TECHNOLOGY ADOPTION: FACTORS INFLUENCING THE ADOPTION DECISION OF THE INTERNET OF THINGS IN A BUSINESS ENVIRONMENT

FLAVIO LOBO
University of São Paulo, Av. Prof. Luciano Gualberto, 908, 05508-900 Sao Paulo, Brazil
flavio.lobo@usp.br

EDUARDO VASCONCELLOS
University of São Paulo, Av. Prof. Luciano Gualberto, 908, 05508-900 Sao Paulo, Brazil
epgdvasc@gmail.com

LILIANA VASCONCELLOS GUEDES
University of São Paulo, Av. Prof. Luciano Gualberto, 908, 05508-900 Sao Paulo, Brazil
lilianav@usp.br

The Internet of things (IoT) represents a new paradigm of integration of various technologies and communication solutions, and finds applications in many different domains. This topic has had little exploration in the social sciences and this study helps bridge that gap by investigating the challenge of adopting innovations based on the Internet of Things (IoT), more specifically factors that affect the adoption decision. The realization of the vision of IoT still requires more investment in research and development because of its novelty and complexity. Beyond the technical issues, large-scale adoption is also hampered by the lack of clarity regarding which factors influence the adoption decision of these technologies. The theme adoption of innovation is relevant to those who develop an innovation and want it to be adopted as well as to those who have to decide whether to adopt an innovation or not. As the adoption rate is influenced by factors and decisions that lie both on the side of the supplier as well as the adopter of a technological innovation, this work is based on studies that seek to integrate variables from both sides in order to reflect the systemic nature of this process. Given the nature and novelty of the technology whose adoption is the object of this study, the chosen methodology was multiple case studies, exploratory and qualitative in nature. For the case studies, a total of 8 interviews were conducted and the collection of data was complemented with internal documentation which included executive summaries and detailed information on project execution. The proposed model looked at 4 dimensions: external, internal, technological, and supplier. The first objective was to apply the model to both case studies in order to identify and analyze the key factors influencing the adoption decision for the Internet of things in each company. The second objective was to do a deeper analysis on how the factors related to the technological dimension affected the adoption decision. A comparative analysis was also developed for a deeper understanding of how nuances related to each case may have contributed to the findings, whether these were similar or divergent. What the research has shown is that the model and its factors helped to organize the key issues for analysis in the adoption decision process, serving as support for future studies related to business modelling of IoT solutions. Given the case study methodology, the results cannot be generalized. The proposed model can be applied to both suppliers and adopters of the technological innovation, integrating factors that are external and internal to the company, as well as factors of the IoT technology and factors of the supplier. The model can be easily adapted to serve as a tool in the evaluation and eventual selection of technological innovations.

Keywords: technology adoption, Internet of Things, innovation, IoT

1 INTRODUCTION

Information technology is revolutionizing industry and consumer goods again. Products that once were composed solely of mechanical and electrical parts are becoming complex systems that combine hardware, data storage, sensors, microprocessors, software and connectivity in numerous formats. This is how Porter (2014) introduces us to the Internet of Things (IoT). According to the author, these "smart and connected products," viable thanks to vast improvements in processing power, miniaturization of devices and wireless connectivity, are triggering a "new era of competition."

For Zanelli et al. (2014), the IoT concept aims to make the Internet even more present through easy access and interaction with a wide variety of devices such as home appliances, surveillance cameras, general monitoring sensors (temperature, humidity, speed, location, etc.), vehicles and so on. IoT technology will foster the development of a number of applications that make use of the potentially enormous amount and variety of data generated by such objects to provide new services to citizens, businesses and public administrations. This paradigm certainly finds application in many different domains, such as residential automation, industrial automation, medical care, smart energy management in smart grids, automotive sector in general, be it in cars or traffic management, and many other areas of application (ATZORI et al., 2010).

The social and economic relevance of the Internet of Things is undoubtedly high. According to the market intelligence firm IDC (International Data Corporation), business volume related to IoT technology will correspond to about $ 1.7 trillion by 2020. For the McKinsey Global Institute, an arm of the consulting firm McKinsey & Company (research released in 2015), the economic impact of IoT technology should be US $ 11.1 trillion per year in 2025, and about 70% of this potential should be realized in the business market, that is, in transactions between companies and not between companies and individuals. And just as a volume reference, Swan (2012) reminds us that the number of devices on the Internet exceeded the number of people on the Internet in 2008, and it is estimated to reach 50 billion by 2020.

There is no single way to define what the Internet of Things is, but the authors seem to converge around the idea that this set of technologies has the potential to generate a significant volume of technological innovations in the most diverse areas of information technology applications. This wide possibility of applications for the same technology is, at the same time, an incentive and an obstacle to its adoption (ATZORI et al., 2010).

Therefore, from a systems perspective, the realization of the IoT vision still requires more research and development investments due to its novelty and complexity (Porter, 2014). In addition to technical difficulties, large-scale adoption is also hampered by the lack of a clear and widely accepted business model that can attract investment to promote the deployment of these technologies.

The adoption of innovations is a complex process, especially when the innovation or technology in question is nascent (ROGERS, 2003), as is the case of the Internet of Things. Several authors talk about the benefits of the solutions that will come as the technological challenges related to the theme are overcome. None of these authors, however, discusses the challenge of adoption in the many environments and market segments where solutions can be applied. The lack of a model for the study of the adoption of this technology led us to the elaboration of a framework that contemplates the several dimensions related to the adoption decision. The first objective of this paper is (i) to analyze how the dimensions of the model would apply to the adoption decision in the cases studied, focusing on the business market. As this is a relatively recent technology with few references to case studies, there is a need for a detailed analysis in order to generate knowledge on the topic of adoption of technological innovation in this area, thus allowing the improvement of the model. Therefore, it is defined as the second objective of this work (ii) to identify and analyze the relative influence of factors related to the technology dimension in the adoption of innovations based on IoT.

In the following sections, a brief review of the literature on the themes of IoT and technological adoption will be made, and this review further extends into the definition of the adoption model designed for this study. The research methodology will be presented, followed by the presentation and analysis of the case studies. In the end, we will make some final considerations about the study and some suggestions for future research topics.

2 BIBLIOGRAPHIC REVIEW

2.1 Internet of Things

The term "Internet of Things" was first used by the founders of the MIT Auto-ID Center in 1999 (SUNDMAEKER et al., 2010). The term "Auto-ID" refers to a broad class of identification technologies used to automate, reduce errors and increase efficiency, such as bar code, smart cards, sensors, voice recognition and biometrics. The Internet of Things represents a new paradigm of integration of various technologies and communication solutions (ATZORI et al., 2010). For Miranda et al. (2012), the Internet of Things should not emerge as a new category of systems or solutions, but as an incremental evolution as technologies related to this concept are progressively deployed, enabling new functionalities related to the ability of objects to interact with each other and with the world around them.

