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Challenges for development and technological advancement: An analysis of Latin America

Rodrigo Fernandes Malaquias
Escola de Administração de Empresas de São Paulo da Fundação Getulio Vargas and Universidade Federal de Uberlândia

Alberto Luiz Albertin
Escola de Administração de Empresas de São Paulo da Fundação Getulio Vargas

Abstract
This study addresses the challenges for development in Latin America considering the framework of a contemporary technological advancement: the Internet of Things (IoT). Based on this framework, this paper shows the diffusion of IoT-related aspects in three different dimensions: individuals (demand), environment, and technology offer. The low availability of secure Internet servers, the low widespread rate of Internet adoption, inequalities in access to electricity, and adult illiteracy represent important challenges to be faced in Latin America. These variables directly affect IoT diffusion; thus, this paper also presents further directions in this field.

Keywords
Internet of Things, acceptance of technologies, security, development, ICT4D, Latin America

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Introduction
The object of analysis in this study involves a technological innovation, or, in the words of Giusto et al. (2010) and Atzori et al. (2010), a novel paradigm: the Internet of Things (IoT). The IoT "refers to the interconnection of physical objects, by equipping them with sensors, actuators and a means to connect to the Internet" (Dijkman et al., 2015: 672). It is also known as the third wave of the Internet and the fourth industrial revolution (O'Brien, 2016).

According to Weber and Studer (2016), the term Internet of Things was first coined by Kevin Ashton, in 1999. The development of this technology has promoted new forms of communication, such as communication between people and things, and between things and things, which creates a new dynamic for networks and multiplies connections (International Telecommunication Union, 2005). Therefore, the variety of things and objects around us has become able to interact with each other via embedded sensors, and they can cooperate to achieve common goals and send information to storage centers (Giusto et al., 2010; O'Brien, 2016).

Development can be seen "as a process of expanding the real freedoms that people enjoy" (Sen, 1999: 3). Information and communication technologies can contribute to the development of emerging countries (Malaquias et al., 2017); therefore, a more comprehensive way of integrating devices, equipment and objects can also have a positive effect on development. However, before the implementation of contemporary resources, some basic facilities are required, and inequalities in Latin America can affect the diffusion of the IoT at this point, which can effect development in general.

Corresponding author:
Rodrigo Fernandes Malaquias, Avenida João Naves de Ávila, n° 2121, Bloco F, Sala 1F-216, Campus Santa Mônica, Uberlândia / Minas Gerais / Brazil. CEP (zip code): 38.400-902, Phone: +55 (34) 3239-4176.
Email: rodrigofmalaquias@gmail.com

Since the IoT represents a contemporary dimension of information technology, the aim of this paper is to present and discuss some development challenges in emerging economies considering the perspective of a contemporary technology: the Internet of Things. Our body of emerging economies consisted of data of Latin American countries, collected from the World Bank. In comparison with other developing regions, Latin America presents high rates of adult literacy (Machin-Mastromatteo, 2014). Nevertheless, economic, political and cultural inequalities have still increased in Latin America (Martinez-Villa and Machin-Mastromatteo, 2016), which motivates an analysis of potential factors that can contribute with development in such region.

The advancement of the IoT is a result of synergetic activities among different fields of knowledge (Atzori et al., 2010), but few studies "discuss the diffusion of IoT at the macro level" (Hwang et al., 2016: 971). Therefore, using a comprehensive analysis, this paper can contribute to improve some variables related to the region's development, as well as to improve the adoption of the IoT.

IoT framework

Figure 1 presents three big dimensions of the IoT: individuals, environment, and technology offer. This framework involves a comprehensive proposal to understand IoT diffusion together with its contribution to emerging economies.

Considering the demand (which includes the individuals' perspective), the barriers and determinants associated with the acceptance of devices/products connected to the IoT can be understood from the customers' perception. Nevertheless, the effect of these results will expand when researchers combine customers' perception with the other dimensions of the IoT framework: individuals (demand), environment, and technology offer. Therefore, according to Figure 1, the IoT framework does not uniquely consist of different individuals, but also of different companies and dimensions, which increase the complexity of analyzing the determinants of IoT diffusion.

