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KNOWLEDGE MANAGEMENT IN IOT ECOSYSTEMS: HOW TO GENERATE INTELLIGENCE AND CONNECTIVITY

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São Paulo
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GESTÃO DO CONHECIMENTO EM ECOSSISTEMAS DE IOT: COMO GERAR INTELIGÊNCIA E CONECTIVIDADE

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Dissertação apresentada ao Programa de Mestrado Profissional em Administração: Gestão de Projetos da Universidade Nove de Julho – UNINOVE, como requisito parcial para obtenção do grau de **Mestre em Administração**.

Orientador(a): Prof. Dr. Luciano Ferreira da Silva

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Presidente: Prof. Dr. Luciano Ferreira da Silva – Orientador(a), UNINOVE

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DEDICATÓRIA

Dedico estudo é dedicado a minha família, principalmente a meus filhos pelo seu amor e compreensão, aos meus pais que sempre foram minha fonte de inspiração e a todas as pessoas que me encorajaram ao longo do caminho.

DEDICATION

This study is dedicated to my family, mainly my children, for your love and understanding, to my parents, who are my inspiration source and all people who encourage me along the way.

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“Aprender é a única coisa de que a mente nunca se cansa, nunca tem medo e nunca se arrepende”

“Learning is the only thing the mind never exhausts, never fears, and never regrets”

(Leonardo Da Vince)

KNOWLEDGE MANAGEMENT IN IOT ECOSYSTEMS: HOW TO GENERATE INTELLIGENCE AND CONNECTIVITY

Abstract

The Internet of Things (IoT) ecosystem brings a new perspective beyond the technology's discussions towards the creation of intelligence in an interconnected world. In this context, the main challenge is to create an environment capable of responding to the users and organizations in real-time. Thus, this research aims to develop a model to explore the relationship between IoT and KM to generate intelligence and connectivity in IoT smart ecosystem. The research design was divided into four phases. In the first, we conducted an exploratory and preliminary search based on 140 articles to understand the object of study. After this phase, we reached 92 articles from a Systematic Literature Review. As a result of these two phases, we mapped the IoT elements, including connectivity and intelligence, as well, we evidenced that IoT technologies can support KM, which we call KM enablers. Therefore, we found a lack of studies related to KM supporting IoT ecosystems. Thus, in the third phase, we proposed a model based on the intersection of the IoT ecosystem and KM literature. This model was composed of KM processes, KM enablers, IoT ecosystem, connectivity, and intelligence. In the fourth phase, we reviewed the model based on data collection and the in-depth interview method with 12 interviewees who have worked with IoT projects. After the analysis, as findings, we confirmed the data-centric or user-centric perspectives of the IoT ecosystems, the IoT elements, and the potential support of the KM process to enable the IoT ecosystem implementations.

Consequently, this study contributed with two new visions, which we call "Intelligence-Oriented" and "Value Add-Oriented". Besides, the importance of the use of KM processes, mainly the Knowledge Integration process and the role of a solution integrator for an IoT ecosystem more intelligent and connected. This integration brings the vital role of the project managers to cope with the complexity of this kind of project due to the need to manage the Knowledge to accomplish the project deliverables with internal and external stakeholders. Thus, in the IoT ecosystem, it is crucial to understand the business context, to have the know-how of the technologies, and know-how to integrate them and manage all the stakeholders.

Keywords: Internet of Things (IoT), Knowledge Management (KM), Intelligence, Connectivity

GESTÃO DO CONHECIMENTO EM ECOSISTEMAS IOT:
COMO GERAR INTELIGÊNCIA E CONECTIVIDADE

Resumo

O ecossistema da Internet das Coisas (IoT) traz uma nova perspectiva além das discussões da tecnologia em direção à criação de inteligência em um mundo interconectado. Nesse contexto, o principal desafio é criar um ambiente capaz de responder aos usuários e organizações em tempo real. Assim, esta pesquisa tem como objetivo desenvolver um modelo para explorar a relação entre IoT e Gestão do Conhecimento (GC) para gerar inteligência e conectividade a partir de um ecossistema inteligente da IoT. O desenho da pesquisa foi dividido em quatro fases. Na primeira, realizamos uma pesquisa exploratória e preliminar com base em 140 artigos para entender o objeto de estudo. Após essa fase, obtivemos 92 artigos de uma Revisão Sistemática da Literatura. Como resultado dessas duas fases, mapeamos os elementos da IoT, incluindo conectividade e inteligência, e evidenciamos que as tecnologias da IoT podem suportar a GC, o que chamamos de facilitadores de GC. No entanto, encontramos uma falta de estudos relacionados a GC apoiando os ecossistemas de IoT. Assim, na terceira fase, propusemos um modelo baseado na intersecção da literatura em ecossistema de IoT e GC. Este modelo foi composto por processos de GC, capacitadores de GC, ecossistema de IoT, conectividade e inteligência. Na quarta fase, revisamos o modelo com base na coleta de dados e no método de entrevista em profundidade aplicada em 12 entrevistados que tenham trabalhado com projetos de IoT. Confirmamos as perspectivas centradas em dados ou nos usuários dos ecossistemas da IoT, dos elementos da IoT e do suporte potencial do processo de GC para possibilitar as implementações do ecossistema de IoT. Assim, este estudo contribuí com duas novas visões, que chamamos de "Orientado a Inteligência" e "Orientado a Agregação de Valor". Bem como a importância do uso de processos de GC, principalmente do processo de Integração de Conhecimento e do papel de um integrador de soluções na formação e manutenção de ecossistemas de IoT inteligentes and conectados. Essa integração traz o papel vital dos gerentes de projeto para lidar com a complexidade desse tipo de projeto devido à necessidade de gerenciar o conhecimento para realizar as entregas do projeto com as partes interessadas internas e externas. Assim, no ecossistema de IoT, é crucial entender o contexto de negócios, ter o conhecimento das tecnologias e saber como integrá-las e gerenciar todas as partes interessadas.

Palavra-Chaves: Internet of Things (IoT), Gestão do Conhecimento (GC), Inteligência e Conectividade

SUMMARY

1. INTRODUCTION

Our world is becoming more and more digitized with interconnected objects and people. Each year, several new devices with increased capabilities and intelligence are introduced and adopted in the market (Cisco, 2018). The total value of spending with IoT will surpass one trillion dollars in 2022. In this direction, the IoT applications will reach an exponential growth of information, which accelerates the pace of its flow and the ability to process it and create value (Delloite, 2018). Therefore, we can set that a new form of information-driven organization is emerging, benefiting the information stemming from world digitization, such as the economies, industries, and our lives.

However, a challenge arises from this scenario, where the companies have to transform information into something useful to generate more value to the routines of the users and organizations (Gartner, 2018). We can say that this value could come from Knowledge, which will be necessary to apply Knowledge Management (KM) process to convert information into Knowledge.

On the other hand, IoT is evolving to integrate several technologies (Atzori et al., 2010). It should be viewed as an ecosystem, like a community of living organisms (humans and animals) and nonliving components (objects), interacting as a system in the same environment.

Therefore, KM can support IoT by obtaining and using resources to create an environment to store, interpret, structure, convert and share Knowledge continuously in real-time to create intelligence (Uden & He, 2017). Thus, the design of IoT and KM associated to a set of emerging technologies, such as Big Data, Cloud Computing, Artificial Intelligence (AI), and Blockchain, could support new ecosystems interconnected and collaboratively, to enable new capabilities for organizations, and unique experience for users (Miorandi et al., 2012; Santoro et al., 2018).

In the last decade, most of the KM researchers have been focused on the nature of Knowledge, how to create, and how to share and transfer knowledge to others (Gaviria-marin et al., 2018). Thus, when we chose IoT as the object of study, we found there are few studies related to knowledge transformation into wisdom (Rothberg & Erickson, 2017), or into intelligence (Jennex, 2018), or innovation (Tian, 2017). In this sense, there is an excellent opportunity for researchers and project management professionals to deal with the KM and IoT ecosystem to have a better understanding of the new environment and challenges, as the IoT project implementation can be considered a complex project due to the dynamic environment with the involvement of multiple stakeholders and multi-layers of cutting-edge technologies (Ghimire et al., 2017)

1.1 RESEARCH PROBLEM

The main challenge in the IoT ecosystem is to deliver and capture value to users and organizations by connecting technologies and corresponding players. All participants of the ecosystem should work to transform the enormous amount of data into an intelligence while they co-evolve in a dynamic relationship (Bello & Zeadally, 2019; Kolloch & Dellermann, 2018; Kubler et al., 2017; Miorandi et al., 2012; Uden & He, 2017). The advance of ubiquitous and pervasive computing concepts and solutions are bringing the need to have a “smart” environment to use the full potential of the integrated technologies (Al-Fuqaha et al., 2015; Miorandi et al., 2012; Zanella et al., 2014). Part of this challenge in the IoT ecosystem formation is the integration and management of all the stakeholders and the technologies, mainly due to the complexity of the project implementation (Miorandi et al., 2012; Murray et al., 2016; PMI, 2017).

This new reality is capable of responding to the users and organizations in real-time, enabling the interaction and support them with Knowledge and helping on carrying out specific tasks in an easy and fast way (Miorandi et al., 2012). Although there is evidence of increasing studies on the use of IoT, most of the literature is related to technologies. Some researchers are discussing IoT beyond the technology’s platforms (Papert & Pflaum, 2017). However, there are few studies on how IoT and KM could be useful to produce value (Bresciani et al., 2018).

Some authors showed the use of the IoT in KMS (Knowledge Management System) (Howell et al., 2018; Santoro et al., 2018; Shahpasand & Rahimzadeh, 2018; Uden & He, 2017; Yuen et al., 2018), as long as Bresciani et al. (2018) exploited theoretically how information and communication technologies support services in smart cities. Anum et al. (2018) proposed a model based on the combination of KM and AI.

Jennex (2018) presented a conceptual paper about the relationship between IoT, Big Data, Data, Information, Knowledge, and actionable intelligence. Tan et al. (2017) suggested an e-learning service model to support the life-cycle process management considering the learner´s behaviors. However, the literature still presents the discussion of the relationship between IoT and KM, focusing on IoT technologies, such as the study of Uden and He (2017). Additionally, other researchers propose conceptual models to convert data into Knowledge, but none mentioned how KM works with the IoT ecosystem to generate intelligence and connectivity (Porter & Heppelmann, 2014). Then, based on this gap, we propose to answer the following research question: How KM and IoT could generate intelligence and connectivity in the IoT smart ecosystem?

1.2 MAIN AIM

This study aims to develop a model to explore the relationship between IoT and KM to generate intelligence and connectivity in IoT smart ecosystem.

1.3 SPECIFIC AIMS

- Understand the relationship between IoT and KM in the literature;
- Explore how IoT support IoT smart ecosystem
- Explore how KM support IoT smart ecosystem;
- Analyze how intelligence create an IoT smart ecosystem
- Analyze how connectivity creates an IoT smart ecosystem.

1.4 REASONS FOR RESEARCH STUDY

IoT connects the virtual and physical worlds through the integration of several technologies (Atzori et al., 2010), supporting the generation of Knowledge in real-time to create new business models. There are several discussions about IoT technologies based on the Systematic Literature Review (SLR). We found nine papers of a total of ninety-two related to KM and the IoT ecosystem. This fact was identified by other researchers (Papert & Pflaum, 2017). Also, we identified the initial discussion about the relationship between KM and IoT ecosystem since there are only conceptual models about intelligence generation on IoT ecosystems.

The utilization of the Knowledge for value creation brings the development of KM, considering the human capital and its corresponding technologies (Anum et al., 2018). KM increases the speed of response with better knowledge access, supporting several types of applications and services, mainly associated with IoT (Lokshina et al., 2018; Uden & He, 2017). The KM researchers frequently use the well-known Data-Information-Knowledge-Wisdom (DIKW) model to explain how to move out from data to wisdom (Jennex, 2018; Lokshina et al., 2018), including Big Data (Jennex, 2018). However, in the real-time environment, the intelligence should be generated by a network of Knowledge using additional elements of KM Enablers and KM processes. The smart environment extract and exchange knowledge from multiple sources, supporting the integration and collaboration among objects, living beings, and organizations in real-time (Bresciani et al., 2018).

Therefore, the combination of IoT and KM capabilities should generate real-time collective Knowledge by the connectivity. They should enable actionable and personalized intelligence for each organization or user within a real, digital, and smart virtual environment.

Several initiatives are arising with the advance of the IoT technologies, but the challenges are to manage large-scale projects in different types of segments with several players, including the perspective of the end-users (Gubbi et al., 2013; Miorandi et al., 2012; Murray et al., 2016). Sometimes interacting in cross industries and countries programs (Kubler et al., 2017; Scuotto et al., 2016).

1.5 RESEARCH STRUCTURE

This study is organized in 6 Sessions. Session 1 is related to the introduction of the research theme, research problem, research objectives, and reason for this study and research structure. Session 2 covers the literature review with IoT definition, IoT ecosystem, business model and Innovation, IoT elements and KM and IoT. Session 3 presents the method used to search the literature and proposed method to explore the theme empirically. Session 4 shows the analysis of results and discussion based on the data collection. Session 5 reveals the contribution to practice. Session 6 presents the final remarks of the study with the limitations and future researchers and, finally, the list of the references used in this research. After the references, there are three appendices.

2. LITERATURE REVIEW

This session covers the literature review about IoT and KM. The concepts present allow understanding the ideas of the relationship between IoT and KM to build a Smart IoT Ecosystem.

2.1 IOT DEFINITION

The term IoT appeared at the Massachusetts Institute of Technology's AutoID lab, and it has been evolving since 1999. It was initially attributed to Radio-Frequency Identification (RFID) (Atzori et al., 2010; Hakanen & Rajala, 2018; Shahpasand & Rahimzadeh, 2018; Xu et al., 2014), playing an essential role as an enabler of identification technology. RFID associate to sensing technologies, widely used in industrial, manufacturing and supply chain contexts or environments for tracking objects, people, and animals (Atzori et al., 2010; Kortuem et al., 2010; Miorandi et al., 2012; Xu, 2011; Xu et al., 2014; Yuen et al., 2018). The adoption of IoT technologies has expanded as the cost of sensors and actuators equipment declined and also with the evolution of communication technology and higher ability to collect, read and analyze the large amount the data (Lim et al., 2018; Uden & He, 2017).

Thus, IoT started transforming physical and traditional objects to smart objects by using new technologies that came from the evolution of manufacturing and supply fields called now Industry 4.0 (Lasi, 2014). The objects equipped with identification and tracking technologies interact in wired and wireless sensor and actuator network using advanced communication protocols. The devices collect data, process information, and take action autonomously on behalf of the owner (Bhatti et al., 2014).

Smart or intelligent objects have the following characteristics (Al-Fuqaha et al., 2015; Atzori et al., 2010; Gubbi et al., 2013; Kortuem et al., 2010; Miorandi et al., 2012; Porter & Heppelmann, 2014; Xu et al., 2014; Zanella et al., 2014):

i) physical components such as the mechanical and electrical part of the product;
ii) a unique identifier associated at least one name and one address;
iii) microcontrollers, transceivers, ports, antennae, sensors, memory, control with wireless communication;
iv) a set of digital and collaboration communication functionalities, such as protocols for messages exchanges and the ability to accept and reply messages;

v) computing capabilities such as the ability to match messages, network management tasks;

vi) ability to understand events and human activities occurring in the physical world;

vii) autonomous and proactive behavior and context awareness; ability to converse with the user in terms of input, output, control, and feedback;

Therefore, the IoT concept evolved to be a network of the things encompassed by a portfolio of devices, sensors, and labels to collect a large amount of data (Atzori et al., 2010; Gubbi et al., 2013; Lim et al., 2018; Shahpasand & Rahimzadeh, 2018). Some researchers are mentioning IoT as a dynamic and informational network based on communication protocols standardized and interoperable. The physical and virtual things have identification and attributes, and intelligent interfaces seamlessly integrate them.

Initially, IoT was built on three pillars based on the ability of smart objects: (i) be identifiable (anything identifies itself), (ii) to communicate (anything communicates), and (iii) to interact (anything interacts) (Miorandi, 2012). Based on these three pillars, and the application of IoT, we can adopt the following concepts: “things oriented”, where anything is identified; “internet-oriented” where anything communicates and interacts, and “semantic oriented” on how information can be represented, stored, interconnected, searched, and organized to generate knowledge (Atzori et al., 2010; Gubbi et al., 2013). Therefore, these three perspectives should work among themselves to create an IoT environment. Some authors call this environment as Web of Things, described as a network of interconnected objects, end-users, and other entities.

This environment possesses a set of supporting technologies to provide services and applications, where data and information are collected to be used in the interaction of the physical and virtual world (Atzori et al., 2010; Gubbi et al., 2013; Miorandi et al., 2012; Xu et al., 2014). Thus, IoT environment can be data-centric, where the internet is used for publishing and retrieving information (Atzori et al., 2010; Miorandi et al., 2012), or it can be user-centric, where the information is shared and supported by data analytics and cloud computing technologies (Gubbi et al., 2013).

Thus, IoT meaning is expanding while devices (sensors and mobiles), network infrastructure, communication protocols and new technologies, such as Big Data, AI, Cloud Computing, and Blockchain, are evolving associated with advancing of ubiquitous and pervasive computing concepts (Al-Fuqaha et al., 2015; Miorandi et al., 2012; Zanella et al., 2014).

IoT is evolving to an Internet of "Everything” based on a network of objects and humans, using the embedded computational devices, and several types of applications. This network creates new functionalities and services to users and organizations (Miorandi et al., 2012; Porter & Heppelmann, 2014; Schatten et al., 2016; Zanella et al., 2014).

For those reasons, there is not a commonly IoT definition by researchers, yet (Rong et al., 2015; Uden & He, 2017). Besides that, IoT should be evaluated beyond the technology’s platform (Papert & Pflaum, 2017), which has been discussed massively in the literature so far. The smart environment capable of responding to users, interacting and supporting them with information and helping on carrying out specific tasks (Miorandi et al., 2012), and integrated by several stakeholders, bring IoT as a business ecosystem view, not only as a set of technological tools (Kubler et al., 2017; Pang et al., 2015; Papert & Pflaum, 2017; Rong et al., 2015). Therefore, some researchers started mentioning IoT as an ecosystem which orients the point of view and discussion of this study (Jara et al., 2014; Kubler et al., 2017; Pang et al., 2015; Rong et al., 2015; Scuotto et al., 2016).

2.2 IOT ECOSYSTEM, BUSINESS MODEL AND INNOVATION

In the business ecosystem, companies and individuals work collaboratively to co-evolve capabilities to create value by providing products and services in a dynamic and uncertain environment (Moore, 1993). In this environment, the stakeholders work in cooperative behavior, continually reorganizing and forming dynamic communities. These communities can be merged or split to increase the diversity of the ecosystem. Thus, the dynamic network of diverse elements, with social and technological components, can co-evolve over time (Chae, 2019). The focus of an ecosystem is to provide a common platform with several players of hardware manufacturers, software developers, and service providers to generate value to all stakeholders, including the final customer of the product or services (Hamidi & Jahanshahifard, 2018).