Porter (2014) indicates that the change in the nature of products is forcing companies to rethink the entire development, manufacturing, operation, and service cycle, with the potential to break / reinvent existing value chains and open new and important strategic options. From the managerial point of view, the author identifies 4 basic issues impacting competition and the creation of competitive advantages: (1) how the introduction of intelligent and connected products affects the industry structure to which the company belongs, including the definition of the boundaries of such industry; (2) how these new products impact the configuration of the value chain and the set of activities required to compete in the selected markets; (3) what new types of strategic choices should be made to ensure / generate new competitive advantages; and (4) what are the organizational implications of embracing these new technologies and what are the main challenges related to successfully implementing them.

As the Internet of Things is a broad concept, both from the point of view of the technologies involved as well as the possible applications, a brief summary will be made with the purpose of defining the scope and understanding of this theme for the present work:

- Internet of Things (IoT): refers to the application of the concepts, architectures and set of technologies needed to offer solutions that fit within the concept of Internet of Things, as defined by Atzori (2010), Porter (2014) and Miorandi et al. (2012). In the course of this paper, the expressions "IoT", "IoT solution", and "IoT technology" refer to this concept.

- Cloud computing: refers to the communication and computing infrastructure (hardware and software) for the creation of high value-added services (LAVALLE et al, 2012; RAJKUMAR et.al., 2009). In the course of this paper, the expressions "cloud", "cloud solution", and "cloud technology" refer to this concept.

Porter (2014) argues that IoT technology is the basis for the creation of connected and intelligent products. To assist in the definition of a reference model for IoT technology, the points below summarize the vision and scope of an IoT solution according to Atzori et. al. (2010), Porter (2014), Swan (2012), Uckelmann et al. (2011), and Wu et al. (2011):

- Uses intelligent products, equipped with sensors and / or actuators, capable of capturing diverse information about the environment around them or the system in which they are inserted;
- Smart products have the ability to communicate (wired or wireless) and connect to a cloud solution over the Internet for sending and receiving information;
- The data captured by the sensors are treated in the cloud and generate some kind of response to the device / intelligent product (instruction for the product to perform some task) or to the user of the IoT solution discussed (information presented back to the user through some mechanism relevant to his/her/its context).

2.2 Adoption of Innovations

Adoption and diffusion of innovations are interrelated concepts, as well as the study of innovation and its processes. Rogers's (2003) definition of diffusion is widely used: "the process by which an innovation is communicated by certain channels over a period of time between members of a particular social system." According to Tidd et al. (2009), terms typically associated with this definition, such as "adoption" or "technology transfer", do not find a single or widely accepted definition. Rogers (2003) even defined the decision-making process about adopting an innovation as the one through which the individual (or unit of adoption) moves from the first knowledge about innovation to then forming an attitude / opinion about that innovation, making the decision to adopt or reject, then implement and use the new idea, and finally confirm or not this decision. These steps are conceptually called (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation. The result of this process leads to the adoption or rejection of an innovation. In this context, adoption means choosing to make full use of an innovation as the best alternative at that time. The author emphasizes that both the adoption decision and the rejection decision can be reversed at a later time and do not reflect a permanent condition. Frambach (1993) uses the definition of Rogers (2003) whereas for Hall and Kahn (2002), technology adoption refers to the decision to acquire and use a new invention or innovation. Regardless of the definition used, it is important to understand the elements that make up this process.

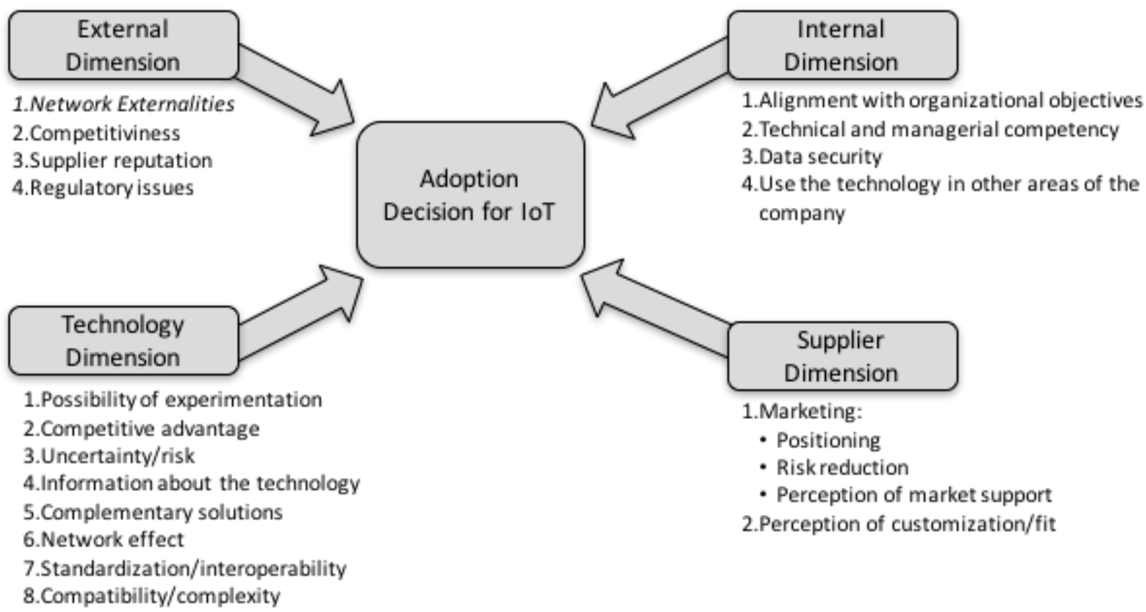
According to Rogers (2003), the four main elements in the adoption and diffusion of innovations are (1) the innovation itself, i.e. an idea, a practice or an object perceived as new by an individual or unit of adoption; (2) the channels of communication, or the means through which a message leaves one individual and reaches another (interpersonal, mass communication, etc.); (3) the time interval analyzed, being relevant in 3 different moments / criteria: (I) in the innovation decision process, (ii) in the "innovativity" of the adopter, that is, how soon or late the adoption occurs when compared to other members of the same system, (iii) the adoption rate, typically measured as the number of members of a given system adopting the innovation in a given period of time; and (4) the social system in which innovation seeks to be inserted, defined as the set of interrelated and engaged units that work together to solve a given problem in order to achieve a common goal.