Firstly, users have to accept the technology: they will start to use it, attribute it a value/sign, recommend (or not) its use to friends and colleagues, and decide about continuing using it. In the traditional model for technology acceptance (the Technology Acceptance Model, TAM), two particular beliefs are relevant to study behavior in the acceptance of technology: perceived usefulness and perceived ease of use (Davis, 1989; Davis et al., 1989).

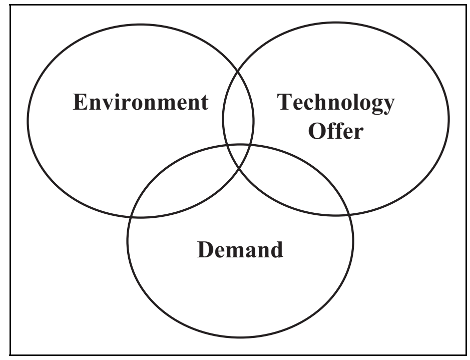

Figure 1. The IoT Dimensions
Source: based on Albertin and Albertin (2017).

On the one hand, some technologies can be voluntarily accepted by users (Venkatesh and Davis, 2000); on the other hand, other technologies are mandatory for users. In the context of the IoT, although individuals are able to select products that they intend or do not intend to use, the possibility of choosing whether to use it can decrease with technology advancements. The following paragraph shows an example.

Currently, even popular cars have been already equipped with Bluetooth connections, and the driver can connect his/her personal smartphone to the car. On the other hand, information about average velocity, routes, and places usually visited by the driver can be registered in large databases and used later by companies. Therefore, even involuntarily, the driver has to accept the rules of the IoT if he/she wants the benefits of connecting his/her smartphones to the car through Bluetooth. This is an example of mandatory adoption of an IoT resource.

Atzori et al. (2010) reported and reviewed enabling technologies related to the IoT. They noticed that the IoT enables the development of a broad set of applications, but a very small part of them is available currently. As open issues, the authors highlighted problems related to data integrity, security, and privacy. Indeed, security and privacy concerns are in the agenda of contemporary technology challenges, as we can consult, for example, in recent literature on mobile apps (Zhou, 2011; Malaquias and Hwang, 2016). Also, all the three elements in Figure 1 have some relation with security and privacy.

Issues with security and privacy are directly related to the Internet of Things. IoT devices have their benefits for individuals and for businesses, but they also create risks (Weber, 2015), especially privacy risks.

The IoT is in a phase of rapid growth (Dijkman et al., 2015), but the quick diffusion of IoT resources has not taken place (Chen, 2011; Hwang et al., 2016). As the other kinds of technology, the IoT also needs to be accepted and used by individuals. However, different from other technologies which enable security and trust analysis while considering the opinion of the final user about an app (such as mobile banking), testing the determinant factors of the IoT tends to be a more abstract and complex task. This is because the IoT is available in diverse products and involves different resources.

Furthermore, there are ethical issues in IoT environments. The existing technological resources are not necessarily enough to manage large and dynamic databases. There is an increasing demand for large databases and managing tools, as well as for individuals who interact and use these databases. The data also need to be safely stored and free of hackers' invasion, since they consist of detailed information about people's daily activities, especially for information technology innovators.

These situations should be foreseen by companies, and their respective protocols should be formally registered inside entities. Moreover, the government and regulatory bodies need to develop research and studies in order to create mechanisms that allow the use of information according to ethical requirements, and apply penalties when necessary.

About the technology offer, as previously commented, companies need to rely on professionals who can understand, manage and work with contemporary concepts of large databases. Storing and managing large databases has drastically changed with the IoT availability; as a consequence, courses on big data management have been offered by universities. As the IoT is a phenomenon with international reach, these training courses have to be offered in different countries around the world. The development level of countries is a basic variable to be included in the analysis of training opportunities to be offered to individuals.