Thus, IoT creates a network, not only connecting things but also connecting all the stakeholders to contribute to the evolution of the business ecosystem (Rong et al., 2015). Consequently, we can describe the IoT ecosystem as an evolutionary socio-economic and technological environment shared by cross-industries stakeholders to provide value to users and organizations (Kolloch & Dellermann, 2018; Mineraud et al., 2016). The stakeholders such as buyers, suppliers, makers, associations, government, and other influencers, develop or co-create solutions, applications, products, and services collectively.

Some researchers continue studying IoT from a technological perspective, but some of them are expanding their researchers considering technology integration and applications. This new perspective offers a smarter ecosystem view of IoT (Bhatti et al., 2014; Cicirelli et al., 2019; Gomez et al., 2019; Jara et al., 2014; Vlachostergiou et al., 2016). This new perspective of IoT brought some discussions such as Open Source technologies (Li, 2018); IoT Startup ecosystem for new technologies creation (Lim et al., 2018); Big Data (Chae, 2019); and IoT platform as middleware and infrastructure to promote interaction of users (Mineraud et al., 2016). Kolloch and Dellermann (2018) mention an innovation ecosystem as a social system (human actor-network) and a technological system (non-human actor-network)

The main challenge to build an IoT ecosystem is to change the vertical or silos created by each player or stakeholder (Bello & Zeadally, 2019; Kubler et al., 2017). There is no formalization or fixed context in the IoT ecosystems, with new actors entering or leaving anytime, generating a business and technologies environment highly dynamic. Thus, it is vital to identify the key stakeholders, understand their requirements and contributions on the IoT co-creation, and find out a viable business model (Ikävalko et al., 2018; Metso & Kans, 2017; Tesch et al., 2017). Thus, the security and privacy of users or stakeholders become essential to enable the IoT ecosystems (Ammar et al., 2018; Díaz López et al., 2018; Martínez et al., 2017; Mohamad Noor & Hassan, 2019; Park et al., 2016).

Despite the technical issues, the success of an IoT business model depends on how the business model is created and implemented to capture value (Uden & He, 2017). However, studies about IoT ecosystem business models are still under development. Some authors mention a closed ecosystem that allows a single company to control technology, data, the direction of products, and services development. However, this approach demands high investments and additional challenges in terms of technology spread in ecosystem formation (Porter & Heppelmann, 2014) or when the ecosystem becomes more mature (Leminen, Rajahonka, Westerlund, & Wendelin, 2018; Rong et al., 2015). Other authors mention the importance of the role of the solution integrator, in the open ecosystem for industries collaboration (Baccelli et al., 2018; Papert & Pflaum, 2017; Santoro et al., 2018). In both cases, in the closed and open ecosystem, the IoT project implementations are complicated due to the technological uncertainty, system scope, multiple stakeholders and coordination of the project knowledge management (Ahern et al., 2014; Shenhar & Laufer, 1995).

Leminen et al. (2018) identified four types of IoT business models based on the kind of ecosystem and the nature of the services involved. The first type is the value chain efficiency, which represents standard with single-purpose applications and services produced in a hierarchical and closed ecosystem. The second type is the industry collaboration, which combines connectivity and collaboration in an open ecosystem across industries. The third type is the horizontal market, oriented by customers and services. The fourth type is the IoT application, which is created by others through a platform, where the organization acts as an integrator with partners to offer multi-services to customers in a closed ecosystem.

One example of an innovative and open ecosystem is the Smart Cities, joining citizens and many heterogeneous stakeholders, such as private and public sectors (Díaz-díaz et al., 2017; Scuotto et al., 2016; Tang et al., 2018). In this case, the success of this type of ecosystem is the collaborative ecosystem by creating alliances with principal stakeholders to develop products and services across several platforms to add value to the entire ecosystem (Pang et al., 2015; Yu et al., 2016). Another form of innovation is the social platform called Social Internet of Things (SIoT) (Ahmad et al., 2018), where the convergence between different industries promote the creation of new products and services for users, which actively communicate and interact with each other (Kim & Shin, 2016).

In this context of IoT solutions and applications, it is important to understand what constitutes an IoT ecosystem, which is explored in the next section.

2.3 IOT ELEMENTS

The functionalities of IoT ecosystems that enable a Smart environment need to be viewed on how the technological and human entities interact (Kolloch & Dellermann, 2018), on how these components are integrated with the functions and capabilities of new products and services (Porter & Heppelmann, 2014), and on how the dynamic interaction among actors, stakeholders, things, and technologies occur while they co-evolve with each other. Typically, researchers consider IoT elements as layers in an IoT architecture and focus on just a few of them or a single element (Atzori et al., 2010; Cicirelli et al., 2019; Li et al., 2018; Miorandi et al., 2012; Porter & Heppelmann, 2014).

Papert & Pflaum (2017) suggested that the overall structure of an IoT ecosystem model can be divided into two parts, namely the device and application. However, the SLR approach used herein revealed three parts, which are presented in Figure 1.

Some authors mention that an overall structure of an IoT ecosystem model can be divided into two parts, namely the “device part” and the “application part” (Papert & Pflaum, 2017). However, after analyzing literature, we classified the elements into three parts, as they can be seen in Figure 1.

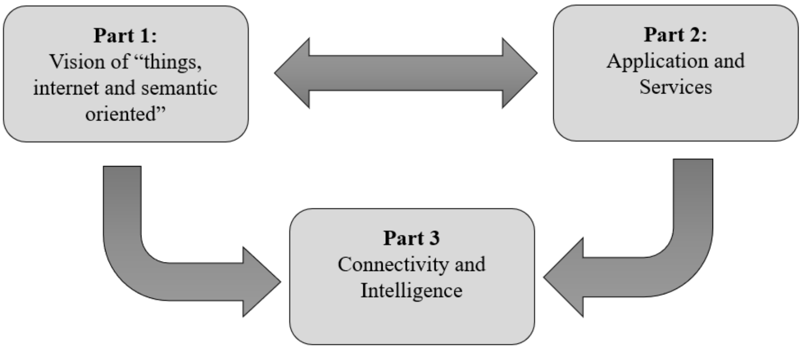

Figure 1 – IoT elements
Source: Elaborated by authors, 2019

Part 1 allows the vision of “things oriented”, “internet-oriented” and “semantic oriented”, which are composed of Identification, Sensing, Communication, Computing, Data Storage, and Semantic (Atzori et al., 2010; Bello & Zeadally, 2016; Gubbi et al., 2013; Miorandi et al., 2012). Part 2 is the “Applications and Services”, which enable the direct interface with objects, humans or machines. Therefore, Part 3 link both Part 1 and Part 2 through “Connectivity and Intelligence” to enable the smart IoT environment (Papert & Pflaum, 2017; Porter & Heppelmann, 2014). In the next sessions, we will describe these three parts in detail.

2.4 PART 1: “THINGS, INTERNET AND SEMANTIC ORIENTED” VISION

In this section, we will present the components of Part 1, including identification, sensing, communication, computing, data storage, and semantic.

2.4.1 IDENTIFICATION

Most of IoT applications require unique identifiers. The ability to uniquely identify “Things” is critical for the success of IoT. Every element connected must be determined by their unique identification, location, and functionalities (Atzori et al., 2010; Gubbi et al., 2013). In the RFID technology, the automatic identification of anything (people, animals, and objects) is made using embedded microchips or attached tags with an antenna, which allows data communication with a reader, using radio waves (Gubbi et al., 2013; Miorandi et al., 2012). However, an identification method needs to be used to provide a clear identity for each object within the network (Al-Fuqaha et al., 2015).

Many identification methods are available such as the Electronic Product Code (EPC) or Unique/Universal/Ubiquitous Identifier (UID), or also a Digital Objects Identifiers (DOI). However, identification methods are not globally unique and the addressing methods such as IPv6, IPv4, 6LoWPAN, can help this unique identification of objects (Al-Fuqaha et al., 2015; Atzori et al., 2010; Jara et al., 2014). Besides, the IoT environment should also consider the identification of people, which can be verified by signatures (Andersen et al., 2016).

2.4.2 SENSING

Objects can interface with the physical environment in a passive and active way, exchange information among different devices, representing the coupling between the digital and the physical realms. This equipment can create a network of sensors in wireless communication. The ability to sense the environment and to self-organize into ad hoc networks represent one of the more essential elements of IoT (Miorandi et al., 2012). However, there are several problems related to protocols such as the scarce availability of IP addresses or the sensor nodes stay in a standby mode to save energy (Atzori et al., 2010).

2.4.3 COMMUNICATION

Communication is established when devices and objects (physical or virtual) are connected using communication protocols with or without human intervention via the internet or wireless technologies to gather or sharing data and information (Bello & Zeadally, 2016; Murray et al., 2016). There are five types of device communications: i) communication with people interference to trigger an alert for decision making; ii) communication without people interference to perform an action or to identify or locate other devices; iii) direct communication with people to obtain information for decision making or to transmit information; iv) communication to gather information or to report their state to another device, and v) communication to transmit gathered data, store data or retrieve data for an automatic decision making (Bello et al., 2017).

In the context of communication, the challenge is to select the right communication technology to meet the requirements of a specific context since there are several options, such as RFID technologies and Constrained-Node Network (CNN) technologies. However, the core of several IoT environments is wireless networking (Gomez et al., 2019).

2.4.4 COMPUTING

The ubiquitous computing provides interconnected smart objects endowed with communication, network and computing capabilities across a wide range of a distributed infrastructure with services and technologies (Miorandi et al., 2012), complementing the vision of everywhere and anywhere (Atzori et al., 2010). Thus, the ubiquitous computing provides a connected smart object with smart devices in a network environment (Jara et al., 2014; Rathore et al., 2018).

Processing units (e.g., microcontrollers, microprocessors), software applications, and cloud platforms are important computational parts of the IoT, which will facilitate the smart objects to send data to the Cloud for Big Data to be processed in real-time (Al-Fuqaha et al., 2015). However, there are many challenges related to an integrated environment with all technologies such as Cloud Computing, Big Data, AI (Gubbi et al., 2013), and Blockchain (Chae, 2019). Those technologies need to deal with an enormous amount of dynamic data generated from devices and IoT applications. They require massive data storage, huge processing speed to enable real-time interaction, decision making, and high-speed broadband networks to stream data, audio, or video in a secure and private environment (Atzori et al., 2010; Gubbi et al., 2013; Miorandi et al., 2012).

2.4.5 DATA STORAGE

Cloud computing offers a dynamic method of accumulating and storing data, providing huge storage capacity, and process data in real-time (Bello & Zeadally, 2016). Cloud Computing enables end-to-end applications and services, and users to access applications on-demand from anywhere offered by and for multiple stakeholders in a reliable and decentralized manner (Gubbi et al., 2013).

There are some challenges to enable Cloud Computing for IoT such as: “Synchronization” between different cloud vendors or cloud platforms to provide real-time services; “Standardization” to interoperate with the various vendors; “Balancing” the differences in infrastructure between general cloud service environments and IoT requirements; “Reliability” differences in the security mechanisms between the IoT devices and the cloud platforms; “Management” Cloud computing and IoT systems have different resources and components; “Enhancement” to ensure better IoT cloud-based services to meet the customer´s expectations (Al-Fuqaha et al., 2015).

Big data consist of an enormous amount of high-speed data to be collected to process and analyze through various sources, such as sensors, systems, emails, transactions, audios, videos, social networks and media files. The main characteristics of Big Data are high volume, high velocity, and wide variety (Rathore et al., 2018). Volume is the amount of data (terabytes to exabytes). A variety of data can be represented by many different formats (structured data, semi-structured data, unstructured data, text, multimedia). Velocity is the speed of the data that are generated and processed (streaming data, milliseconds to second to respond) (Lokshina et al., 2018; Uden & He, 2017). Big data requires complex computations to extract Knowledge to be useful for the IoT environment (Uden & He, 2017), such as in the real-time data monitoring (Funabiki et al., 2017). Thus, Big Data Ecosystem not just involve digital technologies and tools, but also knowledge, skills, concepts, organizations, and other social and institutional contexts combining business intelligence, data mining, data warehousing, analytical platforms, computing architecture, data processing framework, infrastructure analytical talents, beliefs, methodologies, professional meetings, and institutions (Chae, 2019). However, some challenges inhibit the progress and value creation of IoT and Big Data, such as heterogeneity, scale, timeliness, complexity, security, and privacy (Lokshina et al., 2018).

A smart environment is composed of different kinds of devices that continuously capture and exchange information in reliable communication with a security mechanism to preserve privacy and confidentiality, ensuring the availability of the services in the IoT ecosystem. Law and policy, business administration, criminology, psychology, and economics should support this environment (Park et al., 2016).

Thus, we can use the Blockchain to address several aspects of security and privacy, where each participant of the network is accountable for its roles in the overall transaction. In this way, we can prevent disputes by allowing tracking the sources of insecurity as well as in handling crises such as security vulnerability. Blockchain uses mathematical techniques for encrypting and decrypting data, keeping them private when it is being transmitted or stored electronically, by creating blocks of signed transactions (Kshetri, 2017).

The Cloud Computing offers a management mechanism for Big Data (Al-Fuqaha et al., 2015; Sharma, 2016) since Big Data and IoT are connected due to many physical objects like humans, animals, plants, smartphones, computers, equipped with sensors to the internet to generate a huge amount of data available for analysis (Uden & He, 2017).

Both Cloud Computing and Blockchain have security protection concepts embedded, where data is fully encrypted. Some cloud services providers use of "zero trusts" network, based on the assumption that trustworthiness needs to be considered for every single device, once one device is hacked, it does not affect the whole network. Others use an improved model called "security micro-segmentation" or use the "cyber risk-free zone" to monitor constantly some suspicious activities to provide real-time response. However, Cloud Computing works in a centralized model, which becomes more problematic and potentially cause risky when the number of network nodes grows bigger, mainly in the IoT environment (Kshetri, 2017). So, a decentralized model of Blockchain is more appropriate and effective for IoT (Kshetri, 2017; Valtanen et al., 2019). Therefore, the combination of Cloud Computing, Big Data, and Blockchain support the data storage for a smart environment.

2.4.6 SEMANTIC

Semantic means the ability to extract Knowledge, including how to represent, model, store, interconnect, search, and organize information (Al-Fuqaha et al., 2015; Atzori et al., 2010). A semantic data model is the data representation to provide meaning, context, and relationships (Chakraborty et al., 2017).

The semantic technology combines a knowledge-based system (KBS) and rule systems with appropriate and standardized formats, language, models, ontologies and semantic descriptions of data content, to generate useful information. KBS is an information system used to capture Knowledge and expertise from individuals within an organization to solve complex problems (Arnold et al., 2015) and, rules systems such as fuzzy logic, based on a list of rules from opinions and expertise of the qualified professionals (Yuen et al., 2018) forming a knowledge base. They are considered collective terms for computer-aided problem-solving tools and for artificial intelligence, which include expert systems and knowledge-based engineering (KBE) (Irfan, 2019; Reddy et al., 2015).

Thus, semantic technology in IoT environment concerns to identify, capture, structure, formalize, and implement the Knowledge, enabling different applications interoperability and facilitates decision making (Miorandi et al., 2012; Reddy et al., 2015; Yuen et al., 2018). We can also mention the term extraction–transformation–loading (ETL) used to extract, transform, and load the demand information (Fang et al., 2014) on a data store, data mart or data warehouse for data integration from multiples sources or applications (Chakraborty et al., 2017).

Therefore, IoT researchers are studying Knowledge from the technology perspective, such as the generation of the versatile, volatile and huge volume data, that should be stored, processed, analyzed and manipulated for utilization by humans (Anum et al., 2018), They are also researching the use of analytical tools, such as data mining and Machine Learning (Gubbi et al., 2013). In this perspective, Knowledge is defined as the appropriate collection of useful and applicable information. At the same time, other researchers consider Knowledge more subjective and intangible, when compared to information or data, as if the individuals incorporate them into their beliefs, values, procedures, and actions (Uden & He, 2017). Although, currently, the systemic development of Knowledge considers the human knowledge capability as an inspiration for dealing with the knowledge issues into machines and system analytics, using memory models and learning protocols, mainly in the AI (Anum et al., 2018).

Thus, a new term as part of ETL tools, called Semantic Web of Things (SWoT), has contributed to the creation of auto-interpreting and auto-describing machines to manage data heterogeneity (Howell et al., 2018; Vlachostergiou et al., 2016). However, it is still a challenge to execute it in the real world (Shahpasand & Rahimzadeh, 2018) since it requires robust semantic interoperability to create a shared understanding of the context, meaning and sourcing of data (Howell et al., 2018) to automate the whole data process transformation in the real-time demand linked to an open data cloud (Chakraborty et al., 2017).

2.5 PART 2: APPLICATION AND SERVICES

In the following section, we will present and discuss the Applications and Services that enable the direct interface with objects, humans and machines.

2.5.1 APPLICATION

IoT enables things, and humans interact with each other, creating new solutions and smart environments in several fields, using ubiquitous computing applications and enable data exchange between the domains. They also combine security, tracking, tracing, payment, remote control, maintenance and measurement to provide intelligence and connectivity among humans and machines (Gubbi et al., 2013; Jara et al., 2014; Lim et al., 2018; Murray et al., 2016; Uden & He, 2017), such as in manufacturing, agriculture, home and healthcare (Lim et al., 2018). The applications can be classified on the type of network availability, coverage, scale, heterogeneity, repeatability, user involvement, and impact (Gubbi et al., 2013).

2.5.2 SERVICE

A service is a collection of data and associated behaviors to accomplish a particular function or feature of a device or portions of the device (Xu et al., 2014) or the integration of functionalities and resources provided by smart objects (Miorandi et al., 2012). IoT can have a service-oriented and context-aware architecture, where every virtual and physical object can communicate with one another, and it has a corresponding virtual mirror in the digital domain.

The service-oriented IoT concept allows each component to offer its functionalities as standard services, which might significantly increase the efficiency of both devices and networks involved in IoT (Xu, 2011; Xu et al., 2014). The IoT based service delivery facilitates the harmonization of several applications into interoperable services (Wang et al., 2013), as well, the usage of semantics, data and information understanding, combination and processing from different providers or sources (Scuotto et al., 2016). This new concept moves the current concept of always-on services to always responsive and context-based services, supporting the specific needs of users (Miorandi et al., 2012).

