mis Quart.*, vol. 37, no. 2, pp. 655–662, Jun. 2013.

[196] W. Bauer, M. Hämmerle, S. Schlund, and C. Vocke, "Transforming to a hyper-connected society and economy—Towards an 'industry 4.0,'" *Proc. Manuf.*, vol. 3, pp. 417–424, Jan. 2015, doi: 10.1016/j.promfg.2015.07.200.

[197] E. Fleisch, M. Weinberger, and F. Wortmann, "Geschäftsmodelle im internet der dinge," *HMD Praxis Wirtschaftsinformatik*, vol. 51, no. 6, pp. 812–826, Dec. 2014, doi: 10.1365/s40702-014-0083-3.

[198] M. M. Iivari, P. Ahokangas, M. Komi, M. Tihinen, and K. Valtanen, "Toward ecosystemic business models in the context of industrial internet," *J. Bus. Models*, vol. 4, no. 2, pp. 42–59, Oct. 2016.

[199] V. Govindarajan and P. K. Kopalle, "Disruptiveness of innovations: Measurement and an assessment of reliability and validity," *Strategic Manage. J.*, vol. 27, no. 2, pp. 189–199, Feb. 2006, doi: 10.1002/smj.511.

[200] X. T. Nguyen and Q. K. Luu, "Factors affecting adoption of industry 4.0 by small- and medium-sized enterprises: A case in Ho Chi Minh city, Vietnam," *J. Asian Finance, Econ. Bus.*, vol. 7, no. 6, pp. 255–264, Jun. 2020, doi: 10.13106/jafeb.2020.vol7.no6.255.

[201] R. Neugebauer, S. Hippmann, M. Leis, and M. Landherr, "Industrie 4.0—From the perspective of applied research," *Proc. CIRP*, vol. 57, pp. 2–7, Jan. 2016, doi: 10.1016/j.procir.2016.11.002.

[202] G. Nick and F. Pongrácz, "How to measure industry 4.0 readiness of cities," *Industry*, vol. 1, no. 2, pp. 136–140, 2016.

[203] M. Dassisti, H. Panetto, M. Lezoche, P. Merla, C. Semeraro, A. Giovannini, and M. Chimienti, "Industry 4.0 paradigm: The viewpoint of the small and medium enterprises," in *Proc. 7th Int. Conf. Inf. Soc. Technol.*, vol. 1, 2017, pp. 50–54.

[204] M. G. Berna, "La cooperación interorganizacional como elementos de aprendizaje en las organizaciones que gestionan su conocimiento: El sector de la construcción en España," Centro Politécnico Superior, Universidad de Zaragoza, Zaragoza, Spain, Tech. Rep., 2011.

[205] C. Bai, P. Dallasega, G. Orzes, and J. Sarkis, "Industry 4.0 technologies assessment: A sustainability perspective," *Int. J. Prod. Econ.*, vol. 229, Nov. 2020, Art. no. 107776, doi: 10.1016/j.ijpe.2020.107776.

[206] R. Brozzi, D. Forti, E. Rauch, and D. T. Matt, "The advantages of industry 4.0 applications for sustainability: Results from a sample of manufacturing companies," *Sustainability*, vol. 12, no. 9, p. 3647, May 2020, doi: 10.3390/su12093647.

[207] W. W. Chin, "The partial least squares approach to structural equation modeling," in *Modern Methods for Business Research*, 1998, pp. 295–336.

[208] D. Cordero and A. Mory, "Education in system engineering: Digital competence," in *Proc. IEEE 6th Int. Conf. Ind. Eng. Appl. (ICIEA)*, Apr. 2019, pp. 677–681, doi: 10.1109/IEA.2019.8715223.

[209] E. Carmines and R. Zeller, "Reliability and validity assessment," *Quant. Appl. Social Sci.*, vol. 97, no. 17, pp. 9–71, 1979.

[210] J. C. Nunnally, *Phychometric Theory*. New York, NY, USA: McGraw-Hill, 1978.

[211] C. Fornell and D. F. Larcker, "Evaluating structural equation models with unobservable variables and measurement error," *J. Marketing Res.*, vol. 18, no. 1, pp. 39–50, 1981.

[212] A. S. Romo, "El liderazgo, la compensación variable, el empowerment psicológico y su impacto en la efectividad del empleado: Un enfoque de modelación mediante ecuaciones estructurales," Monterrey, Mexico, Tech. Rep., 2014.

[213] J. D. Cohen, K. Dunbar, and J. L. McClelland, "On the control of automatic processes: A parallel distributed processing account of the Stroop effect," *Psychol. Rev.*, vol. 97, no. 3, pp. 332–361, 1990.

[214] R. F. Falk and N. B. Miller, *A Primer for Soft Modeling*, Akron, OH, USA, 1992.

[215] B. Efron and R. J. Tibshirani, *An Introduction to the Bootstrap*. New York, NY, USA: Chapman Hall, 1993.

[216] J. Fletcher, S. Sarkani, and T. A. Mazzuchi, "A technology adoption model for broadband internet adoption in India," *J. Global Inf. Technol. Manage.*, vol. 17, no. 3, pp. 150–168, Jul. 2014, doi: 10.1080/1097198X.2014.951294.