The literature on the diffusion and adoption of innovations is rich in models. Some view the process from the point of view of those who develop and want to commercialize the innovation, others do so from the point of view of those who are experiencing the adoption process, both of which are interrelated (TIDD et al., 2009). In other words, regardless of the main objective of a given model, it must always consider issues on both sides, as can be seen in the definition of the model created for this work.

3 TECHNOLOGY ADOPTON MODEL FOR IOT

The research model used here was initially based on the work of Nemoto (2009) on the adoption of RFID technology. This model evolved considering the factors considered important in decision-making processes regarding the adoption of technological innovation according to the following authors: Rogers (2003), Tornatzky and Fleischer (1990), Frambach (1993), Frambach et al. (1998), Frambach and Schillewaert (2002), Porter (2014), Atzori et al. (2010) and Hall and Kahn (2002), just to mention some of the most relevant authors. This model is shown in figure 1 and will be briefly described below.

Figure 1 - Detail of the Dimensions of the Research Model



Source: prepared by the authors based on the bibliographic review

For Rogers (2003), those who develop an innovation play a fundamental role in the eventual adoption and diffusion of the innovation, since the decisions taken during the creation / generation of innovations will have a fundamental impact in this process. The set of activities and decisions that must occur prior to the diffusion process include (1) recognizing a problem, (2) making the decision to invest in research needed to substantiate the innovation, (3) developing this innovation so that it can be (4) marketed and eventually (5) adopted. Only after initial adoption can one think of diffusion and its (6) consequences. Consequently, when we look at the **“supplier dimension”**, or ***supplier-side variables***, we must consider the effort to develop an innovation and its marketing strategy (FRAMBACH, 1993), in addition to the eventual effort to adapt the innovation to the needs of the end-customer (FRAMBACH et al., 1998; FRAMBACH, 1993; ROGERS, 1995).

The probability of adoption of an innovation will depend on the degree to which the supplier is able to develop an innovation that is unique and meets the specific (latent) needs of potential adopters (ROGERS, 2003; FRAMBACH et al., 1998). While this may seem obvious, the authors indicate that most innovations fail because of the inability to be perceived by potential adopters as actually meeting a known problem. Frambach (1993) reinforces the importance of the view of the supplier since the rejection may well come from the fact that the innovation management process was inadequate on the part of the supplier, not understanding for example the needs of his client.

This understanding of customer needs and environments encompasses external and internal business issues, or ***adopter-side variables***. The **"external dimension"** encompasses issues that, although external to the firm, are capable of influencing the adoption of an innovation, such as the requirement of suppliers or customers (FRAMBACH and SCHILLEWAERT, 2002) , the influence of other companies in the market that have already adopted the technology, whether of the same segment or not (Porter, 2014; FRAMBACH, 1993, FRAMBACH et al., 1998; FRAMBACH and SCHILLEWAERT, 2002), the existence of government laws regulating the use of the technology (HALL and KAHN, 2002) and the reputation of supplier companies (EASINGWOOD and BEARD, 1996). All of these can raise the degree of confidence in the technology innovation by the company eventually interested in adopting it.

On the other hand, the **"internal dimension"** includes operational issues of the company that can influence positively or negatively the adoption of the technology. Some examples include coherence with the objectives of the organization and consequent executive support as well as alignment with other business areas (Porter, 2014; LILIEN and YOON, 1989), the existence or not of technical competence (knowledge of technology, design and operation capacity of the technology) and managerial (administrative processes associated with the acquisition, development and maintenance of technical skills) in the company (HALL and KAHN, 2002), the role of data security in the company and if there is a specific policy, as well as its impact (ATZORI et al., 2010; MIORANDI et al., 2012; SWAN, 2012; SUNDMAEKER et. al, 2010) and the ability to use the same technology in other areas of the company (NEMOTO, 2009; PORTER, 2014; LILIEN and YOON, 1989).

In other words, the perception that the innovation was developed to address an important issue for the potential adopter, or how much the innovation is perceived to fit the specific needs of the organization, can have a major impact on the success of a given innovation, influencing its probability of adoption (FRAMBACH et al., 1998). For a more detailed analysis, it is necessary to observe the attributes or characteristics of the innovations (as perceived by those who adopt). The factors related to the “**technology dimension"** are organized in table 1, and the authors generally agree that there is a direct relation between a positive perception by the company regarding a certain factor and the probability of adoption success, as described below. Given the complexity of the IoT technology and the fact that many of its components are still in the process of maturation, we opted in this paper to give special emphasis to the "technology dimension" and its respective factors. In the case studies discussed here, an in-depth analysis of the variables of the model was made, allowing for a more detailed understanding of each factor and its relation to the adoption decision.

Table 1 - Technology Dimension Factors

TECHNOLOGY FACTORS	DESCRIPTION OF THE FACTORS	AUTHORS
Possibility of experimentation	The possibility of testing the technology in the enterprise environment may have a positive relationship with adoption, while the inability to test the technology in question may have a negative relation to adoption	Rogers (2003); Tidd et. al (2009)
Competitive advantages	Adoption of technology can bring competitive advantages of different natures: differentiation (products, services, brand) and / or efficiency (cost reduction, process improvement), and in both cases can have a positive relation to adoption; the lack of competitive advantage can have a negative relation to adoption	Rogers (2003); Porter (2014); Frambach and Schillewaert (2002)
Uncertainty and risk	The uncertainty arising from the difficulty of visualizing or understanding the results/benefits of adopting a technological innovation may have a negative relation to adoption	Rogers (2003); Frambach and Schillewaert (2002)
Information about the technology	The availability of good quality information about the technology in question may have a positive relationship to adoption, while the unavailability or doubt about the origin of the information may have a negative relation to the adoption	Rogers (2003); Fichman (2002); Frambach and Schillewaert (2002); Framtach et al (1998); Easingwood and Beard (1989); Huizingh (2011); Ritter and Genunden (2003)
Complementary solutions	The existence of solutions that complement the technological innovation being adopted can have a positive relationship to adoption, while non-existence can be perceived as something that limits the future potential of the innovation, thus having a negative relation to adoption	Frambach et. al (1998); Chesbrough (2003); Hall and Kahn (2002); Moore (1997);Ritter and Genunden (2003)
Network effect	The existence of a network effect, where the value of a technological innovation grows as the number of users of the technology grows (eg telephone, email, etc.), may have a positive relation to adoption	Hall e Kahn (2002);
Standardization and interoperability	The stage of standardization and interoperability between suppliers / parts / components may have a positive relationship to adoption. In other words, high standardization has a positive impact while low standardization has a negative impact by limiting interoperability	Chesbrough (2003); Easingwood and Beard (1989); Ritter and Genunden (2003); Porter (2014)
Compatibility / complexity	The possible impact of compatibility with existing systems and the possible complexity associated with their integration with the new technology. In other words, the need for adaptations or complex changes in the infrastructure and systems to integrate the new technology may have a negative relation to adoption, while the high compatibility and low complexity may have a positive relation to adoption	Rogers (2003); Atzori et. al (2010)