IoT services can be categorized in the following types: i) Identify-related Services, which are the primary services used to identify objects in other types of services; ii) Information Aggregation, which collect and summarize measurements captured by sensors; iii) Collaborative-Aware Services, which use the data collected for decision making and action; iv) Ubiquitous Services, which provide Collaborative-Aware Services anytime to anyone in anywhere (Al-Fuqaha et al., 2015); and v) Opportunistic Service, which considers the dynamicity of service creation or activation, context-awareness, such as location, identify, physical condition, co-location exploited by different stakeholders and temporary service (Casadei et al., 2019).

In order to build an IoT service ecosystem some activities should be followed with the support of a solution integrator: (i) definition of the IoT service type to be provided; (ii) definition of the value proposition of the IoT service; (iii) identification of the roles and responsibilities for the execution of IoT service; (iv) business relationship development with the companies or actors to full fill the roles and responsibilities needed to build the ecosystem; (v) negotiation with the partners about compensation; (vi) execution of the IoT service ecosystem in cooperation of the partners (Papert & Pflaum, 2017).

Although there is much progress related to human-computer interfaces and user-centric design methodologies, there are some technical, behavior or even ethical challenges. Those challenges involve multiple stakeholders (consumers, companies, public and private sectors, and technology providers) to develop suitable and scalable service delivery platforms that permit multiple services to coexist (Miorandi et al., 2012). Moreover, there are challenges to creating a collaborative design in a various context in which the system will be used (Uden & He, 2017), besides a social adaptation when a new type of service with predictive analytics influence directly or guide the users in their behavior such as in travel, dietary and medical recommendations (Harwood & Garry, 2017)

Therefore, an IoT service ecosystem should follow some steps for its implementation: (i) definition of the IoT service type to be provided; (ii) definition of the value proposition of the IoT service; (iii) identification of the roles and responsibilities for the execution of IoT service; (iv) business relationship development with the companies or actors to full fill the roles and responsibilities needed to build the ecosystem; (v) negotiation with the partners about compensation; (vi) execution of the IoT service ecosystem in cooperation of the partners. The orchestration of those activities leads to the role of a solution integrator due to the level of business and technology integration to ensure standardization, compliance, scalability, maintainability, integrity, privacy and security (Papert & Pflaum, 2017).

2.5.3 APPLICATION AND SERVICE FIELDS

In this study, we found some applications of IoT that could be seen as an ecosystem. The following examples can be shown:

- Healthcare: The reduction of device cost, the development, and combination of several technologies and the applications are expanding the use of IoT in the healthcare field. A typical IoT health system consists of (1) sensing layer, integrated to different types of hardware, in order to connect to the physical world and collect data, (2) networking layer, to support transference of data in the wired and wireless networks, (3) service layer to create and manage all types of services to satisfy user requirements and (4) interface layer, which offers interaction methods to users and other applications (Farahani et al., 2018). IoT healthcare services can be provided to monitor patient health status (heartbeat, blood pressure and glucose level) mainly after surgery for the elderly or people with disabilities. Data is collected with sensors on wearable technologies or personal computers using wireless networks. Data is sent and transformed in a way that both patients, doctors, hospitals, or any system can understand the meaning to raise alerts or take action without spending more time and money (Farahani et al., 2018; Gomez et al., 2019; Lomotey et al., 2017). There are several benefits in using IoT, such as healthcare solution for everyone needs; seamless integration with different technologies; Big Data processing and Analytics to extract useful, actionable information; ability to personalize and tailor service; lifetime monitoring (past, present and future health); easy to use; cost reduction; doctors involvement or proximity with patients health conditions; availability and accessibility; online assistance; better efficiency of resources; health collaboration around the world (Farahani et al., 2018). So, IoT enable the transformation of clinic-centric healthcare to patient-centric healthcare, or personal healthcare, or end user view, but there are some challenges to overcome such as data management, scalability, interoperability, device–network–human interfaces, security, and privacy (Bietz et al., 2016; Farahani et al., 2018; Gomez et al., 2019; Martínez-Caro et al., 2018; Pang et al., 2015).

- Smart Cities: It can be the most complicated scenario for smart environment involving several domains, including environment, economy, mobility and energy, also multiple actors and stakeholders such as service providers, citizens, administrators, etc., with a complex and diverse technological solution (Gomez et al., 2019), connecting to the physical IT, social network, and business infrastructures (Bresciani et al., 2018; Chifor et al., 2017). Some examples of applications are: i) structural health of building for proper maintenance with continuous monitoring the condition of each building and surrounding areas through data measurements of vibration, deformation, pollution levels, temperature and humidity captured by sensors and interconnected to a centralized control system; ii) waste management such as intelligent waste containers of the collectors truck fleet; iii) air quality monitoring in crowded areas, parks, etc.; iii) noise monitoring to enforce public security; iv) traffic control using the sensing capabilities and GPS installed on vehicles; v) smart parking based on road sensors and intelligent displays to direct drivers along the path for parking in the city; vi) smart lighting to optimize street lighting efficiency according to the time of the day, weather condition and presence of people; and vi) city energy consumption to identify amount of energy required to set priorities for energy efficiency (Antonić et al., 2016; D'elia et al., 2015; Paul et al., 2016; Rathore et al., 2018 ; Sheng et al., 2015; Zanella et al., 2014). The main challenge for these types of applications is the interoperability of technological solutions and standards (Gomez et al., 2019). The explanation is related to the human activities, multiple sources and activities (Hua et al., 2017), active users participation in continuous feedback and the administration of different stakeholders such as government, citizens, universities, private sector, communities, scientists, developers and technology providers, in the smart environment (Chifor et al., 2017; Gutierrez et al., 2018; Hernández-Ramos et al., 2015; Kummitha & Crutzen, 2019).

- Smart Homes: There are several useful services and applications in this field since modern homes already contain technological devices; they are in a controlled environment. They are classified in assistance services, which provide direct support to the particular needs of the users in their daily actions based on their particular needs such as lighting, heating, energy, and security systems controlled remotely, whichever management services to address specific functionalities such as daily power and water consumption from people activities (Gomez et al., 2019; Iqbal et al., 2018; Khan et al., 2017; Lim et al., 2018; Miorandi et al., 2012; Vlachostergiou et al., 2016). Therefore, the smart home services and application challenges are to attend the specific context based on adaptative interaction and personalized of the user´s actions (Vlachostergiou et al., 2016), and security threats (Mao et al., 2018).

- Smart factory and industry 4.0: IoT and Cyber-Physical Systems (CPS) enable smart processes and procedures without or with minimal human intervention to plan, control, optimize the production and enable proactive maintenance and production safety. This smart environment captures real time-intensive data from Industrial IoT (IIoT) for decision making in a timely and accurate way or dynamically autonomous, allowing the optimization of logistics and inventory levels, and prevent quality issues, which can use cloud services, Big Data Analytics. Machine Learning for remote monitoring or business application supporting, but there are challenges in data management, data collection, data security, and application platform integration (Ardito et al., 2019; Gomez et al., 2019; Lim et al., 2018; Ribeiro & Hochwallner, 2018; Shu et al., 2018; Wong & Kim, 2017).

- Other applications: There is also some application in development in different fields such as Transportation and Logistics, Agriculture, Finance Services (Atzori et al., 2010; Chae, 2019; Lim et al., 2018; Paul et al., 2016; Rathore et al., 2018; Rong et al., 2015; Sheng et al., 2015; Shu et al., 2018; Uden & He, 2017; Xu et al., 2014; Yu et al., 2016; Yuen et al., 2018).

2.6 PART 3: CONNECTIVITY AND INTELLIGENCE

In the following section, we will present and discuss connectivity and intelligence. These topics represent the link among all of the IoT elements, allow interactions to take place among anyone, anywhere and at any time and enable the deployment of unique product functions and capabilities, respectively.

2.6.1 CONNECTIVITY

Connectivity complements the vision to connect anyone and anything. There are three components to enable connectivity: i) physical components (objects and living beings) that should be identified within the network via identification methods such as electronics product codes (EPC), ubiquitous codes (uCode), IPv4 and IPv6; ii) smart components (sensors, microprocessors, controls, software, embedded operating system, user interface, etc.) to use for sensing, meaning gathering data from objects or living beings within the network and sending it back to a Data Warehouse, Database, or Cloud; iii) connectivity components (ports, antennae, and protocols allowing wired or wireless connections with the product) to allow information exchange between the object and the operating environment, application, system, user or another object, besides to enable new products and service (Papert & Pflaum, 2017; Porter & Heppelmann, 2014).

Connectivity links devices and application, creating a network which generates data in real-time (Bello & Zeadally, 2016; Papert & Pflaum, 2017). Connectivity can be presented in the ways of i) One to one: individual object connects to the user, organization or other objects; ii) One to many: many objects are connected continuously or intermittently through a centralized system; iii) Many to many: multiple objects connect to many other types of objects and also data sources (Porter & Heppelmann, 2014).

Thus, the connectivity can be viewed in four types of network: i) between devices creating a technological network by connecting objects (Kolloch & Dellermann, 2018); ii) among users and organizations (Uden & He, 2017), creating a business network; iii) among users, creating a social network (Rong, 2015); and iv) between living beings and objects (Atzori et al., 2010). So, the smart connectivity, associated with the network and support of the context computation (Gubbi et al., 2013), allows the formation of an ecosystem with new types of product or service that provides monitoring, control, optimization and autonomy (Porter & Heppelmann, 2014).

Advances in wireless networking technology provide seamless, continuous, ubiquitous connectivity (Bello & Zeadally, 2016), and the greater standardization of communication protocols enable pervasive communication through data collection from diverse sources, leading the vision to anywhere at any time (Xu et al., 2014). The use of the new forms of connectivity and communication between things and people lead to an open-ended and highly dynamic network (Bhatti et al., 2014). This network allows higher interaction of outside players to create new applications, mainly when the ecosystem is at the beginning of the formation or under developing, encourage stakeholders and actors work together to contribute for the future product or service (Leminen et al., 2018; Porter & Heppelmann, 2014; Rong et al., 2015).

2.6.2 INTELLIGENCE

Intelligence is one of the elements to enable a new set of product functions and capabilities for monitoring, control, optimize, and give autonomy (Porter & Heppelmann, 2014). Those capabilities create a smart environment by the ability to gather relevant real-time data, extract knowledge and transform it into intelligence (Bello & Zeadally, 2016). It is a challenging task to interpret data and transform it into something useful for the actionable decision, meaning more intelligence to enable IoT applications or services (Bello & Zeadally, 2019; Miorandi et al., 2012; Uden & He, 2017).

Smart objects will become more intelligent with the use of technology, such as combined with the development of communication networks, processing, and memory capabilities. Moreover, the application of distributed AI concept, considering the autonomous software entities can interact in the environment and among themselves, with the self-organization, self-configuration, self-optimization, and self-protection capabilities to minimize human intervention will create the internet of intelligence things (Miorandi et al., 2012; Xu et al., 2014).

However, information for some services, such as user position via localization system, user physical condition through wearable sensors, user activities combining wearable and environmental sensors, cannot be gotten by direct observation of raw data coming from sensors. So it is needed to process them by a data analysis algorithm, big data analytics or machine learning (Gomez et al., 2019). Although IoT technologies and systems from different kind of sources using AI or any computational analysis are very important for smart environment creation, the human interaction or collaboration is required, which involves additional challenges from the social point of view besides the technical aspect (Gomez et al., 2019; Lokshina et al., 2018; Shin & Jin Park, 2017).

2.7 KM AND IOT

The utilization of the Knowledge for value creation brings the development of KM, considering the human capital (Mirzaie et al., 2019), and its corresponding technologies application as know-how (Anum et al., 2018). KM is a systematic management of processes, methods, and tools to enable the use of Knowledge to create value for organizations and users (Raudeliūnienė et al., 2018).

KM increases the speed of response with better knowledge access, enabling many types of applications, mainly associated with IoT (Lokshina et al., 2018; Uden & He, 2017). IoT and KM allow a real, digital, and virtual world by extracting and exchanging Knowledge from multiple sources, supporting the integration and collaboration among objects, living beings, and organizations (Bresciani et al., 2018).

One of the known KM models is the DIKW (Data-Information-Knowledge-Wisdom) hierarchy published by (Ackoff, 1989). This model presents data converting into information, which turns into Knowledge, which turns into wisdom. These inferences create an additional implication that there is more data than information, more information than Knowledge, and more Knowledge than wisdom (Jennex, 2018). Some studies in a more contemporary version of DIKW hierarchy, replace wisdom by intelligence, extending the concept to competitive intelligence, business intelligence and marketing intelligence, but often they are discussed independently of the KM application (Jennex, 2018; Rothberg & Erickson, 2017; Tian, 2017). Thus, the wisdom or intelligence concept in KM is still ill-defined by the literature since it is not part of the same studies as data and information (Rothberg & Erickson, 2017). The distinction of data, information, knowledge, and wisdom and the correspondent approach in traditional KM and IoT ecosystem is shown in Table 1.

Although there is some distinction among data, information, and Knowledge presented in Table 1, the elements of the traditional model can be classified as types of information. An example is when new Knowledge uses pre-existing data, information and Knowledge (Firestone, 2011) when Knowledge without meaning and context becomes information or data (Bhatti et al., 2014).

There is no practical utility to distinguish Knowledge from the information when predictions are generated based on finding patterns and correlations in different data sources (Tian, 2017), or when Knowledge and information are interchangeable in a knowledge-sharing process (Wang & Noe, 2010). So, the traditional pyramid of Knowledge becomes a formless “network of knowledge” (Weinberger, 2011), where applied Knowledge generate intelligence, which enables decisions and actions based on interpretation of data, information, and Knowledge with no hierarchy (Jennex, 2018; Lokshina et al., 2018). Besides, there is a serious indication that in the future, the distinction of tacit Knowledge and explicit Knowledge might be reduced or eliminated, or they will not be so important (Sumbal et al., 2017).

Table 1 - KM Hierarchy

Type	Traditional KM	KM in IoT ecosystems
Data	Data are basic, discrete, objective facts about something (Jennex, 2018); raw facts (Bhatti et al., 2014) of the accurate observation without any relationship with another element (Lokshina et al., 2018), the flow of events and activities, in an organizational system without any context (Sumbal et al., 2017)	Big Data is structured, unstructured or semi-structured available through a variety of sources (Sumbal et al., 2017) in real-time and on-demand (Uden & He, 2017)
Information	Data in a given context becomes information (Sumbal et al., 2017), providing a useful story, linking of who, what, when, where data such as the description of a specific person, object, situation at a particular time (Jennex, 2018). It is an organized set of data (Bhatti et al., 2014) with some meaning in a context with some premises and interferences to generate conclusions (Lokshina et al., 2018).	Information is generated when data analytics are applied to data, organizing and structure it with some meaning through trends and patterns in a specific context. It can use automated learning through "machine learning" algorithms to identify non-obvious, hidden patterns (Sumbal et al., 2017).
Knowledge	Information becomes Knowledge when it is culturally understood. For example, when someone explains how and why about something or generates insights and understanding into something (Jennex, 2018). The information based on intuition and personal experience converted into Knowledge (Sumbal et al., 2017), or it is an organized combination of data and information, which is added the opinion of an expert person. Knowledge cannot be transmitted easily, only the narration of the experience (Lokshina et al., 2018).	Useful Knowledge is generated through a combination of tacit Knowledge from experienced people and explicit Knowledge from Big Data. In the future predictive Knowledge with the advancement of data analytics may replace tacit Knowledge (Sumbal et al., 2017). Real-time and actionable Knowledge is co-created with users and organizations (Jennex, 2018)
Wisdom / Intelligence	Wisdom is intangible and related to individual experience. It is the ability to add value or make choices (Lokshina et al., 2018). Intelligence is the data transformed into an actionable decision (Uden & He, 2017) or actionable Knowledge based on differente sources (Jennex, 2018).	The use of technology and the development of Knowledge in humans and machine interaction result in collective intelligence (Hakanen & Rajala, 2018). In the IoT smart environment, things/objects and people interact in real-time with each other to enable applications or services in a context to create specfic action or decisions also in real timebased on diffeerent sources (Kortuem et al., 2010; Uden & He, 2017) and collective intelligence

Source: Elaborated by the authors, 2019

In summary, the main objective of KM is to reach specific Knowledge and wisdom needed to run a specific task and provide intelligence to use in the decision-making process.

Therefore, the term intelligence refers to specific, actionable Knowledge, and the entire DIKW hierarchy could be translated into actionable Knowledge, where data or information or Knowledge are interpreted and transformed into something useful or applicable (Jennex, 2018). KM also can be viewed as a learning process to continue to generate intelligence, and it can be implemented as a feedback control in most applications and automatic control systems. It can be extended to life-cycle modeling for services (Tan et al., 2017).

The effective KM requires the functionality of three primary and essential organizational processes: (1) maintain learning loops in all organizational processes, (2) systematically disseminate new and existing Knowledge, and (3) apply knowledge wherever it can be used (Sanchez, 2006).

2.8 KM ENABLERS AND KM PROCESSES

KM has two main dimensions, namely KM Enablers and KM Processes (Santoro et al., 2018). In an effective KM implementation, the KM processes linked to culture, human resources and leadership that are more relevant often than KM Enablers based on technologies and infrastructure (Sedighi et al., 2015).

KM Enablers facilitate KM activities, such as infrastructure and mechanisms for knowledge creation, codifying, protecting, storage, sharing, etc. (Lee & Choi, 2010; Santoro et al., 2018); or also, a range of technologies, called Knowledge Management Systems (KMSs) (Uden & He, 2017). KMS supports the creation of collaborative ecosystems and KM capacity, which increases innovation capacity (Santoro et al., 2018), oriented to manage tangible items such as reports, data, among others, and intangible items such as Knowledge of people (Latino et al., 2016).

IoT technologies can be considered as KM enablers or a kind of KMSs since they allow capturing individuals' Knowledge to disseminate to a broader audience (Santoro et al., 2018). For example, in an intelligent knowledge management system, namely the Internet-of-Things (IoT) Outbound Logistics Knowledge Management System (IOLMS) designed to monitor environmentally-sensitive products and to predict the quality of goods (Yuen et al., 2018). Also, it is verified when Big Data analytics collected from IoT devices to turn data into useful Knowledge, like in an evaluation of traffic conditions on the roads or in an intelligent parking service (Uden & He, 2017).

In IoT ecosystems, Knowledge can have different perspectives. Each of them is important to aggregate additional value to the ecosystem associated with the correspondent technologies or KMSs, as shown in Table 2.