[217] H. Hollenstein, "Determinants of the adoption of information and communication technologies (ICT)," *Struct. Change Econ. Dyn.*, vol. 15, no. 3, pp. 315–342, Sep. 2004, doi: 10.1016/j.strueco.2004.01.003.
[218] M. Stieninger, D. Nedbal, W. Wetzlinger, G. Wagner, and M. A. Erskine, "Factors influencing the organizational adoption of cloud computing: A survey among cloud workers," *Int. J. Inf. Syst. Project Manage.*, vol. 6, no. 1, pp. 5–23, Jan. 2022.
[219] P. Närman, H. Holm, D. Höök, N. Honeth, and P. Johnson, "Using enterprise architecture and technology adoption models to predict application usage," *J. Syst. Softw.*, vol. 85, no. 8, pp. 1953–1967, Aug. 2012, doi: 10.1016/j.jss.2012.02.035.
[220] M. Dalvi-Esfahani, T. Ramayah, and M. Nilashi, "Modelling upper echelons' behavioural drivers of green IT/IS adoption using an integrated interpretive structural modelling—Analytic network process approach," *Telematics Informat.*, vol. 34, no. 2, pp. 583–603, May 2017, doi: 10.1016/j.tele.2016.10.002.

DIEGO CORDERO was born in Azogues, Ecuador, in 1966. He received the degree in computer and informatics systems engineering from the Escuela Politécnica Nacional, Quito, Ecuador, in 1993, the master's degree in management information systems from the Escuela Politécnica del Ejército, Guayaquil, Ecuador, in 2008, and the Ph.D. degree in sciences administration from the Universidad Nacional Autónoma de México (UNAM), Mexico, in 2017.

He worked as a Postdoctoral Researcher with the "Latin America and its Insertion in the Global Order," Ecuador, in 2018. He has held various positions, such as a System Manager, a Strategic Manager, the Dean, the Director of Research, an Academic Director, and the Director of Innovation Processes. He is currently a Research Professor with the Catholic University of Cuenca (UCACUE) and a member of the Green IT Research Group. He is also an Accredited Researcher with the Secretary of Higher Education, Science, Technology, and Innovation, Ecuador, and a Ecuador Node Coordinator of TIC Latin America. He leads research projects. He is the author of two books, ten chapters of book, more than 40 articles, and has participated as a speaker in more than 15 international conferences. His research interests include technology governance and inclusion, green IT, data analytics, and educational innovation.

Dr. Cordero is also an Associate Editor of the *UDA Journal* (Academ).

KLEBER LUNA ALTAMIRANO was born in Azogues, Ecuador, in 1969. He received the degree in economics and finance from the Catholic University of Cuenca, Ecuador, in 1993, the Master of Business Administration degree in human resources and marketing from the University of Guayaquil, Ecuador, and the University of Buenos Aires (UBA), Argentina, in 2009, and the Ph.D. degree in social sciences management from the University of Zulia, Venezuela, in 2022. Since 1989, he has been dedicated himself to the academy being a Teacher in different institutions of secondary and higher education. Making a parenthesis, from 1994 to 1997, he held the position of a General Treasurer of the Provincial Government of Cañar, Ecuador. He was an Economist with the Catholic University of Cuenca, in 2001. He is currently a Research Professor with the Academic Unit of Administration, Catholic University of Cuenca. He was the Director and the Co-Director of several research projects approved in calls made by the Catholic University of Cuenca. He was a speaker at various international congresses inside and outside the country. He has received several publications of scientific articles in different journals indexed in high-impact databases. He has published books and book chapters under scientific standards. He was a member of the Digital Science Research Network registered in the Higher Education System and the National System of Science, Technology, Innovation, Ancestral Knowledge, issued by agreement no. SENESCYT-2018-040 and registration number REG-RED-18-0063.

JANICE ORDÓÑEZ PARRA was born in Cuenca, Ecuador, in 1975. She received the degree in administration, public accountant, and commercial engineering from the Catholic University of Cuenca, in 2004, the master's degree in accounting and finance with a mention in management and tax planning from the University of Azuay, in 2012, and the Ph.D. degree in accounting from the Autonomous University of Nuevo León, Mexico, in 2022.

From 1994 to 2014, she worked in the Ecuadorian financial system. From 2012 to 2017, she was the Director of the Accounting and Auditing Program. Since 2012, she has been a Research Professor of accounting and auditing career with the Catholic University of Cuenca in the undergraduate and postgraduate option. She has presented and published research papers at various conferences, academic events, national and international research projects, framed in the line of banking and finance as well as auditing and internal control. She is a member of the Ecuadorian Network of Scientific Women REMCI, a Researcher accredited by Senescyt, and a peer evaluator of national and international journals.

WILLIAM SARMIENTO ESPINOZA was born in Cuenca, Ecuador, in 1964. He received the degree in administration from the Catholic University of Cuenca, Ecuador, in 2002, and the master's degree in didactics of mathematics from the University of Cuenca, Ecuador, in 2014. Since 1992, he has been dedicated himself to the academy being a Teacher at the private school the Asunción, a Professor at the University of Azuay, and a Professor with the Catholic University of Cuenca. He was a Public Accountant and a Commercial Engineer with the Catholic University of Cuenca, in 2002. He was a Specialist in university teaching with the Catholic University of Cuenca, in 2015. He has held various positions, such as the Director of Accounting and Auditing Career, the Sub Dean of the Academic Unit of Administration, and an Academic Advisor with the Catholic University of Cuenca. He is currently a Research Professor with the Academic Unit of Administration, Catholic University of Cuenca. He was the Director and the Co-Director of several research projects approved in calls made by the Catholic University of Cuenca. He was also a speaker at various international congresses inside and outside the country. He has published scientific articles, books, and book chapters under scientific standards.