An important construct in the literature of information systems is social influence (Venkatesh and Morris, 2000; Hwang, 2014), which represents the degree to which an individual considers the opinion of others about his/her need to use a new system. The adherence to this construct in the analysis of acceptance and use of technologies has been confirmed by different authors using different technologies. In fact, this construct is especially relevant in technologies that involve risks, because users can motivate themselves through personal recommendations/opinions from friends and colleagues, or when individuals realize that other people who use such technologies benefit from them. The IoT framework is comprehensive, but the inclusion of the variable 'social influence' to improve the understanding of this technology can guide us to new strategic actions.

Given the considerations of the IoT framework, the next section analyzes the potential contribution of this contemporary technology to development in emerging economies. In this case, our focus is on Latin America.

The IoT and development in Latin America

In order to analyze the potential benefits of the IoT for the development of Latin America, we collected data from the World Bank (2017). Appendix A presents each indicator considered in this research, its definition and its respective year of reference, according to the most recent data available when this study started. Appendix B presents the countries of Latin America and their populations, in which Brazil and Mexico correspond to more than half of the population of the region.

Basic services

A widespread use of IoT resources depends on two major factors: access to electricity and access to the Internet (individuals using the Internet). The former, access to electricity, seems to be a basic variable, but the average rate is still 92.5% in the countries of the region. In some countries, the rate is 100% (in Argentina, Chile, and Cuba), but there are still some regions in which this variable needs special attention, such as the case of Haiti (with the lowest rate, 37.9%) and Nicaragua (with 81.9% of access to electricity).

About the access to Internet (individuals using the Internet), according to the data collected from the World Bank (2017), the average rate in Latin America is only 45.7%, with a minimum of 12.2% in Haiti, a rate of 19.7% in Nicaragua and 20.4% in Honduras; the highest values were registered in Argentina (69.4%), Uruguay (64.6%), and Chile (64.3%). To talk about IoT adoption, first we need to talk about access to Internet and basic facilities, and the indexes available in Latin America indicate a relevant challenge in this regard, since the country with the highest rate of access to Internet registered that less than 70% of individuals used the Internet in the past three months.

Moreover, in Latin American countries, the number of individuals that hold an account with a financial institution is a variable that can be improved. The use of financial services is basic for people. There are contemporary technologies to access banking services, such as Internet banking and mobile banking, but before using these technologies, individuals need to have a bank account. Based on the World Bank Data (2017), the average percentage of people who have an account with a financial institution (age 15+) in Latin America is only 43.6%; the maximum value is 68.1% (in Brazil) and the minimum is 17.5% (in Haiti). These figures indicate a great potential not only for IoT resources, but also for contributions of basic technologies.

Mobile phone, secure Internet services and GDP (Gross Domestic Product)

Despite the low rates of Internet access and the improvements required about electricity access, the mobile phone subscription rates indicate some favorable indexes for some countries such as Uruguay, Panama and Costa Rica, in which, on average, there is more than one subscription per person. On the other hand, in other regions (Cuba, Belize, and Guyana), the rate is still low; the lowest value was registered in Cuba, with 29.7 subscriptions per 100 people. Although some countries have good indexes for mobile phone subscription, there is an expressive inequality regarding this variable in the region.

Based on the data from the World Bank (2017), the use of servers with encryption technology represents another item with high dispersion, with low frequency in Haiti, Venezuela, Honduras, Nicaragua and Bolivia (less than 20 secure Internet servers per 1 million people in each of these countries). On the other hand, Belize, Chile, Panama, Uruguay, and Costa Rica have more than 100 secure servers per 1 million people (the maximum value was registered in Belize, with 150.1). As previously mentioned, security and privacy are key issues in the context of the IoT. The absence of secure servers may decrease the intention to adopt devices and equipment connected to Internet, which can negatively affect IoT adoption.

The contribution to the GDP in the region comes mainly from the service sector, with an average of 62.7% (27.9% from industry, and 9.4% from agriculture). This situation is equivalent among the countries (all countries have at least 51% of their respective GDP from services). It indicates the relevance of information technology services for this sector, especially with optimized management of services in logistics, hotels, restaurants, transportation, government, finance, education, and health care.