Source: authors based on bibliographic review

4 METHODOLOGY

Given the nature of the technology whose adoption is the object of this study, we opted for two case studies, exploratory and qualitative in nature. For Gil (2006), the greatest usefulness of the case study is verified in exploratory researches and for its flexibility; it is also recommended in the initial phases of an investigation on complex subjects, being this one of the main reasons for the option of the exploratory case study approach for this research. There is also the issue of the contemporaneity of the theme, where the factors that influence the decision to adopt the technology are still not clearly identifiable, justifying the execution of a deep and exhaustive study of few objects, allowing for their comprehensive and detailed exploration. The result of the research can thus contribute to the elaboration of future theories, as indicated by Eisenhardt (1989).

The Internet of Things technology, like most ICT technologies, is not restricted to a single type of application or market segment that can be used to define the target population. Although there are market segments with higher potential for early adoption (energy, logistics, health, etc.), the population is too broad. Consequently, the identification and selection of the cases was made based on three main criteria: (1) the use of IoT technology in an application considered typical according to the bibliographic review; (2) cases should be related to adoption in the business market, not consumer market, regardless of the segment; (3) the company should have already made the decision to adopt the IoT technology, although the project could still be in the implementation phase. It was also a relevant factor in the choice of cases the possibility of the researcher to have access to at least 2 people (in each case) who had participated in the adoption decision.

The interview was the main technique used to collect primary data, and the instrument chosen was the semi-structured interview script used with the people involved in the decision to adopt the IoT technology. Together with the interview script, a table describing the factors and dimensions was used to facilitate the understanding of the model and help improve interview productivity. Both were elaborated based on the conceptual model and duly tested, being the improvements incorporated in the final tool for data collection. The pre-test of the interview script was carried out with 2 market executives (companies providing information technology solutions) and one academic, all of them in person and with an average duration of 1 ½ hours. Further details on the interviews carried out in each company are presented in the description and analysis of the cases.

The information collected during the interviews was complemented by documentation presented during the discussions, including descriptions of the projects, follow-up reports on the decision process and implementation plan of the chosen solutions.

5 DESCRIPTION OF THE CASE STUDIES AND ANALYSIS

For this research, 2 companies were selected to conduct the case studies. The companies and their profiles are presented in the section below and for confidentiality the names have been replaced by Company A and Company B. Interviews were conducted between March and July 2015. In the following sections, there will also be an overview of how the 4 dimensions influenced the adoption decision, a detailed analysis of the technology decision factors, and a brief comparative analysis between the two cases.

5.1 Companies in the case studies

Company A belongs to the electricity supply segment and is implementing a pilot project of smart grid. The choice of this case is justified because this is one of the segments considered of prime applicability for IoT solutions since these offer significant benefits both for the company and for its customers (ATZORI et al., 2010; PORTER, 2014). In November 2014, the company announced a USD 30 million project under the smart grid concept, which provided for the installation of 62,000 smart meters in the city of Barueri, metropolitan region of São Paulo, Brazil. The project, funded by Finep (an organization of the Brazilian federal government devoted to funding of science and technology projects), directly impacts 250,000 people and involves agreements with suppliers such as Cisco Systems, WEG, Siemens and Itron. The completion of the smart reader deployment was expected by the end of 2017, and the completion of the project by the end of 2018.

For the smart meters, among the important innovations are the ability to communicate using radio frequency technologies (transmission of information over a wireless network) and Power Line Communication (protocol using the electric cable itself for data transmission). In addition, this is the first open-standard communication project developed by an energy company in Brazil. The use of open standards allows for the interoperability among multiple smart meter manufacturers.

The “Intelligent Networks” project, as it was named by the company, represents a new way of managing the electricity grid with significant improvements in the automation of operations and capacity planning of the energy networks of Company A, via a new and centralized Distribution Operations Center. For customers, the company highlights the ability to track consumption daily, through the company's website or mobile and tablet applications (better ability to manage expenses) and possibility of receiving automatic notifications when there are network problems. For the network operation, the project enables automatic fault detection and remote repair (lower cost, faster), while also improving the prevention of network problems. Additional benefits of the Smart Grid deployment include the prepayment of the electric bill (as done with mobile phone services), the large-scale micro-generation of renewable energy and the application of a differentiated rate according to the time of day of the energy consumption.

For the data collection, 4 people from 2 different organizational groups were interviewed. The interviewees of the measurement group were the "Intelligent Networks" project leader and one of the engineers involved in adoption decision for the technology deployed in the project. In the governance group, interviewees were the coordinator and one of the engineers responsible for the project in that team. In addition to team members in Company A, the IoT solutions manager from the leading provider of smart meter technology (Cisco Systems) was also interviewed. The interviews with the company were all face-to-face and with an average duration of 1 and a half hours each. The interview with the supplier was by telephone and lasted 1 hour and a half.

Company B is a multinational organization in the telecommunications segment. The choice of this case is justified because telecommunications companies play a fundamental role in the development of the Internet of Things ecosystem for the business market (ATZORI et al., 2010; PORTER, 2014). In this case, the company has as one of its strategic directives to grow offering services that make its communication infrastructure more valuable (or of greater added value) for its clients. The Internet of Things offers the potential to develop new solutions to meet specific needs of customers and uses as a base a telecommunications network. Therefore, IoT presents itself as an important technology for the company to achieve its goal of creating new products and services with higher added value, thus differentiating itself in the market. Given that IoT technology is still somewhat a novelty, the company opted for a strategy of creating an ecosystem of development of new products and services. The following is a brief description of the key components of this strategy:

- Fostering the ecosystem of IoT solution developers by creating and delivering development kits at specific events. The company today offers 4 different kits: basic kit (brightness, contact, temperature and light sensors), 3G / 4G kit (expands the functionality of the basic kit with 3G and 4G communication), wearable kit (small and packaged as a clock, with temperature sensors, humidity, accelerometer, a buzzer (sound), and LEDs for messages, with *Bluetooth Low Energy* connectivity), and connectivity kit (communication gateway that allows interaction between different communication architectures and devices);
- Partnerships with universities, such as master's and doctoral scholarships at FEI and USP, in addition to classes on IoT technology at Mauá University, all in the city of São Paulo, Brazil;

- Initiatives to develop solutions for problems in client companies using concepts of open innovation, where the client company brings a real problem for which it seeks a solution and Company B articulates internal resources together with the universities and other suppliers in the market for the creation of a "proof of concept" that meets the specific needs indicated by the client company.