Table 2: Knowledge perspectives, KM and KMS implication in the IoT ecosystem

Knowledge Perspectives	Description	KM objectives in the IoT ecosystem	KMSs objectives in the IoT ecosystem
State of mind	Knowledge is the state of knowing and understanding (Alavi & Leidner, 2001). Individuals create Knowledge, but also it is created from heterogeneous and voluminous data using analytics by automated learning through "machine learning" algorithms to identify non-obvious, hidden patterns of information (Sumbal et al., 2017). There are two types of Knowledge: Explicit Knowledge, which is expressed formally, and it can be shared and the tacit knowledge, which is highly personal and hard to formalize (Nonaka et al., 2000)	Enhance learning and understanding of the individual or organization, considering that Knowledge can be made explicit and managed explicitly. The new Knowledge can be created through definable, manageable learning processes(Sanchez, 2006).	Provide access to the knowledge sources or KMSs (Alavi & Leidner, 2001) or/and use data analytics with automated learning (Sanzogni et al., 2017) or knowledge learning tools (Tan et al., 2017). AI, "machine learning" algorithms to identify non-obvious, hidden patterns of information (Sanzogni et al., 2017; Sumbal et al., 2017). There is a severe indication that in the future, the distinction of tacit Knowledge and explicit Knowledge might be reduced or eliminated, or they will not be so crucial as machines can learn and replace human actions (Sumbal et al., 2017).
Object or Stock or Asset	Knowledge stocks are accumulated knowledge assets that are internal Knowledge of an organization. (Ambos et al., 2013) Knowledge can be viewed as a thing/object/asset to be stored and manipulated to facilitate access to and retrieval of content (Alavi & Leidner, 2001). New Knowledge is created using the existing knowledge assets (Nonaka et al., 2000)	Manage knowledge stocks (Alavi & Leidner, 2001) in real-time or on-demand data, organizing access and retrieval of content (Uden & He, 2017)	Gather and store data, information, and knowledge from multiple sources, including machine data and social data, in real-time or on-demand data (Alavi & Leidner, 2001; Uden & He, 2017). Provide effective search and retrieval mechanisms for locating relevant information (just-in-time and just-what-is-needed data by using AI) (Uden & He, 2017).
Flow or Process	Knowledge flow is the experience and Knowledge created and exchanged from an organization to another to diffuse, accumulate, or share Knowledge (Lin et al., 2012).	Manage knowledge flows and the process of creation, sharing and distributing knowledge (Lin et al., 2012)	Use information systems and internet environments such as virtual forums in a trust context and appropriate structure for people exchanging and transferring experience inside and outside organizations (Mirzaee & Ghaffari, 2018; Zablith et al., 2016).

Capability	Have the capacity for a specific action or use information, learning and experience resulting in an ability to interpret information and to determine what information is necessary to influence action (Alavi & Leidner, 2001).	Build core competencies, know-how (Alavi & Leidner, 2001) and intellectual capital or expertise (Rothberg & Erickson, 2017). Manage knowledge infrastructure (technology, structure, and culture) and knowledge processes (acquisition, conversion, application, protection) (Gold et al., 2001)	Support development of individual and organizational competencies to enhance intellectual capital (Alavi & Leidner, 2001; Rothberg & Erickson, 2017) through the management of knowledge infrastructure and processes (Gold et al., 2001).
Data, Information, and Knowledge	Data are basic, discrete, objective facts about something (Jennex, 2018). Data in a given context becomes information (Sumbal et al., 2017), the information based on intuition and personal experience convert into Knowledge (Sumbal et al., 2017).	Provide useful or actionable Knowledge and facilitate the assimilation of information (Alavi & Leidner, 2001; Jennex, 2018)	Support user assimilation of information through big data analytics (data mining and AI tools) (Alavi & Leidner, 2001; Sanzogni et al., 2017)

Source: Elaborated by the authors, 2019 - inspired by Alavi & Leidner (2001).

Therefore, KM enablers are supported by IoT technologies in the following cases: i) a user collect data from diverse sources, objects, companies or operate the environment, allowing better information and analysis for decision-making process; ii) companies track and monitor interactions of products embedded with sensors and associated to the behavioral data from customers to make better decisions; iii) Data from a large number of sensors with an awareness of real-time events, particularly when associated to visualization technologies; iv) decision-making process; v) productivity while systems adjust automatically to complex situations without human interventions; vi) rapid real-time sensing of unpredictable conditions and in instantaneous responses guided by automated systems; vii) personalized experience (Uden & He, 2017).

In summary, KM enablers are related to Part 1 of the IoT elements, enabling the vision of “things oriented,” “internet-oriented,” and “semantic oriented” or all IoT technologies related to Identification, Sensing, Communication, Computing, Data Storage and Semantic. On the other hand, the KM Processes support the coordination of knowledge management effectively. They can be processes of knowledge creation, acquiring, sharing, exchange, transfer, and application (Bhatti et al., 2014; Jennex, 2018; Santoro et al., 2018; Uden & He, 2017). Some authors add the processes of knowledge storage and retrieval (Alavi & Leidner, 2001; Mirzaie et al., 2019), others mention knowledge conversion or codification (Gold et al., 2001; Kao, 2017; Raudeliūnienė et al., 2018). In this study, we will consider the following main KM processes: Knowledge creation (acquiring and conversion), Knowledge storage, Knowledge transfer and sharing, and Knowledge Application (García-Sánchez et al., 2017; Mirzaie et al., 2019). All these processes are interconnected and interdependent, and they can co-occur (Alavi & Leidner, 2001).

The knowledge creation process replaces existing content or develops new content based on the development of new knowledge through different interactions or sources (Bhatt, 2001). New knowledge can be created by the collaboration between individuals, teams, organizations, industries and the whole environment in which they operate (Lee & Choi, 2010; Turner et al., 2012). Knowledge creation can be divided into two steps: Knowledge acquisition and Knowledge conversion.

Knowledge acquisition refers to develop new knowledge from data, information, or knowledge (Gold et al., 2001). It is related to search, identification, and access to new knowledge (Alavi & Leidner, 2001), and it usually comes outside the company (Gavrilova et al., 2018). It is an important and complex process that includes intensive interactions with external partners, understanding market trends and technological changes, mainly for small and medium enterprises (SMEs), which can acquire knowledge and opportunities through "learning by doing" (Liao & Barnes, 2015). The knowledge acquisition can be supported by IoT with sensors network to capture data and Big Data (Tian, 2017). Although it is important to develop and maintain an effective external knowledge acquisition, also it is needed to facilitate different information and knowledge transformation methods, considering the tacit knowledge (Liao & Barnes, 2015).

Knowledge conversion refers to make the acquired knowledge useful for the organization and other actors by arranging and transforming tacit knowledge into explicit knowledge (Gold et al., 2001). The knowledge conversion can be based on known SECI model (Sumbal et al., 2017; Tian, 2017), with four stages moving between the tacit and explicit dimensions of knowledge and growing in a spiral flow: (1) Socialization (tacit to tacit) refers to converting social interactions and shared experience among individuals; (2) Externalization (tacit to explicit) refers to converting tacit knowledge to new explicit knowledge (e.g., articulation of best practices or lessons learned); (3) Combination (explicit to explicit) refers to the creation of new explicit knowledge by assimilating, categorizing, reclassifying, and synthesizing existing explicit knowledge; (4) Internalization (explicit to tacit) refers to creation of new tacit knowledge from explicit knowledge (e.g., the learning and understanding that results from reading or discussion) (Nonaka et al., 2000). This framework in a spiral effect can spread the knowledge from the individual to the group, to the organizational level, to the industries level, and beyond (Zablith et al., 2016). The main challenges are to find the conditions to facilitate knowledge creation, such as the cultural environment rather than the source or state of the knowledge (Alavi & Leidner, 2001).

Knowledge storage refers to the knowledge acquired, created and shared that should be stored with the appropriate protection (Gavrilova et al., 2018). This storage can be done through the organizational memory that includes knowledge exist in various component forms, such as written documentation, structured information stored in electronic databases, codified human knowledge stored in expert systems, documented organizational procedures and processes and tacit knowledge acquired by individuals and networks of individuals (Alavi & Leidner, 2001).

Knowledge transfer and sharing refer to the ability to transfer knowledge from the individual to the team, from the team to the KM process level, from the KM to the organization, and from the organization to the industry. Individuals acquire knowledge differently based on their previous knowledge and experiences, and they can transfer to teams to build collective knowledge for the organizations (Turner et al., 2012). Communication processes and information flows drive knowledge transfer in organizations, composed of five elements (1) perceived value of the source units knowledge, (2) motivational disposition of the source or willingness to share knowledge, (3) existence and richness of transmission channels, (4) motivational disposition to receive or desire to acquire knowledge, and (5) the absorptive capacity, which is defined as the ability not only to acquire and assimilate but also to use knowledge (Gupta & Govindarajan, 2000).

Knowledge transfer involves knowledge sharing by the knowledge source and knowledge acquisition by the destination. Knowledge sharing or knowledge exchange provides information, skills and expertise about some activity or know-how in order to collaborate to solve problems, develop ideas or new procedures and policies (Wang & Noe, 2010). The objective is to allow external and internal people or teams to discuss via different forms such as face to face meetings, internet, database and best practices communities to disseminate knowledge (Wu, 2016). The use of an information system for knowledge sharing, in an internet environment with virtual forums, in a trust context between people with the appropriate structure for exchanging and transferring experience could create a competitive advantage for the organizations (Mirzaee & Ghaffari, 2018). Although the challenge is not only to exchange knowledge inside the organizations but also with the external organizations, in a common language or format translated to different platforms and applications (Zablith et al., 2016).

Knowledge application is an important activity to make knowledge active and relevant to generate value to the organizations (Bhatt, 2001), since it is common the individuals' access and assimilate knowledge; however, they are not usually applying it (Alavi & Leidner, 2001). The useful knowledge should solve problems and support the everyday activities (Bhatt, 2001; Gold et al., 2001; Wu, 2016), or in the organizational routines combined with the use of technologies (Alavi & Leidner, 2001).

Knowledge integration is the ability to combine different types of external and internal knowledge in a continuous and collective process to develop a new set of knowledge to solve a specific task or outcome (Bresciani et al., 2018). It is the ability to transform knowledge into action from distinct types of actors with specialized and complementary knowledge to achieve the aim of the network. The challenge of knowledge integration is to identify the right actors with their specific contribution of knowledge as well their compatibility in the network, besides interacting human and social context where the knowledge is created or needed (Tiwari, 2015). Thus, knowledge integration is the orchestration of knowledge creation, knowledge storage, knowledge transfer and knowledge application in a network of firms or stakeholders, where each actor possesses a specific knowledge to be jointed and transformed in a collective knowledge to be applied in a specific accomplish. In the IoT environment, there are opportunities to develop knowledge, mainly related to knowledge heterogeneity, which combines knowledge of multiples disciplines, organizations, and social networks with the support of the technologies and new system architectures to develop multidisciplinary Knowledge bases (Anum et al., 2018). Thus IoT could leverage KM processes capabilities to transform data into actionable knowledge or decision with the support of technologies and analytical tools, social skills and experiences to co-creation of real-time knowledge with stakeholders regularly (Jennex, 2018; Santoro et al., 2018; Uden & He, 2017). The KM processes can support Part 2 of IoT elements related to Applications and Services with direct interface with objects, humans, and machines.

2.9 KM AND CONNECTIVITY & INTELLIGENCE

In an IoT Ecosystem, knowledge, information and data are part of a KM processes network, with no hierarchy neither sequence. The use of technological contents and technology-based services and applications, supported by KM Enablers, turn data into information and knowledge. Moreover, the combination of the development of knowledge in humans and machines result in collective intelligence (Hakanen & Rajala, 2018). This notion lead to the co-creation of new real-time knowledge (Uden & He, 2017) to generate a smart environment (Anum et al., 2018). Thus, the combination of KM enablers and KM processes, mainly with the focus on the Knowledge integration process, provides a way to generate knowledge to individuals, teams, organizations, industries and the whole environment (Turner et al., 2012). As a consequence, it results in a higher Connectivity and Intelligence (Part 3 of IoT elements) to enable an intelligent and smart IoT ecosystem. Based on the context presented until here, we propose that:

Proposition 1: IoT Ecosystem will be more effective with Connectivity and Intelligence generation based on the KM Enablers and KM Processes.

This proposition is represented in a model of IoT-KM, as shown in Figure 2.

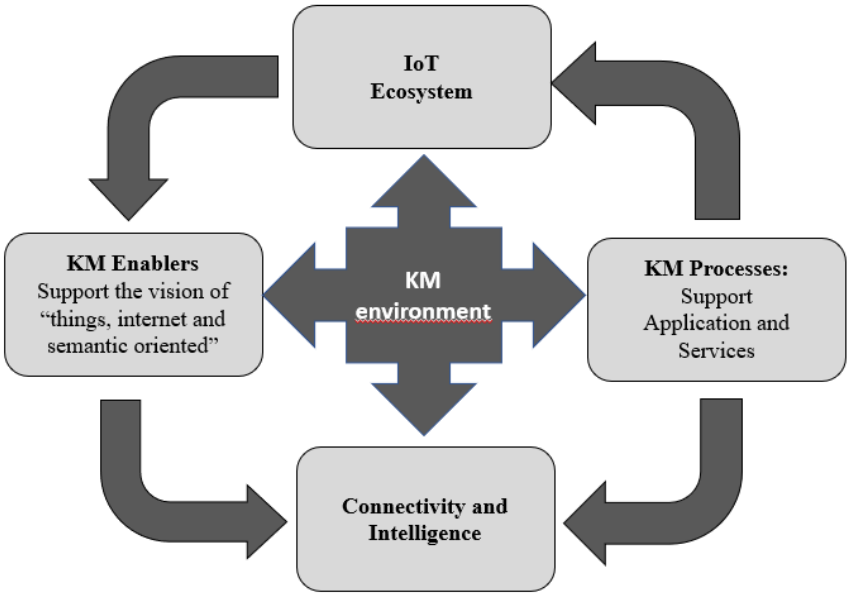

Figure 2 – Proposed IoT-KM model
Source: Elaborated by the authors

An integrated IoT environment has brought additional challenges beyond the technology itself or beyond the discussion of the KM enablers or the IoT elements such as Identification, Sensing, Communication, Computing, Data Storage and Semantics. The researchers started to discuss the IoT Applications and Services through case study researches. However, the discussion of human capital or the interaction of human beings, or the stakeholders working collaboratively in the virtual and physical world is, in the beginning, to understand how to create a smart and sustainable ecosystem.

On the KM perspective, IoT elements support KM enablers, and the KM processes could enable the IoT smart ecosystem by the enhancement of "Connectivity" and "Intelligence" in the KM environment. The Connectivity is more related to Knowledge Acquisition, Knowledge Transfer and Knowledge Sharing Processes. At the same time, the Intelligence is more related to Knowledge Conversion, Knowledge Storage and Knowledge Application, although all processes are interdependent and complementary among them. The Knowledge Integration process is directly associated with the process of co-evolution and continuous learning that brings together all the KM processes to create and use specific knowledge through collective knowledge. Consequently, the Connectivity and Intelligence are parts of the continuous Knowledge lifecycle among objects, individuals, organizations and the whole environment.

In the smart environment, the life cycle of KM processes can be highly dynamic, as well as new actionable knowledge or intelligence generated to feed another life cycle in real-time. Continuous learning must lead the generation of actionable intelligence, an evolutionary network, or, ultimately, in an IoT Smart Ecosystem.

Therefore, Proposition 1 is based on the review and interpretation of the literature, also examples of IoT edge companies and market reports. The conclusion is that KM and IoT can leverage each other to create intelligent ecosystems by using the best of emergent technologies. The conjunction with KM processes and KM enablers generates intelligence with IoT elements in different knowledge perspectives using the spiral of learning (Nonaka et al., 2000) within a network of data, information, and knowledge. This conclusion is reinforced by the three basic foundations of an effective KM, which are the maintenance of learning loops, systematically disseminate new and existing knowledge, and apply knowledge wherever it can be used (Sanchez, 2006).

An essential aspect of the ideas presented is to distance themselves from models that treat KM in a linear and unidirectional way. One of the main points of the new proposal is the dynamic, interactive systems that learn and teach. This study tries to propose a conceptual KM-IoT Smart integrated model, so further investigation and empirical study continue this discussion, and probably this model might evolve. At the same time, the technologies and application advances and new concepts are developed for the new digital world. Therefore, in the next section, we present the methodological procedures applied to validate the proposition 1.

3 RESEARCH METHOD

This section presents the research approach, research strategy, and method to understand how IoT and KM generate intelligence and connectivity in IoT smart ecosystem. The research approach for this study is qualitative, which is used for exploring and understanding the meaning of the individuals and groups (Creswell & Creswell, 2017). The collect process follows the in-depth interview, which provides answers to questions of the type “how”, which allows inferences from interaction built from the participants (Creswell & Creswell, 2017). The research strategy for data analysis is the Grounded Theory based in Charmaz (Charmaz, 2006).

3.1 RESEARCH DESIGN

The research design is divided into four phases, presented in Figure 3. Each phase shown in Figure 3 will be explained later on in this sub-session.

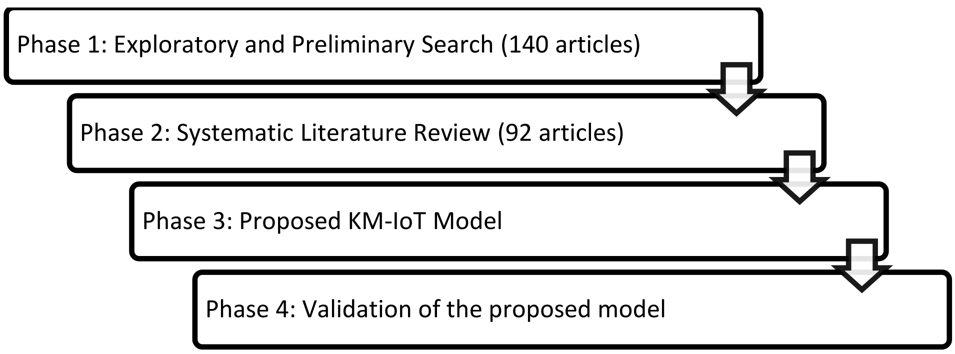

Figure 3. Research Design in 4th Phases
Source: Elaborated by the authors, 2019.

In the first phase, we conducted an exploratory and preliminary literature search to understand the main topics related to IoT and KM. We performed several searches in the Web of Science (WoS), which covers scientific and academic researchers in the fields of science, social science, and arts and humanities. This first process of data collection was performed in September and October 2018. In this step, we found 140 articles considered relevant based on general information. We use these articles to build a literature mapping that seeks the coherence between ideas, grouping themes, areas, among others (Creswell & Creswell, 2017).

Thus, we applied an exploratory approach that facilitates a deep understanding of the subject based on the recursiveness way from data collection and treatment according to the qualitative approach. This type of research does not follow the traditional narrative literature review since the first phase assists the second phase in connecting future research to the question and concerns found by past research (Tranfield et al., 2003).

We evaluated the literature using Atlas.TI, software for qualitative software analysis. We code the main concepts and related themes, and the conceptual map was generated, according to Figure 4.