Education, urban population and life expectancy

The previous two topics indicated some challenges to be faced in Latin America to increase the chances of a widespread use of IoT resources. Additionally, this section points out two special variables that can directly benefit from the IoT and technology. It is the case of training activities for teachers in primary education. On average, 87% of these teachers are trained, but this information has some missing values for some countries. Therefore, caution is needed for generalizations. e-learning courses, the use of mobile devices to study and conduct academic activities, reading electronic books and other alternatives available through connected mobile devices can contribute to these indexes.

Moreover, the adult illiteracy rate represents another important issue to be addressed through technology. None of the countries of the sample has a 100% rate of adult literacy (the highest values are: 99.7% in Cuba, 98.4% in Uruguay, 98.1% in Argentina, and 97.6% in Costa Rica). The countries with the lowest rates are Haiti (60.7%) and Guatemala (79.1%). To improve the literacy rate, technology can also be used, since learners can access playful alternatives, which increase their motivation to learn and practice. Virtual environments can also increase the motivation of adults in reading and writing.

On average, 70.0% of the population of Latin American countries live in urban areas. So, there is a significant part of the population that does not necessarily access the resources available in large cities and relies on basic and simple infrastructure to live. Guyana, Belize and Guatemala are the countries with the lowest indexes of population in urban areas. Therefore, the application of technology in rural areas represents an important factor to promote human, social and economic development. In countries where near or more than 90% of the population lives in urban areas (Uruguay, Argentina and Chile), the adoption of Internet-connected devices and equipment has great chances of success.

Life expectancy, on average, is around 74.2 years in Latin America but the figures present some dispersion too. For example, Haiti has a life expectancy of 63.1 years, while Chile has 81.8. Older people tend to be reluctant in the use of information technology. In fact, age is a variable that affects technology acceptance (Venkatesh et al., 2003), and, according to the values for life expectancy in the region, IoT technology will have to be accepted by younger users but also by older individuals. Therefore, this variable and the initiatives to facilitate Internet access for individuals without any familiarity with technology must be included in the agenda of governments, funding agencies, and universities of the region.

Conclusion

Even with different levels of intensity, the Internet of Things is among us. It is a fact. Technology and the use of contemporary technological resources can contribute to development, providing better conditions for people. Based on these considerations, the IoT can improve and contribute to the development of emerging economies, such as the case of Latin American countries.

On the other hand, the widespread adoption of the IoT requires resources - some of them are basic resources that cause difficulties for people when missing, as they are in some countries of Latin America. For example, many individuals do not have access to electricity and Internet. To improve the chances of success in IoT use, we need to invest in these areas.

This reinforces the statement about inequalities that exist even in wealthy countries (Sen, 1999), and corroborates previous research studies (Martinez-Villa and Machin-Mastromatteo, 2016) that indicate inequalities in Latin America. With adequate investments, for example, from government, telecommunication companies, and universities, the technological infrastructure in the region can change and contribute to new initiatives to improve quality of life. Such initiatives can have a positive effect on basic education offered to students and contribute to reducing the illiteracy rate of some countries in Latin America.

The framework presented in this paper indicates that the IoT involves a multifaceted scenario; nevertheless, at least in the Latin American region, the starting point is still in basic services. Further research can be developed to address and explore the points that are discussed in this study. There are also some open issues. For example, what can technology bring to the indigenous population in Latin American countries? How do these individuals interact with mobile devices? How can these individuals benefit from IoT technology?

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ORCID iD

Rodrigo Fernandes Malaquias https://orcid.org/0000-0002-7126-1051

References

Albertin AL and Albertin RMM (2017) A Internet das coisas irá muito além das coisas. *GVExecutivo* 16(2): 12–17.

Atzori L, Iera A and Morabito G (2010) The Internet of Things: a survey. *Computer Networks* 54: 2787–2805.

Chen Y (2011) Understanding technology adoption through system dynamics approach: a case study of RFID technology. *2011 IFIP Ninth International Conference on Embedded and Ubiquitous Computing*. 366–371.

Davis FD (1989) Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly* 13(3): 319–340.

Davis FD, Bagozzi RP and Warshaw PR (1989) User acceptance of computer technology: a comparison of two theoretical models. *Management Science* 35(8): 982–1003.