- Prototyping solutions for *intelligent cities*, where several typically verticalized solutions can interact within a single platform. The company has been developing this concept in the city of Aguas de São Pedro, in the state of São Paulo, Brazil, implementing a set of solutions based on the IoT concept in the areas of education, tourism, health and public management.

For the data collection, three people were interviewed: the manager of the innovation center, the technical leader of the innovation center and the leader for Internet of Things solutions focused on smart cities. The interviews were all face-to-face with an average duration of 1 and a half hours each.

5.2 Overview of the model dimensions in the case studies

Table 2 summarizes the applicability and influence of each of the dimensions discussed in the literature review when applied to both case studies, thus meeting the first objective of this paper.

Table 2 - Synthesis of the dimensions of the model applied to the cases studied

	Synthesis - Company A	Synthesis - Company B
EXTERNAL DIMENSION	The external dimension had a weak influence on the adoption decision. Because the company has taken a leadership position in a typically conservative sector from the standpoint of technological innovation, it has influenced more than it has been influenced by entities inside and outside the value chain. The reputation of the chosen suppliers to participate in the design of the project and after the implementation was the factor that had the greatest relative importance in this dimension.	The external dimension had a balanced influence on the adoption decision since the main direction or impulse came from the internal dimension through the need to seek new growth opportunities for the company. Government regulation, however, plays an important role both in the core business (telecommunications) and in one of the major areas of future expansion (smart cities). This was, along with the supplier reputation, one of the main factors that positively influenced the adoption of IoT technology.
INTERNAL DIMENSION	The internal dimension had a strong relevance in the adoption decision. The strong strategic alignment was fundamental for the correct allocation of internal resources and the search for external financing resources, thus allowing the creation of so-called "technology blocks". Given the need to integrate the benefits of the new solution into the company's current operation in the short and medium terms, a key factor was the need to adapt the current infrastructure, both physically for the implementation of new meters and logically for integration with existing management systems.	The internal dimension was of great importance in the adoption decision, starting with the strategic direction of making the company a "Digital Telco". Since the demand and consequent market size for a telecommunications operator is determined and limited by the license and operating territory, the only way to expand this market is through new services that increase the value of the network / communications infrastructure to the company's customers. IoT technology plays a key role in creating these opportunities for additional value generation for current and new customers, since the "isolated" or plain offer of communication service makes the company less competitive.
TECHNOLOGICAL DIMENSION	The technology dimension had a strong influence on the adoption decision in Company A. The most important factor was standardization, which is one of the key issues in the adoption of IoT solutions given the high fragmentation of ongoing initiatives trying to create standards in the market. Because the architecture was designed to be multi-vendor, this issue was critical in the adoption decision.	For Company B, the technology dimension also had a strong influence on the adoption decision. As the main objective is the generation of new opportunities to add value to the communication infrastructure for current and new customers, the "network effect" was considered the most important factor since more customers and devices transmitting more data over the network increase the possibility of generating value. The "complementary solutions" factor also had a strong influence on adoption by aligning with the constant search for synergistic opportunities between the company's IoT platform and solutions to the specific needs of customer problems.
SUPPLIER DIMENSION	The supplier dimension did play a role to identify viable alternatives of supplier companies, but the definition / specification of the project and its parameters was made by the company itself with the collaboration of multiple entities, including research centers and suppliers, and not only by influence of a single supplier. In fact, there were well-know suppliers who preferred not to participate in the project because of the architecture based on open standards and that enabled interoperability / interchangeability.	The supplier dimension in this particular case study was analyzed taking into consideration the company in the role of provider of IoT technology. The two factors that the company perceives to be of greater influence in the adoption by the clients are market support and risk reduction. Positioning factors and perception of adequacy are perceived as having weak influence because of the strategy of how the company offers the solutions, as detailed in the case study.

Source: authors

The next section will provide a more detailed analysis of each factor related to the technology dimension in the respective use cases.

5.3 Analysis of the Technological Factors for the Cases Studied

5.3.1 Possibility of experimentation: the possibility of testing the technology can be a motivating factor for its adoption, given the risks involved in any project.

For Company A, the possibility to create a proof of concept was fundamental in the decision to go ahead with the design and adoption of the technologies in question. Rogers (2003) points out that this factor has a positive relation with the adoption decision and that during the experimentation it is common to have adjustments in the innovation so that it better suits the needs of the company, this being a reality in this case (project concept defining the parameters of how the parties should interact in a multi-vendor environment). Another point indicated by the author is that this factor seems to be more relevant to the early adopters, a position clearly chosen by the company for this project.

In the case of Company B, this factor had a very strong influence on the adoption decision since the company first started exploring the idea using IoT technologies. The experimentation was part of the learning process for the development of the *Fiware cloud solution*, which became a key part of the technology portfolio offering of the company, as well as the IoT kits developed in Brazil. Rogers (2003) highlights the positive relationship that exists in experimentation and adoption of a new technology. The author also refers to the concept of creating an innovation that is easy to be experienced, and this can be clearly observed in the creation of development kits whose objective is precisely to enable experimentation by the solution developers.

5.3.2 Competitive advantages: when the adoption makes it possible for the company to achieve market differentiation in its offerings and improve its brand perception, and / or efficiency gains that result in an improved product / service offer.

This was the only factor with very strong influence for both companies studied. In the case of Company A, the main motivation of the project was to adapt the operation to the needs of the Brazilian market, aligned with global trends, seeking product improvements (energy supply) and enabling the conversation with the customer. The idea is that the technology is used to improve the quality of the service offer reducing costs and improving the overall offer of the company. From a differentiation stand-point, customers have access to information about energy consumption in real time and are notified automatically in case of system failures / interruptions. With regards to efficiency, customers can generate their own energy and return surplus to the grid (ability to integrate micro-generation of energy), as well as automatic fault detection and the possibility of remote repair, which in addition to be a preventive feature of the system, also reduces the cost of repair and increases the speed of response to the customer. Porter (2014) emphasizes that solutions based on IoT can significantly affect the competitive structure of an industry or market segment. The high degree of innovation of the solution defined in the "Intelligent Networks" project seeks both efficiency (reduced losses and improved operational costs) and differentiation (improved quality of customer service). These benefits fit into what Rogers (2003) calls economic factors of relative advantage, and this is one of the ways in which the value of innovation can be perceived by the adopter. Frambach and Schillewaert (2002) also identify a positive relationship between this factor and the adoption decision.