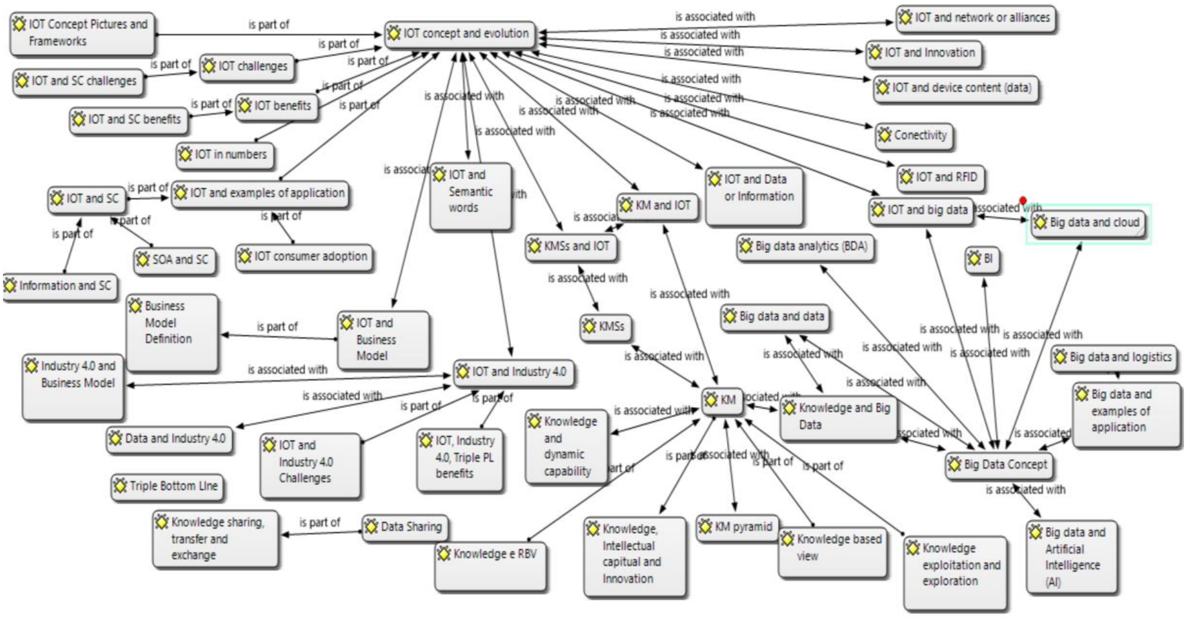

Figure 4 - Conceptual Map from the literature review

Source: Elaborated by the authors, 2019.

This conceptual map shows the focus on the technical aspects of the technology's evolution, such as RFID, Big Data, Cloud Computing, and Blockchain, besides the application of each technology in a separate way. It seems to have a strong relationship between KM and Big Data, and not directly with KM and IoT. Thus, we decided to perform to explore the theme using an academic protocol, using an SLR in the second phase of this research.

The SLR assist in understanding the research content, the alignment among the several sources, authors and future research perspectives (Horkoff et al., 2015), besides creating a pattern to follow by establishing a routine starting from the research protocol to research results, based on certain assumptions in the procedure applied in this study (Tranfield et al., 2003).

The research question was defined based on the gap found in the literature for the second phase of this research: How KM and IoT generate intelligence and connectivity in the IoT smart ecosystem? Thus, a new search was done in the WoS on April 7th, 2019, considering the following steps: i) Build a string of keywords related to the research question; ii) Establish the criteria of inclusion and exclusion; iii) Analyze the literature systematically; iv) Classify or group by categories and themes.

The following string was used on WoS: ("IoT" or "Internet of Things" or "Internet of Everything") AND ("Ecosystem" Or "Knowledge Management" Or "KM"). The search on WoS presented 800 documents. The criteria of exclusion were determined to filter the database, based on the following rules: only Document Type = Article, and WoS categories = computer science information systems or computer science theory methods or computer science interdisciplinary applications or information science library science or business or management or green-sustainable science technology or engineering industrial or operations research management science or multidisciplinary sciences. The result of the filtering process presented 173 articles.

The 173 articles were analyzed to understand the “corpus of the research.” The articles were published between the years 2011 and 2019. It is worth mentioning that in 2016 increased the number of articles, nevertheless in less of 4 months of 2019, the number of articles is higher than in 2016, according to Figure 5.

Year of Publication	Number of Articles	% of 173
2019	27	15.607 %
2018	67	38.728 %
2017	34	19.653 %
2016	26	15.029 %
2015	10	5.780 %
2014	4	2.312 %
2013	3	1.734 %
2012	1	0.578 %
2011	1	0.578 %

Figure 5 – 173 Articles per published year

Source: data from Web of Science, 2019.

The top five sources of publications correspond to 30% of all articles, according to Figure 6.

Source	Number of Articles	% of 173
IEEE INTERNET OF THINGS JOURNAL	18	10.405 %
FUTURE GENERATION COMPUTER SYSTEMS THE INTERNATIONAL JOURNAL OF ESCIENCE	14	8.092 %
IEEE ACCESS	10	5.780 %
INTERNATIONAL JOURNAL OF SUSTAINABLE DEVELOPMENT AND WORLD ECOLOGY	5	2.890 %
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	5	2.890 %

Figure 6 - Publication Sources

Source: data from Web of Science, 2019.

We use the software VOSviewer version 1.6.10 to identify Keywords in the 173 articles. It was found 947 Keywords with 39 keywords appearing at least five times, according to to Figure 7.

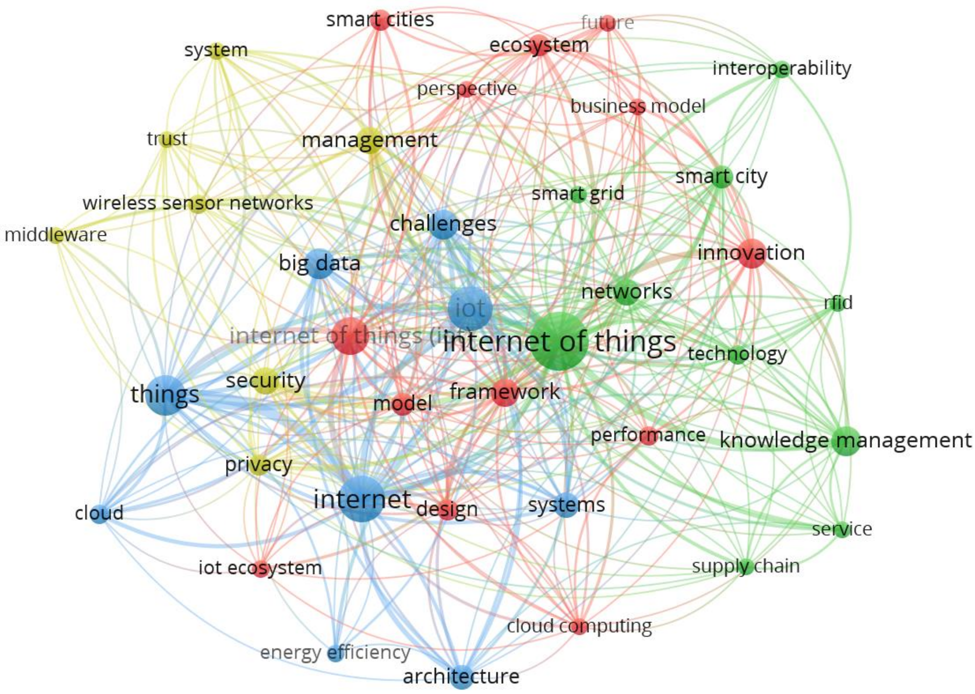

Figure 7 – Keywords Network

Source: Tree of Science generated by the author, 2019

We analyzed the abstracts based on the Keywords and supporting the analysis of the main topics covered in this research. We classified the 173 articles in technical perspective or business perspective articles. The summary of the classification is shown in Figure 8.

Classification	Number of articles
Technical Article	89
Business Article	84
Total of Articles	**173**

Figure 8 - Publication Sources

Source: Elaborated by author, 2019

The 84 articles Business Article were classified as showed in Figure 9.

Classification	Number of articles
Application	21
Big Data	7
Blockchain+ Security	11
IoT Ecosystem	24
Innovation + Business Model	6
KM	9
Services	6
Business or Relevant Article	**84**

Figure 9 – Business or Relevant Articles Classification

Source: Elaborated by author, 2019

We loaded the 173 articles into Tree of Science (TOS) web application, which uses network algorithms to optimize the search and selection of articles. In Figure 10, the orange balls represent the classic articles cited by the 173 articles, the brown balls represent the structural cited articles, and the green balls represent the most recent cited articles. The size of the balls represents the relevance of the article.

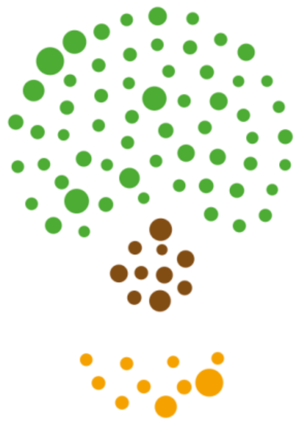

Figure 10 –Tree of cited articles distribution

Source: Elaborated by author, 2019

The eight classic articles (orange balls) are related to IoT and smart objects. We removed the article by Eisenhardt (1989) related to research methodology and the book of Vermesan et al. (2011) from the database. Seven articles of the eight articles are related to the basic definition or surveys about IoT, and one article of the eight articles is related to the application in Smart Cities.

The ten most cited articles (orange balls) are related to Ecosystem, KM, Innovation, and Security, and the ten most recent (green balls) articles are related to Ecosystem, KM, Innovation, Application, Business Model, and Services. We removed the article from Brillenger (2018) associated with Mapping Business Model Risk Factors because it is not related to the subject of this study. It is important to point out that we also included eight classic articles in this study, which we can consider the relevant IoT literature discussion.

The summary of all articles with the identification of most cited, classic, business and technical articles is presented in Figure 11.

Classification	**Articles**
Most Cited	24
Classic	8
Business Article	60
Technical Article	89
Total Business or Relevant Article	**181**

Figure 11 – Classification Summary of the total of Articles

Source: Elaborated by author, 2019

We decided to remove the 89 technical articles from the database because our objective is to understand the KM and IoT from the business perspective and not to discuss the technical literature. The final number of articles is 92, as shown in Figure 12.

Classification	Number of articles
Business Article	76
Classic articles (added)	8
Total of Articles	**92**

Figure 12 –Final Number of Articles

Source: Elaborated by author, 2019

We built a proposed model in the third phase based on the intersection of the IoT ecosystem, IoT and KM literature. This intersection is represented in the Ven Diagram of Figure 13, using the following sources besides the articles of RSL: i) some articles found in the first phase; ii) articles related to KM and associated IoT technologies such as RFID, Big Data, Cloud Computing; and Blockchain, and iii) additional search in the WoS database related to KM processes, KBS, ETL and complex projects with 17 articles

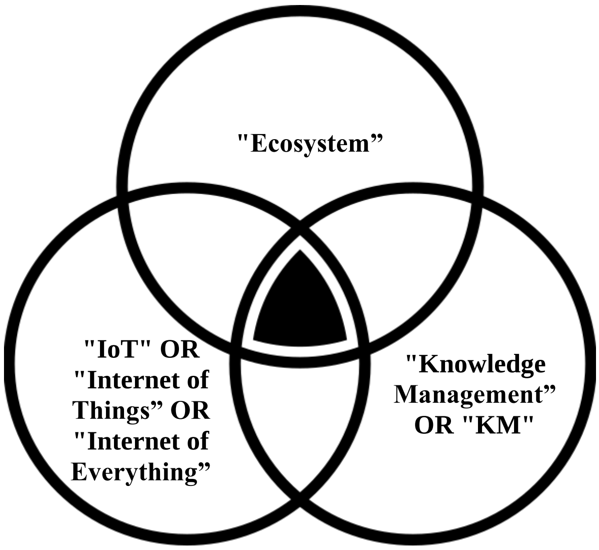

Figure 13 –Ven Diagram

Source: Elaborated by author, 2019

The fourth phase is the validation of the proposed model following the qualitative approach in a descriptive and exploratory based on in-depth interviews. This phase is composed of data collection and data analysis procedure

3.2 DATA COLLECTION AND ANALYSIS PROCEDURES OF EMPIRICAL PHASE

For this phase of the study, we select the in-depth interview method since it is considered one of the most important sources of facts, experiences, points of view, and opinions (Turner, 2010). Thus, data collection conducted by interviews to understand the relationship between IoT and KM and how intelligence is created in the IoT ecosystem. A qualitative approach allows an intentional selection of respondents for a greater understanding of the problem (Creswell & Creswell, 2017), that happened with pre-established criteria to compose the sample.

The interviews were conducted in an in-depth interview manner, considering a set of topics to be followed, serving as a guide for the questions, avoiding limitations on the phenomena study, given the exploratory approach of the research. Thus, it also allowed making improvised questions to complement the information on the subject, as unexpected data may appear from participants (Jacob & Furgerson, 2012).

The topics related to KM Enablers and KM Processes based on the literature review should answer the research question. The items and questions applied during the interviews are described in Table 4.

Table 4 – Interview Protocol

Objective	Topics	Type of Questions	References
Check if there are KM processes to support IoT ecosystem	KM Processes: Knowledge creation (acquiring and conversion), Knowledge storage, Knowledge transfer and sharing, and Knowledge Application	How does the IoT ecosystem work regarding knowledge?	(Alavi & Leidner, 2001; García-Sánchez et al., 2017; Mirzaie et al., 2019)
Check if the IoT ecosystem create knowledge and convert it to be used	The knowledge creation process replaces existing content or develops new content based on the development of new knowledge through different interactions or sources. New knowledge can be created by the collaboration between individuals, teams, organizations, industries and the whole environment	How does Knowledge is created? How does the |Knowldege is acquired? How does the Knowledge is converted to Useful Knowledge (tacit to explicit)	(Bhatt, 2001; Lee & Choi, 2010; Turner et al., 2012)

Check how knowledge is retained in the IoT ecosystem	Knowledge storage refers to the knowledge acquired, created, and shared that should be stored with the appropriate protection. One way is through organizational memory.	How does the knowledge is stored or retained?	(Alavi & Leidner, 2001; Gavrilova et al., 2018)
Check if the IoT ecosystem generate collective knowledge, and the knowledge is shared among teams	Knowledge transfer and sharing refer to the ability to transfer knowledge from the individual to the team, from the team to the KM process level, from the KM to the organization, and from the organization to the industry. Individuals acquire knowledge differently based on their previous knowledge and experiences, and they can transfer to teams to build collective knowledge for the organizations.	How does knowledge is transferred or shared? Is there any process to generate collective knowledge?	(Gupta & Govindarajan, 2000; Turner et al., 2012; Zablith et al., 2016)
Check if the knowledge is applied continuously	Knowledge application is to make knowledge active and relevant to generate value to the organizations since it is common the individuals' access and assimilate knowledge, but no apply it. The useful knowledge should solve problems and support the daily everyday activities in a practical way or the organizational routines combined with the use of technologies.	How does the knowledge created is applied in different situations or from collective to personal needs	(Alavi & Leidner, 2001; Bhatt, 2001; Gold et al., 2001; Wu, 2016)
Check if the IoT ecosystem works in a continuous and collective knowledge to personal to the collective knowledge	Knowledge integration is the ability to combine different types of external and internal knowledge in a continuous and collective process to develop a new set of knowledge to solve a specific task or outcome. Thus, knowledge integration is the orchestration of knowledge creation, knowledge storage, knowledge transfer and knowledge application in a network of firms or stakeholders.	How does knowledge is continuously created and applied? From individual knowledge to collective knowledge to individual knowledge	(Bresciani et al., 2018; Tiwari, 2015)

Check if there are technologies to support KM activities	KM enablers are supported by IoT technologies i) a user collect data from diverse sources, objects, companies ii) companies track and monitor interactions of products embedded with sensors iii) Data from a large number; iv) decision-making process; v) productivity while systems adjust automatically without human interventions; vi) rapid real-time sensing of unpredictable conditions vii) personalized experience	How does technology support the IoT ecosystem?	(Uden & He, 2017)
Check if connective and intelligence support the IoT smart environment	KM enablers and KM processes provide a way to generate knowledge to individual, teams, organizations, industries and the whole environment, resulting in a higher Connectivity and Intelligence to enable an intelligent and smart IoT ecosystem	How does the technology and process of knowledge management answered in the previous questions generate more intelligence and connectivity?	(Turner et al., 2012)

Source Elaborated by the authors, 2019

One aspect that been reinforced is that the respondents have experience or be part of an IoT ecosystem. For a comprehensive data collection, the sample constituted the different type of stakeholders, since IoT ecosystem is composed of industry stakeholders such as buyers, suppliers, manufacturers, associations and government, who develop or co-create solutions, applications, products collectively, and services to add value to users and organizations (Kolloch & Dellermann, 2018). Thus, twelve interviews were carried out between January and March 2020. The profile of the interviewees is shown in Table 3.

Table 3: Profile of the interviewees

#	Function or Role	Segment	Professional Experience	Experience with IoT	Type of Stakeholder	Interview duration
E1	Service Coordinator	Technology and Corporate Education	20 years	14 years	Solution Provider	1h17min
E2	VP Operation South American	Energy Optimizing	25 years	3 years	Solution Provider	40 min
E3	RF Consultant	RFID	25 years	14 years	Consultant	1h17min
E4	IoT Platform Application Engineer	Technology	17 years	14 years	Technology	50 min
E5	Smart garbage	Logistics and Mineral	14 years	3 years	Industry	44min
E6	Startup owner	Technology	20 years	2 years	Startup	28min
E7	Global Innovator	Consultant	24 years	11 years	Technology	1h12min
E8	Business Executive	Association	20 years	14 years	Association	51min
E9	CEO - owner	Innovation / Industry 4.0	25 years	4 years	Consultant	48min
E10	Technology Innovation Manager	Technology/Blockchain	30 years	3 years	Technology	34min
E11	Consultant	Business Transformation	37 years	6 years	Consultant	1h12min
E12	Account Manager	Information and Communication Technology (ICT)	27 years	10 years	Technology	1h14min

Source: Elaborated by the authors, 2020

All interviews were transcribed e uploaded as primary documents in the software of qualitative analysis called Atlas.TI. The analysis process takes place through a kind of mirroring of the original documents in the software. The documents do not undergo any intervention by the software, as their content remains in the original, but it goes through a coding process where codes are assigned to text fragments. Each text fragment is treated as a quotation and represents the substantive reality that is indexed to a code. We follow the search for patterns of behavior in the interviewees' discourses, which allowed for analytical generalizations from evidence (Miles & Huberman, 1994) or even the construction of theories (Charmaz, 2006).