Dijkman RM, Sprenkels B, Peeters T and Janssen A (2015) Business models for the Internet of Things. *International Journal of Information Management* 35: 672–678.

Giusto D, Iera A, Morabito G and Atzori L (Editors) (2010) *The Internet of Things*. Springer.

Hwang Y (2014) Understanding social influence theory and personal goals in e-learning. *Information Development* 32(3): 466–477.

Hwang Y-M, Kim MG and Rho J-J (2016) Understanding Internet of Things (IoT) diffusion: focusing on value configuration of RFID and sensors in business cases (2008-2012). *Information Development* 32(4): 969–985.

International Telecommunication Union (2005) *The Internet of Things*. ITU Internet Report. Retrieved from: www.itu.int

Machin-Mastromatteo JD (2014) Is information enough to save the region? *Information Development* 31(1): 89–91.

Malaquias FFO and Hwang Y (2016) Trust in mobile banking under conditions of information asymmetry: empirical evidence from Brazil. *Information Development* 32(5): 1600–1612.

Malaquias RF, Malaquias FFO and Hwang Y (2017) The role of information and communication technology for development in Brazil. *Information Technology for Development* 23(1): 179–193.

Martinez-Villa BA and Machin-Mastromatteo JD (2016) Four theories to improve justice in Latin America. *Information Development* 32(4): 1284–1288.

O'Brien HM (2016) The Internet of Things. *Journal of Internet Law* 19(12): 12–20.

Sen A (1999) *Development as freedom*. New York, NY: Anchor Books.

Venkatesh V and Davis FD (2000) A theoretical extension of the technology acceptance model: four longitudinal field studies. *Management Science* 46(2): 186–204.

Venkatesh V and Morris MG (2000) Why don't men ever stop to ask for directions? Gender, social influence, and their role in technology acceptance and usage behavior. *MIS Quarterly* 24(1): 115–139.

Venkatesh V, Morris MG, Davis GB and Davis FD (2003) User acceptance of information technology: toward a unified view. *MIS Quarterly* 27(3): 425–478.

Weber RH (2015) Internet of Things: privacy issues revisited. *Computer Law & Security Review* 31: 618–627.

Weber RH and Studer E (2016) Cybersecurity in the Internet of Things: legal aspects. *Computer Law & Security Review* 32: 715–728.

World Bank (2017) *World Bank Open Data* - free and open access to global development data. Retrieved from: www.data.worldbank.org

Zhou T (2011) The effect of initial trust on user adoption of mobile payment. *Information Development* 27(4): 290–300.

About the authors

Rodrigo Fernandes Malaquias: Currently (2016/2017), he is developing his pos-doc research at Escola de Administração de Empresas de São Paulo da Fundação Getulio Vargas (FGV-EAESP). He is a Full Time Professor at Universidade Federal de Uberlândia (UFU), Brazil. In 2012, he received his PhD in Business Administration from FGV-EAESP, Brazil. In 2015, he was a Visiting Research Scholar at DePaul University in Chicago, USA, where he developed his first pos-doc research. His research includes finance, accounting, mobile banking, e-commerce, and cross-country studies. His papers have been published or accepted for publication by peer-reviewed journals, including *Research in International Business and Finance, Accounting & Finance Review (USP), Computers in Human Behavior, Information Development, Information Technology for Development, Journal of Electronic Commerce Research, Brazilian Review of Finance, Brazilian Business Review, Journal of Operations and Supply Chain Management, Technology and Disability*, among others. Address: Avenida João Naves de Ávila, n° 2121, Bloco F, Sala 1F-216, Campus Santa Mônica, Uberlândia / Minas Gerais / Brazil. CEP (zip code): 38.400-902, Phone: +55 (34) 3239-4176. Email: rodrigofmalaquias@gmail.com