For Company B, the main advantage sought was differentiation, since IoT technology is one of the pillars of the company's strategy to become a telecommunications operator that adds more value to its solutions, thus gaining market share from competitors that offer only the communication infrastructure. This positive relation with the adoption decision is indicated by Frambach and Schillewaert (2002) as being true and the differentiation in the market is one of the main motivators in the decision to adopt IoT according to Porter (2014). It is clear in the case of Company B what the author has referred to as the capacity that IoT-based solutions may have to significantly affect the competitive structure of an industry or market segment, once it fundamentally shifts the service offering references for telecom companies. The concept of relative advantage indicated by Rogers (2003) also applies to this case since the innovations associated with IoT technology enable the company's customers to participate in the creation of solutions that up until now were unavailable, such as the concept of smart cities.

5.3.3 Uncertainty and risk: difficulty in visualizing results.

For Company A, the issue of risk of project implementation had a strong influence and was always treated as parts/segments, from the client to the network. The main risk to be addressed in this case was the eventual inability to access the meter for reading (information capturing) and consequently contingencies were created. For example, collecting information from the meter would be done in an automated (remote) or manual way, the latter being the process in place today. In the case of remote data collection, this would be via radio frequency (RF) or PLC (power line communication - through the power grid itself). For wireless communication (RF) there would also be two alternatives, via Wimax technology (main method) or GSM / 3G cellular technology (alternative method). In other words, the project always contemplates mechanisms to minimize the risks of operation, thus facilitating the adoption decision. For Rogers (2003), every innovation brings a degree of uncertainty associated with the novelty introduced and this has an impact on the adoption decision. Regarding the five stages indicated by the author as part of the decision process (knowledge, persuasion, decision, implementation and confirmation), the example above shows how the company dealt with uncertainty in the decision and implementation stages.

Company B is seen in the market as being very conservative regarding risk and always seeks to minimize or eliminate risks in new projects. To achieve this goal, every project goes through a thorough and intense process of ratification of the business plan. When the technology was evaluated at the company’s headquarters, this factor had a very strong and positive influence because of the scope that the technology would have in other business areas, contributing significantly to the goal of making the company a "digital telco". Since the decision made at headquarters had already undergone this rigorous analysis, the same was not necessary in Brazil. From a local point (at the Innovations center), this factor had weak influence. This variation of risk perception is consistent with Rogers's (2003) view, where every innovation brings a degree of uncertainty associated with the novelty introduced and this has an impact on the adoption decision process. Regarding the 5 stages indicated by the author as part of the decision process (knowledge, persuasion, decision, implementation and confirmation), the example above shows how the company dealt with the uncertainty of the stages of knowledge, persuasion and decision.

5.3.4 Information about the technology: the availability of information about the technology can influence the decision-making capacity for adoption.

This was the only factor with strong influence for both companies studied. Company A's R & D projects are always linked to external centers of excellence, such as the University of São Paulo (knowledge of the electrical grid) and other non-profit research organizations for the telecommunications part of the solution. All parties assisted in prospecting and research, and were led by a team from Company A itself – this is currently established as part of the innovation process in the company. Thus, once the framework of the project was formed and specific elements of the solution were defined, the company sought suppliers to meet those needs. In other words, the information theme had a strong influence on the adoption decision, and the mechanisms used to obtain the information were both internal (innovation team) and external (universities, research centers, suppliers). This alignment between internal and external resources is consistent with the open innovation mechanisms indicated by Ritter and Genunden (2003) and Chesbrough (2003), and is highly dependent on what Frambach (1993) defined as "absorption capacity", i.e. the existence or not of the technical / managerial competence to process and consequently absorb the available information to generate value for the company during the decision-making process.

In the case of Company B, the high relevance of this factor was always present from the beginning of the project. The high availability of information at headquarters and the exchange of experiences with the innovation center in Brazil was a facilitating element in the decision making. In general, one of the main sources of information was the developer communities using the Fiware cloud solution and the tools to assist in deploying the solutions built on this platform. As already seen in the previous case, the availability of information played an important role and had a strong influence on the adoption decision, which is reinforced by Frambach (1993) regarding the probability of adoption of an innovation (increases according to the availability, quality and value of available information). The author also highlights the role of the supplier and its marketing strategy, which appears clearly in this case. It is interesting to note that in this case study the company's "absorption capacity" for information (FRAMBACH, 1993) was quite high because of the already developed competence at headquarters. Another point that applies to this case is the exchange of knowledge in the developer network (users of the IoT kits and the Fiware cloud solution). One of the areas where the company seeks to apply concepts of open innovation is precisely in the exchange of information with the community of developers, what Huizingh (2011) called information flows (*inbound* and *outbound*), where the company both educates the market (*outbound*) and learns from the solutions developed (*inbound*).

5.3.5 Complementary solutions: the existence of solutions that complement the innovation adopted can influence the decision.

The influence of this factor was weak for Company A, although there was a perceived benefit, albeit indirect. For example, the creation of a communication infrastructure that can be shared with other services in a city. In other words, it was not a critical success factor in designing the project itself, but the potential for complementary solutions could have a positive impact today.

Unlike Company A, the influence of this factor was very strong for Company B given the need to make its cloud solution as attractive as possible to potential customers. Additionally, the idea is for independent developers to use IoT kits to create solutions that address specific market problems, thereby increasing market opportunities for both the developer company (only needs to focus / invest in the development of the specific solution, without worrying about the infrastructure) and for Company B (does not need to try to serve the entire market, and therefore can focus only on its core competencies: telecommunications and, in the IoT case, make the cloud solution available to all companies, be them developers or end-customers). Another way of creating complementary solutions is through open innovation projects with clients seeking solutions to specific problems, as was the case with the company Natura and the project of remote monitoring of temperature and humidity in fruit drying mats in the Amazon. This complementarity of solutions using internal and external knowledge is at the core of what Chesbrough (2003) called open innovation. For the author, the challenge for companies is to precisely select what they should focus on while developing partnerships that can extend their ability to reach new markets, providing more complete solutions for a wider range of customers. An area where Company B has invested a lot of time and resource in is the development of what Huizingh (2011) calls open innovation processes. That is, searching for ways to systematize the interactions with the developer companies so that this work becomes something that grows in scale in an organized and constant way, not being done only reactively for isolated opportunities.