Thus, we follow (Charmaz, 2006) recommendation, which indicates that the categories were constituted from the interviews conducted and built from the data-driven and the theory-driven perspectives. The process follows coding parts of the text used as how quotation in the discussion of the results. Each code was analyzed with its relationship in data-driven and theory-driven perspectives. The first one represents meanings created from the corpus analysis (data from the interviews). The second perspective represents codes (theoretical abstractions) that were previously identified in the literature, such as those that allowed built the questions presented in Table 4. Thus, this process was performed based on the coding technique, which Creswell (2010) described as a process of organizing the material and assigning labels of the categories highlighted with a term (code), based on the participant's actual language.

The coding and analysis process followed from open coding, it was initially carried out, identifying in the interviews the categories of analysis (Charmaz, 2006). The second codification cycle applied was axial coding, in which the codes are grouped to allow the representation of cause and effect relationships, explanations, properties, among others, based on data or even on the theory raised. It occurs by consolidating the research results. The last step of the analysis, the selective coding, sought to refine the initial categories and establish meaning in the relationships and explanations combined with theoretical and empirical evidence.

Therefore, based on the general framework constructed from the incidents (quotations) and relating them hierarchically with other second-order codes (axial), more abstract categories are obtained to explain the reality studied (Charmaz, 2006; Saldaña, 2016). In the analysis process, the interviews were performed until reaching theoretical saturation, which means the information collected was considered enough when the information begins to be repeated, and no new relevant data is found. (Guest & Johnson, 2006). The Interviews were recorded with the interviewee's consent, and they took the time required for respondents to expose their experiences on the subject. All the content presented during the interviews was fully transcribed and imported into data analysis software Atlas TI (Friese, 2002).

4 ANALYSIS OF RESULTS AND DISCUSSION

In this section, we presented the analysis of the results and discussion related to the relationship of KM and IoT ecosystems and how intelligence and connectivity create and IoT smart ecosystems based on the data collected in the interviews

In the current IoT stage, there is evidence about the different implementations of applications and services in an interconnected environment, considering the technologies that we already have available, even having some technological challenges to overcome. The interviewees believe in IoT market potential and its value adds for the companies and users, although the market is in the early stages of the technology's adoption. There are several proofs of concept projects and companies discovering and experimenting with the IoT technologies applications. Therefore, the companies are still unwilling to invest in something they do not know the real value, although they understand that IoT can provide a competitive advantage, according to the following interviewees:

- E5: "[…] the board of directors has to believe in the cost reductions since the competition use the manual process. The main factor was to show examples in other fields, convinced that technology and intelligence could work […] and present a proposal [...]"
- E9: "[...] platform aggregating some kind of value […] improvement of quality, improvement in the operation and eventually knowledge generation […] when identifying the problem […] you start generating some results […]"
- E11: "[...] how to land IoT thought technology, solution […] to collect fruits from IoT […]"
- E8: "[...] it adds value through the capture of information […] become the decision making more precise […]"
- E12: "Mobile operators are envisioning that IoT business can bring additional revenue[…]
- "E11: "[…] in the retail market, we understand several uses, but we are in the process of experimentation, validation […] for adoption and the multiplication of these technologies in different perspectives […]"
- E10:"[…] Companies already understand the benefit […] there is an adoption curve, there are the early adopters, who are people who want to try everything of the new technology, but they are the minority, you know, the majority wait for the large part of the market to use. So, it is the normal cycle. It takes a long time, from the first to adopt to others, too […]"
- E9: "[…] we understood that is a possible competitive differentiation […]"

Therefore, as the IoT adoption is in the early stages, the decision-makers, in general, still do not understand how IoT works and its benefits. Part of the interviewees perform educational work for the market, as they mention:

- E4: “Although the company offers processors for IoT solutions, some pilots are run directly by us to influence the use of the technology […]”
- E9: “It involves the size of the problem to be solved, where to apply IoT, and in some cases, we act as an educating agent within the company with workshops to show what is Industry 4.0, IoT, how to get the benefits […]. They are starting understanding, start groping […] mainly doing tests […] there are several initiatives […] with some internal committees to discuss how the technologies work, as drones [….] how to apply […] IoT, Big Data, Analytics, artificial intelligence [….]”
- E11: “I think they do not understand the value, the real value […] in reality, you talk to your family or even within the company […] who knows what it is IoT […]”
- E12: “[…] it is a continuous work to present the use cases to explore the network and to show the potential source of revenues […]”
- E1: “[…] our mission is to try to bring the academic world closer to industry. We have the center of excellence to try consistently work on that […]”

Although the respondents are working in the dissemination and recognition of IoT, they cited several successful project implementation and how they define IoT based on their experience, as we show in the following statements:

- E5: “[…] I see it as a set of solutions […] when you start to get into the technical side of the communication, information generation, database, […]All the logic behind it […] it is not a single tool. It is a set of tools […] it can be used in several segments, several different types of operations […]”
- E12: “[…] a straightforward definition of IoT is a solution in systems that interacts in the same environment […]. It serves as a tool to collect information for better decision making […]”
- E3: “In an IoT environment, the object must be intelligent, it must have means of communication and it must have data analysis. It is not IoT if there is not data analysis, so people think that if you put a system with raspberry, it is IoT.”
- E10: “[…] Yes, you will usually add other solutions. It will not be pure IoT […] IoT, it is not just a software solution, right? So whenever you have the software, you have to have someone who works with hardware and know-how about IoT in general […] you need to work with a partner [...] there is not a simple project […]”

Therefore, most of the respondents define IoT as a set of solutions, with several applied technologies, having an intelligent object, capturing data, interacting with the environment, analyzing data, and adding value to companies and users. These statements are consistent with the literature, considering an IoT environment with a set of supporting technologies to provide services and applications, where data and information are collected to be used in the interaction of the physical and virtual environment (Atzori et al., 2010; Gubbi et al., 2013; Miorandi et al., 2012; Xu et al., 2014).

This environment materializes by a common platform with several stakeholders (Hamidi & Jahanshahifard, 2018), that has several elements divided into layers, as mentioned by some interviewed, such as:

- E8: "[…] the GS1 system is a set of standards applied in some stages. The GS1 system has three pillars: the first is identification [...], the second pillar is capture data, and the third pillar is the data sharing […]"
- E9: "[…] I need to collect data from the object, people, or equipment. Data flows within a network to cloud, transform into information in a dashboard to monitor the environment and add some other layers like artificial intelligence, machine learning […]"
- E6: "We invested in the development of a platform […] to collect data with some gadgets […] to migrate to the second layer with a back office to analyze data and in the third layer was a front-end with a dashboard […]"

Besides of the layers, most of the IoT elements cited by the respondents relates to different types of technologies like the following ones: Big Data, Cloud Computing, Blockchain, Data Lake, 5G technology, object detection technologies, cameras for facial recognition and cognitive biometrics, wi-fi, RFID, beacon, access point, Arduino, Raspberry, QR Code, augmented reality, Bluetooth, DataMatrix and Artificial Intelligence. Thus, we extract some parts of the interviews to bring as examples:

- E4: "[...] IoT is not a single solution, for example, the smartphone is also part of the IoT technologies, with 5G technology […]"
- E10: "it is a market where more solutions come up […] dozens or even hundreds of different boards […] wi-fi, […] cellular signal, […] more memory, […] more

processor, […] even telecom technologies are improving, […], the hardware is going much faster, […] you will usually add other solutions, it will not be pure IoT, […] you can send the information to a mobile application, you can use Blockchain, you can use Big Data to work with the amount of information you receives, may involve several other technologies […]"

- E11: "For example, […] a smart TV is an IoT […] it connects you with the world, through the internet, […], I started to get involved with RFID, […] all these technologies […] artificial intelligence, machine learning, big data, […] all of this in a certain way consists of some kind of hardware, some kind of software, […] all the technologies […] are inside an umbrella, we can call it IoT […]"
- E1: "[...] new technologies […] will open new fronts wi-fi, Bluetooth, QR code […]. Now everyone comes there with their smartphone already captures the information […] several technologies like DataMatrix, RFID and others […]"
- E7: "[…] you have several technologies, where you can apply IoT[…] the smart cameras that are computer vision, put together artificial intelligence, things [...] it is to analyze cognitive biometrics [...] there are devices […]. I can access Google Home, Google artificial intelligence […] when we talk about IoT, we cannot forget about 3D cameras […]."

Thus, we noted that all those technologies are composed of elements of Identification, Sensing, Communication, Computing, Data Storage, and Semantic (Atzori et al., 2010; Bello & Zeadally, 2016; Gubbi et al., 2013; Miorandi et al., 2012). Those elements enable the visions of "things oriented," "internet-oriented," and "semantic oriented," forming an IoT environment.

We also noted that the respondents are very excited about the IoT technologies and their future opportunities. Therefore, we infer the technologies are no longer a limitation for the use of the IoT solution implementation, based on some respondents´affirmations, such as:

- E10: "[…] technological issue is not the problem today. There are already hundreds, literally, hundreds of platforms, of software, of IoT […], all the leading market clouds already have an IoT platform, like WS and Google, IBM, […] the problem is that the companies need to trust, to want to use […], to have a use case that makes sense, that gives a return, [...] the problem is not the technology.

- ”E11: “The main challenge for companies as they collect data from different sources, is the integration and data interpretation […]”

Thus, we verify that companies started using IoT solutions, but they are focusing on collecting data to create dashboards, as we can see in the following affirmations:

- E9 “[…] I need to collect data […] several data are generated […] I transform it into information into a dashboard to monitor the environment [...]”
- E6: “[...] the platform collects data […] filter and analyze them […] the frontend is a dashboard [...].”
- E2: “for a while is unidirectional, you receive information, treat to generate action, but it is not generation action yet […] the main feature is to monitor using a dashboard […]”

Despite the evidenced opportunities and a specific technological maturity achieved to take advantage of the IoT ecosystem, it is still necessary to discuss management and its effectiveness. In the next sections, these discussions about directions and actions to take better advantage of the IoT ecosystem are deepened.

4.1 IOT DATA-CENTRIC AND USER-CENTRIC

Hence, we found that some companies are still concentrating their efforts to collect and store data to become them accessible. This perspective is called an IoT data-centric, which is related to publish and retrieve information using the internet (Atzori et al., 2010; Miorandi et al., 2012). On the other hand, we also confirmed that there is an IoT user-centric perspective, which is related to analyze and share information using technologies of data analytics and cloud computing to support user´s needs (Gubbi et al., 2013), as we show in the following examples:

- E4: “[...] create an artificial intelligence to meet the users' needs […] I use IoT in my life […], for example, […]when I am within 100 m of my house, Amazon sends a signal to my smartphone to open the gate based on the geolocation […]”
- E11: “[…] now there is a technology with facial recognition, …the data analysis is very advanced […] to understand the customer´s behavior and meet their expectation[…].”

- E1: "[…] on the technologies value, you can create intelligence for the business to make better products, for example, if you have a smartwatch, you run with it, you learn from it, how is your heart, how is your beating, it is to allow to improve…[…] the product provides information through analytics.[…]

Hence, in the user-centric perspective, it is necessary to assess the ability to analyze data, information, or knowledge for decision making, which is on a border between the human capacity to generate tacit to explicit knowledge and artificial intelligence. We found a threshold between Semantic and Intelligence concepts. In the literature, semantic means the ability to extract knowledge (Al-Fuqaha et al., 2015; Atzori et al., 2010), and Intelligence is the ability to interpret data and transform it into something useful for actionable decision or actionable knowledge (Jennex, 2018). In both concepts, the human and machine interactions should be considered.

Therefore, we can infer the need for a new IoT vision related to "Intelligence-Oriented" enabled by technologies like machine learning and AI, where data, information, and knowledge transform into Actionable Knowledge individual or collective use. This idea connects to the absorptive capacity theory as cited by Gupta & Govindarajan (2000), which is defined as the ability not only to acquire and assimilate but also to use knowledge, but it will not be part of this study.

Additionally, the use of IoT automates certain types of activities to release the human capacity to perform more intellectual and cognitive activities. The interviewees indicated that the greater use of technologies could improve human activities, such as:

- E11: "[…] the idea that machines will replace people, I think they will replace only those people who were not prepared for this new moment, [...] I think people will continue to have importance as long as they have the intelligence to aggregate to these initiatives […]"
- E8: "[...] they are increasing human capacity […] people will spend energy on things more productive […] to generate more value in other tasks […] machines and technology can replace people in repetitive activities […] improve the quality of life, dignity […] we will have the replacement of several functions […]"
- E12: "[…] IoT releases people to reach other objectives […]"

Therefore, we confirm the need to have a smart environment capable of responding to users, interacting and supporting them with information and helping on carrying out specific tasks (Miorandi et al., 2012). In other words, a more user-centric vision that adds value to those who use the results of the data generated by IoT technologies.

4.2 KM AND IOT RELANTIOSHIP

At this point, we infer a need for KM to support this vision to generate an intelligent environment through the connectivity between humans and machines. According to the literature, the utilization of the knowledge for value creation brings the development of KM, considering the human capital (Mirzaie et al., 2019), and its corresponding technologies application as know-how (Anum et al., 2018). This need intensifies when an IoT environment integrates with real-time technologies, considering the KM increases the speed of response with better knowledge access, enabling many types of applications, mainly associated with IoT (Lokshina et al., 2018; Uden & He, 2017).

The confirmation of the relationship between KM and IoT will be evaluated in two dimensions: KM Enablers and KM Processes (Santoro et al., 2018).

According to the Uden and He (2017), IoT technologies support KM enablers in the following cases: i) a user collect data from diverse sources, objects, companies; ii) companies track and monitor interactions of products embedded with sensors and associated to the behavioral data from customers to make better decisions; iii) Data from a large number of sensors with an awareness of real-time events, particularly when associated to visualization technologies; iv) decision-making process; v) productivity while systems adjust automatically to complex situations without human interventions; vi) rapid real-time sensing of unpredictable conditions, and in instantaneous responses guided by automated systems; vii) personalized experience.

We identified each of the cases based on the interviews, as shown in Table 5.

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Table 5: Analysis of KM enablers

KM enablers	Statements
A user collect data from diverse sources, objects, companies	• E11: "[...] companies are collecting data from different sources […] there is a concept Data Lake [...] to integrate data come from the internet [...] from physical stores, payment means, […]different points of customer contact […]"
Companies track and monitor interactions of products embedded with sensors and associated with the behavioral data from customers to make better decisions	• E1 Pueri: "[...] to improve ...start during the product launch…understand if people use the feature …launch a second version of the product with better functionalities based on people's feedback…the company collected data to understand customer behavior and to learn consumption habits…" • E4: "[...] an example of the application in the retail is the sensor based on cameras to evaluate the people's behavior. A credit assessment was done based on the Chinese's behavior using facial recognition, …how they walk, cross the road, throw garbage on the street…or in schools to check the behavior of the students in the classroom…" • E7: "[...] equipment capable of obtaining any information about the human body [...] a camera has resources to get information…human behavior…using biometry …and artificial intelligence […]"
Data from a large number of sensors with an awareness of real-time events, particularly when associated with visualization technologies	• E2: "[...] the main feature of the system is to monitor and generate a dashboard […] it controls everything [...] in real-time […] with the integrated system […] the manager knows everything [...] all material and activities are tracked […] we see the site with higher and lower performance[…] • E5 "[...] there are cameras [...] to monitor all events...the images were transmitted in real-time via smartphones […]"
Decision-making process	• E2: "[...] the implementation of sensors facilitate the measurement of a process, […] and with data to analyze I can make a better decision […]" • E8: "[...] you have answers [...] that you did not know, and now you can make different decisions based on data […] understand the scenario was difficult in the past […] the effort and time to understand the situation was huge […]".
Productivity while systems adjust automatically to complex situations without human interventions	• E7: "[...] the last news is the cognitive biometrics […] I can use the IoT to analyze the oxygeometry when we breathe […] if I get up if I am tense, stressed […] now I am using to get focus […] when I leave from the engagement state using, the smartphone warns me […]. I can do whole automation at home using digital minimalism [...]. Moreover, we can also have the neurolinguistic programming […]if I have a camera at home, using facial recognition […] considering my emotional state […]. I have much information on the face […] if I arrive stressed, a smart home can turn on a light, make the environment more relaxing, put on a song, […]. I am working on a project using artificial intelligence to analyze pages to find nudity estimating the age to characterizes pedophilia to use by the police…"
Rapid real-time sensing of unpredictable conditions and in instantaneous responses guided by the automated system:	• E7: "[...]there are several technologies [...], for example, smartwatches [...] intelligent cameras to detect accidents [...] a drone can take the first aid to the local before the ambulance.E4: "[…] In the case of life insurance, there are already wearables, such as the smartwatch, to evaluates the heartbeat, tracking where you are. In-car protection, if your car does not have a sensor in it, the smartphone is used, and with the insurance application, it is possible to know its location, car data, fuel, etc. […]. Another application is in the inventory accuracy […] track the stocked material. It is possible to analyze the information with the data collected through Big Data for decision making, having the physical inventory updates for immediate stock replenishment. The stock can be replenished directly by the gondola's information through sensors that collect data and send data to drones, which visually evaluate the shelf and to confirm the lack of material.

Personalized experience	• E4: "...create an artificial intelligence to meet the users' needs. I use IoT in my life….for example, with Alexa voice assistant to remember my appointments, to order my weekly purchases in the supermarket, which includes healthier and organic food..control my entire house….the lights..garage door…TV channel [….] when I am within 100 m of my house, a signal is sent by my smartphone to open the gate based on the geolocation […]" • E7: "[...]I designed a prototype to detect skin cancer…where the doctors can not be, or it takes a long time to get the diagnostic….for local with hard access…with 87% of accuracy[…]"

Source Elaborated by the authors, 2020

Thus, we confirmed that IoT technologies are KM enablers or a kind of KMSs, which facilitates the vision of "things-oriented", "internet-oriented", "semantic-oriented," and "intelligence-oriented" of in an IoT environment. However, there are some paradigms in companies about accumulated data, since they are in repositories with difficult access and they do not have utility so far, as presented to the following interviewee's statements:

- E9: "[...] use the information […] transform into knowledge […] otherwise, it becomes a lot of data […] as in the mining, oil and gas industries, they have lots of data generated from the last 20, 30 years […] for regulatory issues, but they do absolutely nothing […]"
- E1: "[...] which data is essential [...] what I can do with the data [...] from my point of view, unstructured data is useless, because you do not know how to use […] "
- E2: "[...] we need to know what we can do with the data [...] to generate knowledge form the data analysis […]"
- E3: There is no point in sending data if you do not have means to analyze it [...] this is essential to talk about the internet of things and some other pillars […]"

Additionally, we can say that there is an essential difference considering the generation of knowledge in an IoT environment, which is real-time data, in constant monitoring with decisions or actions in real-time. At this point, we need to consider connectivity as an essential element to keep the data "alive" or in an organic way, which aligns with ecosystem formation. Thus, considering this point of view, connectivity ensures seamless, continuous, and ubiquitous interaction with humans, objects, and machines as the respondents declare in the following:

- E9: "[…] The first step is the digital context in operation through data collection. The second step is connectivity; otherwise, data will be local. Connectivity is sent data from de local computer to send to cloud […]; thus, I can analyze data from anywhere […] data is available […]".