Alberto Luiz Albertin: Professor Albertin holds an MsC and a PhD degree in Business Administration from Faculdade de Economia, Administração e Contabilidade da Universidade de São Paulo (FEA-USP). He is a full time Professor at Escola de Administração de Empresas de São Paulo da Fundação Getulio Vargas (FGV-EAESP) and the coordinator of the Center for Applied Information Technology (CIA), of the Programme for Excellence in Business in Digital Age (NED) and of the Post Graduation Programs at FGV-EAESP. He is also a consultant in Administration of Information Technology, Business in Digital Age and Project Management, having completed several projects on Administration of Information Technology, Planning, Organizational Diagnosis, Strategic Use of Information Technology, Business in the Digital Age and Project Management. Previously, he has worked for several years in national and multinational companies in the IT area. He also wrote various studies, researches and articles about Information Technology and has won many prizes for his works. He serves as a speaker, lecturer and coordinator in various seminars, conferences and courses on IT, Business in the Digital Age and Project Management. Email: albertin@fgv.br

Appendix A

Description of the indexes used to develop the analysis

Index from The World Bank	Year	Description
Access to electricity (% of population)	2014	Represents "the percentage of population with access to electricity".
Account at a financial institution (% age 15+) [ts]	2014	"Denotes the percentage of respondents who report having an account (by themselves or together with someone else) at a bank or another type of financial institution" (% age 15+).
Adult literacy rate, population 15+ years, both sexes (%)	2015	"Percentage of the population age 15 and above who can, with understanding, read and write a short, simple statement on their everyday life".
Agriculture, value added (% of GDP)	2015	"Agriculture corresponds to ISIC divisions 1-5 and includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs".
Individuals using the Internet (% of population)	2015	"Internet users are individuals who have used the Internet (from any location) in the last 3 months".
Industry, value added (% of GDP)	2015	"Industry corresponds to ISIC divisions 10-45 and includes manufacturing (ISIC divisions 15-37). It comprises value added in mining, manufacturing (also reported as a separate subgroup), construction, electricity, water, and gas. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs".
Life expectancy at birth, total (years)	2015	It indicates "the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life".
Mobile cellular subscriptions (per 100 people)	2015	It indicates "subscriptions to a public mobile telephone service that provide access to the PSTN using cellular technology [...]. The indicator applies to all mobile cellular subscriptions that offer voice communications. It excludes subscriptions via data cards or USB modems, subscriptions to public mobile data services, private trunked mobile radio, telepoint, radio paging and telemetry services".
Percentage of teachers in primary education who are trained, both sexes (%)	2015	It indicates "the percentage of primary school teachers who have received the minimum organized teacher training (pre-service or in-service) required for teaching in a given country".
Secure Internet servers (per 1 million people)	2016	It represents "servers using encryption technology in Internet transactions".
Services, etc., value added (% of GDP)	2015	"Services correspond to ISIC divisions 50-99 and they include value added in wholesale and retail trade (including hotels and restaurants), transport, and government, financial, professional, and personal services such as education, health care, and real estate services. Also included are imputed bank service charges, import duties, and any statistical discrepancies noted by national compilers as well as discrepancies arising from rescaling. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs".
Urban population (% of total)	2015	Represents people living in urban areas.

Source: This content is based on the spreadsheets downloaded from the World Bank (2017). The description of each index is also from the spreadsheets downloaded from the World Bank (2017).

Appendix B

Countries of Latin America included in the research

Country	Population	%
Argentina	43,847,430	7.0
Belize	366,954	0.1
Bolivia	10,887,882	1.7
Brazil	207,652,865	33.1
Chile	17,909,754	2.9
Colombia	48,653,419	7.8
Costa Rica	4,857,274	0.8
Cuba	11,475,982	1.8
El Salvador	6,344,722	1.0
Ecuador	16,385,068	2.6
Guyana	773,303	0.1
Guatemala	16,582,469	2.6
Haiti	10,847,334	1.7
Honduras	9,112,867	1.5
Mexico	127,540,423	20.3
Nicaragua	6,149,928	1.0
Panama	4,034,119	0.6
Paraguay	6,725,308	1.1
Peru	31,773,839	5.1
Dominican Republic	10,648,791	1.7
Uruguay	3,444,006	0.5
Venezuela, RB	31,568,179	5.0

Source: The World Bank (2017); population in the year of 2015.