5.3.6 Network Effect: the value of innovation grows as the number of users of the technology grows (ex: telephone, email, etc).

This factor had a strong adoption influence for Company A when looking at the med-term. An example is the perspective of cost reduction of parts/equipment as more companies in the ecosystem adopt the technology. The company adopted an innovative and leading position in a traditionally reactive market in the generation of innovations, which generated a movement in the market and similar projects were developed by other companies, such as Light and CPFL (energy companies in other states in Brazil). The perception of value by end-customers also generates a positive spiral of demand for new benefits that consequently become part of the standard service offered by the company, thus generating competitive pressure in the market.

The influence of this factor was very strong for Company B as well and is directly related to the previous factor. In a certain way, enabling the “network effect” is part of the IoT strategy of the company, and consequently this was the most important factor for the company. The more devices generating data in the Company B network, and connecting to the cloud solution (Fiware), the greater the possibility of generating value to customers, thus differentiating itself in the market. This is a case where the network effect can be either direct or indirect (HALL & KAHN, 2002). The effect is direct when the value of the innovation increases as the number of users increases, for instance a solution based on the "wearable" IoT kit; or indirect, when the growth of the network of users generates benefits for all users, in this case taking as an example the potential of insights coming from the cloud solution (Fiware) as the amount of information from clients grows, allowing even cross-pollination between customers (when duly authorized by them).

5.3.7 Standardization and interoperability: the existence of market standards and the capability for multi-vendor solutions to function interchangeably may facilitate the adoption decision.

From the point of view of Company A, this was the most influential factor in the adoption decision for the technology dimension. The definition of the project had as a basic premise the interoperability / "interchangeability" between the suppliers. The architecture was defined based on adopted market standards and these were the basis for the specification of the parts to be used in the project. As an example, the communication architecture definition was based on the architecture proposed by Cisco Systems and implemented by the 3 meter vendors, all adhering to the open communication standard (Siemens, Itron and WEG, selected among 9 candidates).

It is interesting to note that for Company B, this factor had no influence on the adoption decision. Considering that the effort to create market standards for the communication aspect of the sensors was already well advanced, the company created the IoT kits using the main standards and included in its portfolio the gateway as one of the kits. This gateway translates the different communication protocols that a particular solution will need and thus increases flexibility for the developers. In terms of interaction with the cloud solution, the company also used a strategy to build on key available standards when it specified Fiware (e.g., security protocols). In fact, most IoT solutions that connect to the company's cloud solution will indeed be multi-vendor, but the company does not understand that this is a limiting factor today in its ability to develop new markets and find differentiation. This strategy is in line with Easingwood and Beard's (1996) view that the launch of high technology solutions had the potential to accelerate the development process and ratification of standards, thus increasing the chances of success and adoption of innovations in the market.

5.3.8 Compatibility / complexity: need for adaptations and modifications in the company's information system and infrastructure.

This factor had a very strong influence on the adoption decision for Company A. The IT support team was responsible for the issues related to interfaces with existing systems, as well as information security issues. The influence of this factor was positive despite the high complexity of integration, that is, it helped determine the prioritization of IT resources for project execution. Atzori et al. (2010) indicate the importance of the current effort to standardize the various elements that make up an IoT solution, precisely because of the extremely important role they will play in reducing the complexity of the integration process with existing systems. Without this integration, the capacity to generate value becomes limited (Porter, 2014), significantly reducing the potential for introducing efficiencies and creating competitive differentiation. Rogers (2003) indicates that this limitation directly translates into the rate of adoption of an innovation, in the context of the social system studied. Rogers (2003), like Porter (2014), associates the ability to perceive an advantage brought by the innovation to this capacity to integrate it relatively quickly (less complexity) and effectively (high compatibility).

This factor was also relevant in Company B and had a strong influence on the adoption decision. The communication network of Company B is closed due to security of customer / subscriber data. The IoT solution needs to be integrated with legacy enterprise systems, either for creating vertical solutions or simply integrating with the customer database. This complexity is high and was taken into consideration when deciding on issues related to the cloud solution (Fiware). In other words, although the integration is complex, it is fundamental for the solutions to generate the expected value and have impact on the business (new opportunities). This integration with the existing legacy systems in the company and its value chain is a key step according to Porter (2014), otherwise there will be great internal and external resistance to the solution, thus delaying the adoption process. This same issue is observed by Rogers (2003), indicating that the internal perception of compatibility (ability to integrate with what already exists) and complexity (effort required to perform this integration) has an impact on the rate of adoption of a technology.

5.4 Comparative analysis of the cases studied

The technology factor had a strong influence in the 2 cases, but for different reasons. The issue considered to be of greatest influence for Company A is not perceived as having influence for Company B (standardization / interoperability). This variability is perfectly normal since the objectives and adoption capacities of the companies are different (FRAMBACH & SCHILLEWAERT, 2002). Even with this variation, it is observed that the information factor exerts a strong influence on the two companies, as it has been observed extensively in the literature (FRAMBACH et al., 1998), FICHMAN (2002), FRAMBACH & SCHILLEWAERT (1998), and Ritter & Gunden (2003)). It is interesting to note what Frambach (1993) called the capacity for information absorption, which refers to the capacity of the persons responsible for making decisions regarding the adoption of the innovation to comprehend (or process) information. When this capacity is high, the availability of relevant information positively affects the adoption decision. In cases where this capacity is limited, particularly for emerging technologies, this role can be delegated in part to suppliers who have a strong reputation as technological leaders, reinforcing the role of this dimension (external dimension) and in agreement with Easingwood and Beard (1996). The other two factors that consistently had strong or very strong influence were competitive advantages and network effect. Porter (2014) speaks of competitive advantages brought by IoT technology in efficiency and / or differentiation, being differentiation the one with greater impact in the 2 cases. For Company A in particular, there is what Rogers (2003) calls the relative advantage (smart meters accessed remotely versus sending someone to read it), which enables both differentiation through new services (Internet access) and significant gains in efficiency, thus validating the author's view. The network effect indicated by Hall and Kahn (2002) is present in the cases via the expectation of future importance of the technology as its adoption increases in the market, thus validating the pioneering strategy by the companies studied here. The compatibility and complexity factor, on the other hand, has a challenging relationship with adoption, and cannot be considered merely negative for two reasons: the high complexity of integration with existing systems and the compatibility issues brought by the emergent nature of technology. In the interviews, it was possible to observe what Rogers (2003) pointed out to be natural: a certain acceptance of the fact that complexity is inevitable for new technologies, but this is not necessarily perceived as a negative thing.