- E8: "[...] Most of the time, the confusion happens when we talk about connectivity. At least, I understand that it is the way I connect things to another […]. So I can use wi-fi, 4G, 5G, network or internet […] this is connectivity […]".
- E3: "[...] connectivity happens from the moment I am on my cell phone. I download the application to see how-to uses a product. Thus this information goes to industry wherever is the place, regardless of whether people know or do not know."
- E5: "[…] the truck driver logon on the system through data connection using a smartphone or via radio to inform a central what is happening and vice-versa […]"
- E7: "[...] sometimes, there is no need to have 100% of connectivity. I collect data, and when I have a robust and stable connection, with good latency, I send all at once […]. Other cases demand real-time connection […]"

Thus, the coordination of data, information, and knowledge transformation into actionable knowledge is more dynamic and more complex in real-time, considering all the technologies available combined with human interactions. Therefore, we accept as true that the KM can support IoT with this coordination of KM in IoT will help in an environment considering the daily complexity of human beings, animals, and the use of equipment within an interconnected ecosystem to generate collective and personalized intelligence.

We noted the need for several KM processes to support the application of IoT elements. Thus, in this study, we will consider the following main KM processes: 1) Knowledge creation (acquiring and conversion) demonstrated in Table 6; 2) Knowledge storage demonstrated in Table 7; 3) Knowledge transfer and sharing demonstrated in Table 8; 4) Knowledge Application demonstrated in Table 9; and 5) Knowledge Integration demonstrated in Table 10. We identified in the interviews each of these processes in the following tables and comments.

Table 6: Analysis of Knowledge Creation (acquiring and conversion)

Main Points	Statements
Data collection, visibility, dashboard, tacit knowledge to explicit knowledge	• E2: "[…] We have to know what to do with the data. It is to generate knowledge from data analysis. It is to capture data and to report them. It is to build reports and to generate dashboards to allow to know everything […]." • E6: "[…] There are sensors, […] measuring input and output, operation effectiveness […] doing real-time analysis and making algorithms to calculate how long the operation will take, how much I will spend, […] a dashboard [...]." • E5: "[…] the system started to score, look "x" percent of these routes were successful, they are on time, [...] we could manually get the operator to put the information on how many tons the truck had loaded. Then we could pull up a database and analyze by route, how long it took [...] how many tons he loaded in that, in that period […], what was the average speed he worked. So, all information is in the system, [...], it fed a database, and then we started to pull these reports and start working on statistical data to understand the operation better […]" • E9: "[…] it is the knowledge generation of the operation, the majority of the industry has no idea of what it is doing [...]. I start seeing what is happening in my operation and to discern good and bad things good […]since I am seeing I start understanding what is happening […] in reality, is to transform tacit knowledge into explicit knowledge, when I standardize that, I am doing it a much faster way [...] have you heard of, is it spiral of knowledge of Nonaka and Takeuchi? That is correct. It is to transform tacit knowledge into explicit […]".
Seamless, continuous, ubiquitous connected environment (real-time)	• E4: "[…] The interpretation is in real-time and just a question of who will do it […]" • E2: "[…] Real-Time. Everything that was generated as an alert, whatever alert, for example: in a refrigerator, is the temperature reach a high level, the system releases the alert and sends it to everyone [...] the manager makes a decision […]." • E5: "[…] automatically in real-time in the truck cabin [...] it was very dynamic, in real-time. So, let's say that the driver had left the route, the system would warn you, right? Moreover, if he did not return to the route on a period of the time, the operation center contact him to understand, "oh, what is going on? Why did you get off the route? Do you have a special reason? " • E9: "[…] I already have the equipment taking action on data that they collected […]"
Dynamically actionable knowledge creation with KM enablers support (Big Data, AI and machine learning.)	• E4: "[…] It is possible to analyze the information with the data collected through a Big Data for decision making [...] the utilization of the information is in real-time with decision making using real-time analytics (analyze in real-time), which goes beyond Big Data […]." • E11: "[...] data collection and interpretation […] more and more is artificial intelligence, machine learning […] so there is an intelligence behind we call data science that should evolve a lot in the coming years." • E12: "[…] data arrives and it has to be explored it, I think there is still the human being on the scene, finding a way to explore this data and using a lot of machine learning […]". • E8: "[…] today you have professionals [...] you have tools, you have Big Data, you have BI analysis, artificial intelligence, data scientist, many things are happening nowadays [...] more fashionable is talking about artificial intelligence, you know, the IoT allows you to capture data, feed a giant base and through artificial intelligence, I can extract knowledge from these databases […]"

Prior knowledge of the subject or an objective to explore to implement IoT solution	• E7:: "[…] because the developer executes, the researcher, […] have the mission to bring a broader scenario focused on the business context and […] on solving the technical problem […]". • E2: "[...] You need to know the plant, know the reality, the problem […], you need to know the client's pain. If you do not see the client's pain, you do not know the client's process. You cannot develop it […]". • E9: "[…] knowledge is not the knowledge of data, but knowledge of the tool, knowledge of the technologies […] an example, people keep about artificial l intelligence, but without the right data, it is nothing, it is garbage […]"

Source Elaborated by the authors, 2020

According to the interviewees, the knowledge is created based on the IoT data collection, making them visible on dashboards with the transformation of data into knowledge through analytics. We verify that the data is in real-time. Thus knowledge should be created and be ready to use in real-time for decision making or action in real-time, as this is the main feature of a seamless, continuous, ubiquitous connected environment. Therefore, KM enablers, such as Big Data, AI, and machine learning, support the dynamic "Actionable Knowledge" or "Intelligence generation."

However, in addition to the technologies, it is necessary to have prior knowledge of the business context or an objective to explore from the data generated by IoT. Thus, knowledge generation from the data collected should be analyzed. The analysis can be predictive, using pre-existing data or information, or the analysis can be cognitive, with the learning from the environment itself, according to the interviewee E3: "[..…] data analysis can be predictive or cognitive, what does that mean? You can simply predict what there with analysis from the previous analysis itself to predict what will happen, or it can be cognitive or by learning process from about what is happening around.".

Table 7: Analysis of Knowledge Storage

Main points	Statements
Cloud Computing and Data Lake, a repository to store a large and varied volume of data, structured unstructured, mainly with the evolution of image captured by cameras	• E12: "[…] the majority of the companies are looking for what they call Data Lake, [...] which it is a database we transfer information that was not even captured to this data lake before, so we store data to apply then a series of solutions with machine learning, as it gets fed, we get more and more and more efficient in execution […]." • E9: "[...] it becomes many data, it become a Data Lake […] as in the mining, oil and gas industries, they have lots of data generated from last 20, 30 years […]" • E11: "[…] We have noticed, for example, a great movement of cloud computing, companies are transforming databases now into a cloud, sending this information to the cloud [...]." • E8: "[…] The IoT allows you to capture the data, feed a giant base and through artificial intelligence I can extract knowledge from these databases […]"

	• E7: "[…] I need a knowledge database [...], and I do not have 5,000, 10,000 pictures of people in the wheelchair, so to generate this knowledge database, I could put a camera in public, to calculate, store all the detection of movement with the respective areas, cut out and then I will have an automatic knowledge database, […]. I will not know who is in a wheelchair or not. However, I could calculate some skeleton detection algorithm […] to know if the person is upright, standing or sitting, then by a mathematical statistic there. You could already separate one from the other […]."
Security and Privacy	• E4: There is a significant concern with data privacy. It is a utopia because at the moment you receive a discount or a good offering, you need to make your data available. • E10: "[…] the concern with the data comes at first because you are exposing your data, […] the information security of the company should take care of this […] check if the data is well manipulated […]." • E9: "[...] there is a huge concern related to data traffic, that data must be encrypted, or it can not be in the cloud, because it is not secure […] but currently, Google Maps can show the color of your car, […]" • E3: "[…] need to have a public policy […] associated with the security and privacy of the users […]." • E7: "[…] there is another important point, the IoT has sensitive data […] it is a challenge IoT work […] work with security is something even more challenging. Thus, in summary, it is much information for the market to absorb in real-time. However, the acceleration of development is getting faster and faster….this will aggravate the scenario [...] None company can treat the business without security […]."
Cloud Computing and Blockchain considering security and privacy	• E4: "[…] There is legislation to protect data, and companies are specializing in it. A solution may be unfeasible if there is any restriction that does not meet the legislation. An example is the automatic cars, where Google has a car with 95% autonomy, but the legislation does not approve […]." • E7: "[...] There are several regulatory agencies like ABNT, ANVISA, ANATEL to certify the equipment's […] there are several standards to follow, adding more challenges in the financial and bureaucratical context […]." • E11: "we have an LGPD causing certain terrorism in how we will work with the data following law […] thus another area should be involved in this process […] the legal area […]" • E10: "[...] You have the various advantages that a blockchain provides, for example, you have security, you have the mutability of information, […] so data recorded cannot be changed anymore, and it makes it easier for you to sell data […], or it gives you various benefits, working in a network of multiple players that everyone provides information […] in the same place, with rules, right, of consensus with security with identification […]"

Source Elaborated by the authors, 2020

The respondents mention the use of Data Storage instead of Knowledge Storage. They cite Cloud Computing, which provides massive storage capacity and process data processing in real-time (Bello & Zeadally, 2016), and Data Lake, which allow storing a large and varied volume of data, structured and unstructured, mainly considering images captured by cameras.

Table 8: Analysis of Knowledge Sharing

Main Points	Statements
Data Sharing	• E10: "[…] you share when […] you have a wearable, for example, a watch from sports brands like Nike, Apple […] they get your vital data, they use it, and they return […] you are sharing it with the supplier […] sharing between companies is very rare […]." • E2: "[…] we use the experience of other customers for each segment […] with the interaction between the systems and the user […]." • E9: "I can have companies that want to share with other industries or with branches, and I have companies that do not want me to do a cold analysis of that little problem […]." • E8: "[...] who decides to share is the user [...] the entities and associations […] or the companies decide among them […]" • E1: "I think each company is dealing with the data internally [...]. I could give access to the other partner, only from that part that was not vital […]. I will not give access to confidential information [...]."
Standardization	• E10: "[...] there is still much ground to develop, to create standards, to be established in the market […]" • E9: "[...] to transform tacit knowledge into explicit knowledge ...when I standardize this, I am doing it much faster […]"… • E8: "[...]sometimes people do not know there are standards…they purchase solutions that not fit. They are interoperable….GS1 offers a set of standards […]" • E1: "[…] the problem is standardization ...there are political issues involved, you will get money from the government, you will reinvent the wheel, and that will not talk to anything […]"

Source Elaborated by the authors, 2020

Knowledge transfer or sharing occurs when the end-users agree to send data from their device to a company or a network, confirming the data transference from users to teams to build collective knowledge (Turner et al., 2012). It seems that knowledge sharing is not so common among companies, and maybe it is occurring only inside of each company to solve their problems, based on the interviews.

Table 9: Analysis of Knowledge Application

Main Points	Statements
Tracking	• E4: "[...]inventory management is completely automated with physical inventory updates for immediate stock replenishment. The stock being replenished directly by the gondola's information through sensors that collect data and send information to the drones. They receive the information to evaluate the shelf visually and confirm the lack of material...This application was created to reduce labor cost […]".

Monitoring (people behavior)	• E4: "[…]an example in the retails application is the new sensor based on cameras to assess people's behavior. A pilot made in China for credit assessment, where the behavior of the Chinese was assessed by facial recognition when they walk, how to cross the road, throw garbage on the street[…] a pilot was made in a school to see if students can learn and how they behave in the classroom…Another example is the Amazon Go store, in Seattle, where the customer picks up the product and leaves the store, with monitoring by the entrance and exit camera and the application installed on the smartphone[…]" • E12: "[…]an example of a simple application, it is the credit card machine in the online payment… the user passes the card in the machine…the machine contacts the bank, doing a debiting process to enable payment to the shopkeeper….all IoT application bring a user benefit[…]"
Wearables	• E4: "…In the case of life insurance, there are already wearables, such as the smartwatch, to evaluates the heartbeat, tracking where you are…" • E12: "…one segment is the wearables, the smartwatch, smart band, a series of wearables devices that are generating information all the time, so I have my smartwatch there, I sleep with it, I generate sleep information, I run with it, I generate information about my physical activity, it has my heartbeat, …and countless companies in the application layer are looking for partnerships to have access to this data or somehow get access to be able to offer services, offer discounts or benefits, etc.…"
Smart factory and industry 4.0: Monitoring (industry)	• E6: "..in civil maintenance service… there are sensors…gadgets… cell phones working in operation, measuring input and output, the effectiveness of operation… doing real-time analysis and making algorithms, calculating how long the operation will take, how much more I will spend…" • E12: "…industry in this context of industry 4.0, are enabling technologies …IoT is very present .."
Smart Homes:	• E11: "[…] Samsung started doing some tests…you have a smart TV, where it connects you with the world through the internet,.. a smart fridge...when you closed the fridge, a picture is taken, could access via an app what you there, …when you are at the supermarket you look your app what was in the fridge, what you could buy...I think IoT is already present in our life…you have voice assistants like Alexa and other voice assistants, scheduling your house lights…" • E12: "…for example, smart meters, our water, light and other meters, any type of meter… this field of application is very large… I won't be able to visit the customers' house and change the battery of that device…I need to have a very low battery consumption in the last ten years… I will implement a solution there at the residence, and I won't be back there in the next 10 years …Another example is the Samsung solutions for smart home …connected refrigerator solutions, washing machine solutions…"
Healthcare:	• E2: "…you have a lot of application …if I need medication to be transported in a specific controlled temperature...IoT is fundamental to monitor, patient safety…" • E7: "…we have several technologies ... it goes from biometrics to itself, smartwatches themselves…smart cameras can detect accidents, if two cars collide in a hypothetical example, you can trace the license plate…there are humans, so a drone can take first aid, arrive before an ambulance… • E12: "[…] if the user is practicing exercise, but the heartbeat does not match […] the data is collect and analyzed […] the user is warned to change the habit […] also, there is remote surgery, so imagine the possibility of service in a hospital in the north of the country being done by a robot but it operated by a doctor who is guiding the scalpel with a precise movement …in the field of medicine there is a lot of applications […]"

Agrobusiness:	• E12: "[...] in agribusiness, they are developing countless ideas for applications,…but most of the applications do not require a lot of broadband, low latency…I will just be able to make this application when I have low latency on the network. It depends on the type of service you want to explore […]" •
Customer Experience:	• E12: "[…] there is another block of applications which we call an augmented reality or virtual experience […] an example is a presentation in concert, with the orchestra playing Led Zeppelin songs and, one of the musicians who is a violinist came in a hologram playing with the orchestra…interacting, playing with the orchestra.. so the user was there, the audience watching and suddenly there is a hologram of someone playing together with the orchestra and interacting, talking to the public [...]"

Source Elaborated by the authors, 2020

The interviewees provide several examples in different fields, so we decide to classify the application and services by the primary function to show how IoT is applied. Thus, in the application process, we have the use of knowledge for decision-making or action, which we call Intelligence or Knowledge actionable in real-time, forming a smart ecosystem.

Knowledge application in the IoT perspective, include applications and services, which integrate several functionalities, promoting the interaction between things and humans in a ubiquitous computing ecosystem according to literature (Gubbi et al., 2013; Jara et al., 2014; Lim et al. , 2018; Miorandi et al., 2012; Murray et al., 2016; Uden & He, 2017). Thus, it is an important activity to make knowledge active and relevant to generate value to the organizations (Bhatt, 2001), and this is why it requires continuous, ubiquitous, and ubiquitous connectivity and intelligence.

Table 10: Analysis of Knowledge Integration

Main Points	Statements
Technology integration, partners a\ndsolution integrator	• E6: "[...] The problem is to integrate all into a platform [...,] I will give you one example specific…we developed a routine in the system, so we created the platform idea, we created the methodology to be used, the methodology of processes to be used, data analysis, everything that has the to do with processes and people, we did, the IT […]". • E5: "[…] it was a garbage collection company. We were trying to develop with a partner, before the tracking software, all this technology…" • E11: "[...] you need to find a right partner to help you…you have to invest in training, your people… so it is very complex, this interpretation of technologies, the validation of these technologies, the company has to be very careful in choosing the right partner in choosing suppliers…it is multidisciplinary to the extent that you have within a company, areas that today may not communicate […] • E12: "[…]we build the operator's network and seek as a partner of the operator to provide the possibilities and sources of additional income…it's a transformation process, we left the machine to machine and switched to the integrated IoT ... we said that the industry is the player, because the big

	corporations, they are the drivers of innovation […] you need the industry in that context […]” • E1: “[…] it has been a collaboration […]Digimark has the technology, and HP has the printers that use the technology, if there is no exchange there, it will be useless […] if I have an invisible code that I can print, […]. So I think it depends a lot on the core, on the alliances, on the need, on making a partnership […]” • E3: “[...] if you do not have this integration of technologies with the delivery of data correctly, there is no use of intelligence, the application, traceability, the location and identification of the object, you need to have analysis, the integration between data, and then you have to look if you have a business […] money […]”.
Support the IoT Ecosystem	• E6. “[…] You will understand the market […] in the ecosystem you need to go, after the suppliers, to understand the mindset of them […]” • E2: “[…] the ecosystem is represented by the production chain […].” • E1: “[…] there is an ecosystem that involves several links [...].” • E8: “[…] IoT is treated as an ecosystem […] you do not have someone who sells something that solves the problem [...], so you need to connect this ecosystem, people often buy solutions, and these solutions do not fit, they are not interoperable, and one of the reasons for this interaction [...] lack of interoperability is the lack of a common language for solutions […] need to pay attention, in an application is need to be aligned with the standards because that ahead of time, it will help him to integrate the solution with other solutions [...].”

Source Elaborated by the authors, 2020

The interviewees confirm the need to integrate technologies and partners and the need to have a solution integrator. However, they are not clear on how to use knowledge from different sources to transform knowledge into action. Thus, we can understand that the knowledge integration process supports the transformation of knowledge into actionable knowledge within a network, which is directly related to the concept of the IoT ecosystem. Although the interviewees did not explicitly mention IoT as an ecosystem, we can verify that there are several characteristics of an Ecosystem found in the interviews.

According to Leminen et al. (2018), there are four types of IoT business models based on the kind of ecosystem and the nature of the services involved: (1) the value chain efficiency, which represents standard with single-purpose applications and services produced in a hierarchical and closed ecosystem; (2) the industry collaboration, which combines connectivity and collaboration in an open ecosystem across industries; (3) horizontal market, oriented by customers and services; (4) the IoT application, which is created by others through a platform, where the organization acts as an integrator with partners to offer multi-services to customers in a closed ecosystem. Thus, we decided to check the four types of ecosystems based on the interviews, as shown in Table 11.