6 FINAL CONSIDERATIONS

The idea of developing a model to evaluate the adoption of innovations based on IoT proved to be important and of great value for the companies studied. This feedback was consistent on the part of all interviewees when analyzing how the dimensions of the model applied to the adoption decision in the cases evaluated, thus achieving the first objective of the paper. The detailed analysis of each of the factors in the technology dimension allowed for a deeper understanding of the theme and a better comprehension of how these factors can influence the decision to adopt this type of technology, thus achieving the second objective of the paper.

Throughout the research, it was observed that all the factors can have a positive or negative relation with the decision of adoption, depending on the context of the case being analyzed. This contextual aspect makes the choice / definition of the type of relationship (whether positive or negative) highly subjective, and this is a limitation of the research. Regardless of the influence on the decision, the factors were relevant in the analysis process. In particular, in the case of the technology dimension, this subjectivity becomes softened by the fact that the factors seek to focus on more practical aspects of the technology adopted. Nevertheless, this subjectivity is always present and needs to be managed by other methods contemplated in the decision-making process of a company, which is not part of the scope of this research. The factors selected for the technology dimension are aligned with the issues perceived as key to the decision to adopt IoT technology in its present stage of development.

From an academic point of view, this research contributes to enhance knowledge in the area of adoption of technological innovations validating already established concepts and illustrating how some of these concepts apply to a set of technologies currently initiating their adoption curve. Among the contributions are:

• The proposal of a model to assist in the analysis of the adoption of the Internet of Things, focusing on the business market. This is a segment that has had little academic exploration in terms of adoption of technological innovations.

• Application of the model in real case studies and analysis of factors considered more relevant and capable of contributing to the adoption decision process in the chosen theme, which may later be used for other studies.

• Description of the adoption of IoT technology in the companies studied

For the practice, the research has as its main contribution a better understanding of the factors that influence positively or negatively the decision to adopt a technological innovation, in particular insights on issues related to the decision to adopt IoT technology.

For future studies, in the bibliometric analysis carried out by the authors as part of the initial work of this research, it was identified that there is a low number of articles at the intersection of the themes *Internet of Things* and *business models*. Alternatives for future studies also include: the execution of a complementary quantitative research, enabling the triangulation of methods and increasing the reliability of the research; identify new cases in other market segments, with the possibility of comparing the adoption in companies of the same segment; include in the model the return-on-investment analysis of an IoT solution for a particular organization.

7 REFERENCES

Atzori, L; Iera, A.; Morabito, G. The Internet of Things: A survey. *Computer Networks*, 2010. Volume: 54 Issue: 15.

Cianci, I.; Piro, G.; Grieco, L.; Boggia, G.; Camarda, P., 2012. Content Centric Services in Smart Cities. *2012 Sixth International Conference on Next Generation Mobile Applications, Services and Technologies*, IEEE.

Easingwood, C.; Beard, C., 1996. High Technology Launch Strategies in the U.K. *Industrial Marketing Management* 18(2), p.87-103

Eisenhardt, K., 1989. Building Theories from Case Study Research. *Academy of Management Review*, v. 14, n. 4, p. 532-550.

Fichman, R., 1992 Information Technology Diffusion: A Review of Empirical Research. *MIT Sloan School of Management*, June.

Frambach, R.; Schillewaert, N., 2002. Organizational innovation adoption A multi-level framework of determinants and opportunities for future research. *Journal of Business Research*, 55, p. 163-176

Frambach, R., 1993. An integrated model of organizational adoption and diffusion of innovations. *European Journal of Marketing*, 27, 5, p. 22-41

Frambach, R.; Barkema, H.; Nooteboom, B., 1998. Wedel, M. Adoption of a service innovation in the business market: an empirical test of supply-side variables. *Journal of Business Research*, 41, p. 161-174

Hall, B.; Kahn, B., 2002. Adoption Of New Technology. *New Economy Handbook, National Bureau of Economic Research*, November.

Han, D.; Zhang, J.; Zhang, Y.; Gu, W., 2010. Convergence of Sensor Networks/Internet of Things and Power Grid Information Network at Aggregation Layer. 2010 *International Conference on Power System Technology*, IEEE.

Huizingh, E., 2011. Open innovation: State of the art and future perspectives. *Technovation*, 31, p. 2-9

Miorandi, D.; Sicari S.; De Pellegrini, F.; Chlamtac, I., 2012. Internet of things: Vision, applications and research challenges. *Ad Hoc Networks*, 10, p. 1497-1516

Porter, M.; Heppelmann, J., 2014. How smart, connected products are transforming competition. *Harvard Business Review*, November, p. 65-88

Ritter, T.; Genmunden, 2003. H. Network competence: impact on innovation success and its antecedents. *Journal of Business Research* 56(9), p. 745–755.

Rogers, E., 2003. Diffusion of Innovations, 5th Edition. New York: The Free Press.

Ruban, J., 2010. Review of Wireless Technologies for the Smart Grid. *8th International Symposium "Topical Problems in the Field of Electrical and Power Engineering"*, Pärnu, Estonia, January 11-16.

Sundmaeker, H.; Guillemin, P.; Friess, P.; Woelfflé, S., 2010. Vision and Challenges for Realising the Internet of Things. *CERO-IoT (Cluster of European Research Projects on the Internet of Things)*, March.

Swan, M., 2012. Sensor Mania! The Internet of Things, Wearable Computing, Objective Metrics, and the Quantified Self 2.0. *Journal of Sensor and Actuator Networks*, 1, p. 217-253

TEECE, D.J., 2010. Business models, business strategy and innovation. *Long Range Planning*, 43(2-3), pp. 172-194

Tidd, J., and Bessant, J.R., 2013. Managing innovation: integrating technological, market and organizational change 5th Edition. Chichester: Wiley.

Tornatzky, L., Fleischer, M., 1990. The Processes of TechnologicalInnovation. Lexington: Lexington Books.

Wu, G.;Talwar, S.; Johnsson, K.; Himayat, N.; Johnson, K., 2011. M2M: From Mobile to Embedded Internet. *IEEE Communications Magazine*, April.

Yu, X.; Cecati, C.; Dillon, T.; Simões, M., 2011. The New Frontiers of Smart Grids, an Industrial Perspective. *IEEE Industrial Electronics Magazine*, September.

Zanella, A.; Bui, N.; Castellani, A.; Vangelista, L.; Zorzi, M., 2014. Internet of Things for Smart Cities. *IEEE Internet of Things Journal*, Vol.1 No.1, February.

Zott, C.; Amit, R.; Massa, L., 2011. The Business Model: Recent Developments and Future Research. Journal of Management 2011, 37: 1019 originally published online 2 May.