Table 11: Analysis of Knowledge Integration

Ecosystem Type	Statements
(1) the value chain efficiency, which represents standard with single-purpose applications and services produced in a hierarchical and closed ecosystem;	• E10: "[…] the purpose of the IoT is the use it within in the company, for example, in a factory to control the production of machines […] data is generated for own purpose of analyzing and of predicting that […]." • E5: "[…] with existing technology, it can track the trucks, and using intelligent software, to çcustomize routes according to the historical information of each route […]. Every day, data is collected to map events, holiday days […] all the data goes to the software to recalculate the routes, and the idea was to send via GPS to the trucks, so the driver just need to follow the script and automatically in real-time on the cab of the truck [...]"
(2) the industry collaboration, which combines connectivity and collaboration in an open ecosystem across industries;	• E1: "[…] in the case of Digimark and HP, there is a collaboration […] Digimark has the technology, and HP has the printers that use the technology if there is no exchange there, it will be useless, […]. If I have an invisible code that I can print, but I don't have a printer factory, if I do not disclose it, they lose. So, I think it depends on the core, on the alliances, on the need, on making a partnership.
3) horizontal market, oriented by customers and services;	• E4: "[…] This is the concept of the Amazon Go store, in Seattle, where the customer picks up the product and leaves the store, with monitoring by the entrance and exit camera and the application installed on the smartphone [...]. Another example is to trace the user's profile by his behavior on cameras, monitoring the shopping habits, with a social network, with the smartphone that collects a series of information. […] now, it is possible to have a credit score system that can evaluate you in real-time by consulting the available data and even skipping steps to approve your credit through risk analysis […]." • E11: "[…] China accelerated this process […] now there is a technology with facial recognition, with payment, via the mobile platform without using cards, without using physical contact […]."
4) IoT application is created through a platform, where the organization acts as an integrator with partners to offer multi-services to customers in a closed ecosystem.	• E4: "[…] Intel selects its business partners to support the success case, only in cases where it wants to create reference models, thus partners can assess the potential of the technologies […]." • E6: "[…] The problem is to integrate all of this into the platform [...] within an integrating platform […]." • E12: "[…] countless companies in the application layer is looking for partnerships to have access to this data or somehow get access to be able to offer services, offer discounts or benefits, etc. […]" • E4: "[…] There is usually an integrator of the solutions [...]. This integrator offers "integrated" solutions for the customer to serve the end-user in different types of segments […]." • E8: It is another member of the chain […] solution integrator. The solution integrator usually understands the business […] he is focusing on […] he knows the range of the equipment suppliers, he knows how to choose the pieces to assemble that puzzle to solve the problem of his client […] this element, the solution integrator he usually does not manufacture the devices, but he understands the business […] he knows what have on the market […], so this one is part of this ecosystem […]." • E10: "[…] Yes, you will usually add other solutions; it will not be pure IoT […] IoT, it is not just a software solution, right? So whenever you have the software, you have to have someone who works with hardware and know-how about IoT in general […] you need to work with a partner […]." • E11: "[...] IoT solution necessarily involves hardware, software, an integrator, a second software, second hardware, etc. […] they are based on an ecosystem of partners, an ecosystem of suppliers, an ecosystem of companies and even an ecosystem of people, that contains different profiles […] it is challenging to have a single-player and, whatever the size […] is not possible in the ecosystem, to have the hardware player […] you have the software companies, the developers […]."

	• E9: "[…] you are opening information [...] in the several times, information s serious and sensitive, for example, when you generate productivity information […] it is important for me and how much is a secret for my competitor […]. Once we implement a project for automobilistic industry […] the project was related to localization of cars on the yard […] the staff had a huge concern about data to be encrypted, not using cloud […] but the project was getting expensive […]. We show the Google Maps already have all the information available captured by satellite […] we could count the number os cars and know the color of each one […]." • E8: "[…] In the Vendor Manager Inventory, the information is there to manage the stock […], but there are many retailers that do not let this happen because they understand that it is sensitive and strategic information […] they are afraid that the industry will increase the prices if they know the information, so there are isolated cases of information exchanges in a partnership […]."

Source Elaborated by the authors, 2020

In the first type of ecosystem, where companies are seeking efficiency with single-purpose applications and service, we noted that the large companies are investing in IoT pilot projects or hiring consultancies to improve their operations. On the other hand, small companies have difficulties related to the high level of investments and the need for specialized professionals to escalate the solution. In closed ecosystem cases, companies have some resistance or no interest in having information made available in an "open" cloud, reinforcing the need to control sensitive company information.

On the second ecosystem type, the industry collaboration combines connectivity and collaboration in an open ecosystem across industries. This type of ecosystem seems incipient due to the fear of sharing information for the competition and difficulties in standardization. Maybe this collaboration happens in the no traditional companies or the innovation field to launch new products

On the third ecosystem type, the horizontal market, oriented by customers and services, seems focused on facilitating the daily life of users while companies are creating mechanisms to monitor the behavior of the consumers with the advance in technologies using cameras and facial recognition.

On IoT application, is usually created by others through a platform, where the organization acts as an integrator with partners to offer multi-services to customers in a closed ecosystem. In this ecosystem, large companies are investing in IoT technologies for competitive advantage. Thus they are creating solutions for their use or the market, sometimes using the startup's capability or their technological resources. New companies are emerging in the digital transformation using IoT technologies to offer their traditional products, adding new IoT services. Also, IoT consultancies are emerging to support the IoT technologies and stakeholders' integration to support companies that do not have this kind of knowledge. In the literature, Papert & Pflaum (2017) mention the importance of the role of the solution integrator and partners. It seems the role of the integration is fundamental for the success of the ecosystem.

Therefore, we identified all four types of IoT business models based on the kind of ecosystem and the nature of the services according to the interviews. We confirm the formation of the IoT ecosystems and the need to transform the knowledge int action to creates value for the different stakeholders in their specific needs and the network, which is the primary purpose of the Knowledge Integration Process.

Thus, we confirm the analysis of all KM processes and their application in an IoT environment, combined with the KM enablers. These two KM perspectives demonstrate a two-way relationship between KM and IoT, where IoT supports the KM enablers, and the KM processes can support the IoT ecosystem. Additionally, the IoT ecosystem can benefit from KM to coordinate several operations, from data collection, data transformation into knowledge, knowledge and data storage, knowledge sharing, IoT application implementation, and its maintenance and integration of technologies and stakeholders.

Consequently, KM can support the transformation of knowledge into action and meet individual or ecosystem needs to add value to them. This coordination can be done by a solution integrator that enables the generation of connectivity and intelligence to add value and achieve the desired results.

We also verify that KM should adjust its processes to support the IoT ecosystem, since KM needs to deal with large amounts of data in real-time, such as the decision-making process in real-time, ensuring data security and privacy. The Knowledge creation process must adapt to make knowledge explicit based on data, information, and knowledge generated by both humans and machines, based on prior experience of both technologies and business for its effective implementation. Knowledge storage must support new technologies such as Big Data, Cloud Computing, Blockchain to ensure storage of structured and unstructured data with security and privacy and also having the ability to store both data, information, and knowledge on an ongoing basis. Knowledge transfer or sharing should occur in a more collaborative environment, with the use of social media or direct interaction between users, but also help to create mechanisms to promote trust between companies. Collaboration and knowledge sharing are very incipient due to the fear of sharing information. Knowledge Application and Knowledge Integration Processes are related to the IoT elements of Application and Services, corresponding to the use of Actionable Knowledge to solve a specific problem or objective, and what makes this Intelligence “dynamic” or retrofitted, based on the connectivity between human beings, objects, and machines.

Thus, considering the effectiveness of KM based on the literature, we evaluated the following aspects: (1) maintain learning loops in all organizational processes, (2) systematically disseminate new and existing knowledge, and (3) apply knowledge wherever it can be used (Sanchez, 2006). The evidence is presented based on the following piece of interviews:

- E5: “[...] the first change was simple[…] the system itself already informed on the truck's tracker, and then the driver could see the route he had to follow [...]. The data analysis was done by the analysts […] and after it was sent back to the system as an improvement […] the system retro feed itself […].”
- E1: “[…] several companies are working to receive feedback from the market to improve products […].”

Thus, IoT and KM can generate more intelligence with a feedback of information from the environment, creating a system of continuous learning, whether performed by human beings using cognitive analysis or by searching in the knowledge database, in predictive analysis. Consequently, it creates an organic condition, typical of natural ecosystems, which brings to the perspective of Intelligence-Oriented.

4.3 PROJECT MANAGEMENT IN THE IOT ECOSYSTEM

Based on what has been presented so far, the implementation of several IoT projects is necessary to constitute an IoT ecosystem, as well as to create an integrated and intelligent project environment. Thus, there is a significant gap to be solved in the IoT ecosystem implementation. This gap seems to related to the competencies and capabilities of the professionals to lead the IoT solutions multi-disciplinarity, according to interviewees, as shown in Table 12.

Table 12: Analysis of Project Challenges in IoT Ecosystems

Project Challenges	Statements
Multidisciplinary project	• E10: "[…] a multidisciplinary project, […] it is not as simple to sell as a common system project […]" • E9: "[…] It will not work, then it will be the fault of the technology when, in fact, the problem is not the technology. It is the implementation […]" • E12: "[…] it is not the data engineer, it is a doctor who looks at that data, and he gives you the input, it is a multidisciplinary task, most of the time […]" • E11: "[...] It involves multi-disciplinarity as you have areas within the company that may not communicate [...] they will have to talk to validate the new technology, they need to be responsible […] they worked in a silo so far […]. Nowadays, people need to work in an integrated way […] you need to prepare your team to know how to provide support and to use the tool to extract information […] to input data […]. It is not just buying the hardware; buying the software […], it is much further down […]".
Professional Competences	• E9: "[…] the need of knowledge is not related to the knowledge of data, but knowledge of the tool, knowledge of the technologies and behind of all […] for example, people keep talking in artificial intelligence, but artificial intelligence without the right data, it is nothing, it is garbage […]" • E3: "[...] I hand over the data, I make it clear that I am handing over the data and the IT people who usually know the company rules and business will do these data analyzes to transform it in information […]" • E2:"[...] you need to know the site as if you are the owner because you should live his reality and transform the problem and how it will be the answer. So, it will only be possible if you know the client's pain. If you do not see the client's pain, you don't know the client's process. You can't develop it […]" • E7: "[…] people learn faster, but they also have very superficial knowledge about what is going on behind them. So this balance exists, […]. I am against people, not knowing what is going on. I'm not saying that we need to understand how to use a sliding rule. The basics need to be understood, so mathematics is fundamental, so there is a curve between knowledge and productivity [...] it is a great challenge. There are not enough professionals. The conventional market does not find a programmer to do the basics anymore. I think it is not even the fault of the market, and it is the lack of professionals in the sector [...] the problem is the lack of professionals who master technology [...]". • E6: "[…] I already hired many people for many areas […].The problem of knowledge is a big one, a big problem for all companies, so you have issues from basic, academic, first-degree knowledge […], even the specific, technical knowledge of the area you need. You may find someone very good at coding, but the guy does not know how to write, or he does not understand, he cannot understand the logic of something that you already explained for ten days […]" • E5: "[...] the software company already had the tracking solution in place […] our hardware part was not very complicated, because we just basically needed a good technician in the IT area […] and my maintenance team had good electricians […], and I had my willingness to seek technology and make it work [...]" • E6: "[...] we had a company to support in the project with PMP, PMBook, know how we were going to implement within a methodology of the project implementation [...]".

Source Elaborated by the authors, 2020

On the IoT ecosystem formation, it is crucial to understand the business context, to have the know-how of the technologies, how to integrate them and manage all the stakeholders is the key to the IoT ecosystem formation. These challenges were also identified in the literature about managing large-scale projects in different types of segments with several players, including the perspective of the end-users (Gubbi et al., 2013; Miorandi et al., 2012; Murray et al., 2016).

A project can involve multiple organizations, and the use of best practices on project management can support project implementations. The practical project management can help to meet business objectives, satisfy stakeholders' expectations, increase chances of success, resolve problems and issues, respond to risks promptly, optimize the use of organizational resources, manage constraints, manage change in a better manner (PMI, 2017).

IoT implementation can be considered as a complex project due to the “technological uncertainty” and “system scope” (Shenhar & Laufer, 1995). In this complex and dynamic business environment, with the formation of alliances, partnerships, associations, government, providers, makers, and other influencers there are multiple risks involved not only associated with the technical work, but also including social, cultural, organizational, and technological perspectives (Thamhain, 2013). We believe that KM also can be applied in the project implementation approach, as the management of knowledge uncertainty or incomplete knowledge implies having the learning as a practice, as well as a collective will of mutual interest to accomplish the project goals. In this complex environment, the critical challenge is knowledge governance, which leads to the need for strong leadership (Ahern et al., 2014).

Thus, the project manager has a vital role in managing this kind of complex project, as treated here as IoT Smart Ecosystem, managing the need for knowledge to accomplish the project deliverables with internal and external stakeholders. The project manager should possess technical project management and strategic business management knowledge, understanding, and experience, as well as leadership (PMI, 2017). In IoT solution implementation, the project manager could take the role of solution integrator or support him in the coordination of all activities need to enable this ecosystem.

4.4 SYNTHESIS OF RESULTS

We summarize the findings of this study with the selection of the principal codes classified based on the interviews. Thus, we create a relationship network in the Atlas.TI, grouping the codes by themes or concepts, as shown in Figure 15.

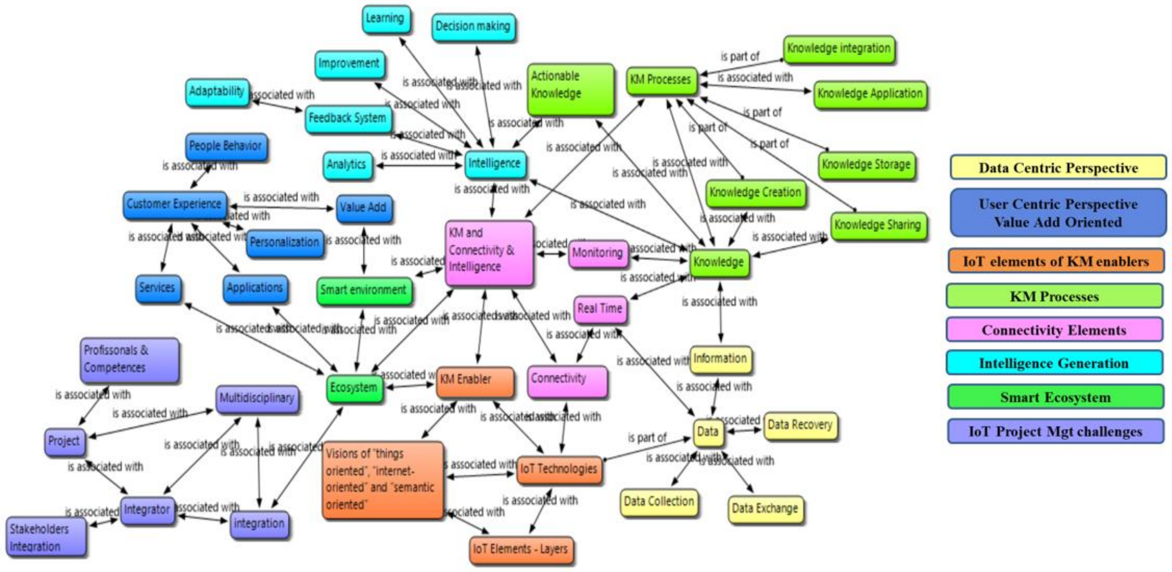

Figure 15 – Analysis of IoT-KM in IoT ecosystems

Source: Elaborated by the authors from Atlas.TI, 2020.

Thus, in the relationship network, each group of the concept is painted in a different color to facilitate the visualization. The yellow color represents the data-centric perspective, and the blue color represents the user and value add perspective. The orange color represents the IoT elements of KM enablers. The light green color represents all KM processes. The rose color represents the connectivity elements. The light blue represents the intelligence generation.. the green color represents the IoT environment or ecosystem, and the violet color represents the challenges in the IoT project management.

According to the literature and the interviews analyzed, IoT ecosystems can be divided into two perspectives: “data-centric” and “user-centric”. In the data-centric view, companies select a theme to collect data, for example, production data, equipment data and energy consumption data, or choose an objective to reach, for example, production efficiency, equipment performance improvement and energy consumption reduction.

Therefore, the main aim of the IoT environment in the data-centric perspective is to collect data, explore it, make it available on dashboards to provide visibility, and sometimes generate data analysis mainly for monitoring purposes, enabling the actions and decision making. Usually, a solution integrator seeks technologies and integrates the stakeholders involved in the solution. This solution integrator should have the know-how of the technologies to be applied in each case and need to understand the business context to provide direction to enable the transformation of data into knowledge and to make it useful.

In the data-centric context, Connectivity is an essential element to feed the database with reliable data and monitor activities. The knowledge generated by the analysis can be applied to solve problems based on past behaviors or applied to predictive analysis, which can trigger some automatic actions. This perspective concretizes the “things-oriented”, “internet-oriented”, and “semantic-oriented” visions. The use of KM processes may be limited to knowledge creation, knowledge storage, with specific data and knowledge transference.

In the user-centric perspective, there is an intense interaction between humans, objects, and machines, which aims to meet the individual and personalized needs of those involved in the Ecosystem, while creating a collective knowledge database. In this perspective, the main focus is on the generation of intelligence or what we call Actionable Knowledge and the application of the knowledge for effective action.

The analysis and monitoring activities in the user-data perspective are done in real-time with decision making or action also in real-time for specific tasks. In this case, Connectivity is one of the critical elements to enable the IoT application and services, creating a ubiquitous environment with objects, humans, and machines in constant interaction. The actions are not predictive because they occur in real-time. This perspective concretizes two new visions: Intelligence-Oriented and Value Add-Oriented.

The Intelligence-Oriented vision enables all data, information, and knowledge to transform into intelligence to enable decision making in real-time in a single interconnect environment. The IoT technologies like AI and machine learning supports intelligence creation added to the cognitive analysis, which can be associated with the absorptive capacity theory. The Value Add-Oriented vision enables the implementation of practical actions to aggregate value to the activities in a learning process, to the point of replacing activities that do not add value by automation, freeing up activities carried out by humans for more noble and cognitive activities. In this scenario, KM processes can be applied to support the creation of an IoT Smart Ecosystem, mainly with the use of Knowledge Sharing and Knowledge Application processes.

On both perspectives, we need to have KM enablers, Connectivity, and KM integration to start the formation of the Ecosystem. Each vision (“things-oriented”, “internet-oriented”, “semantic-oriented”, “intelligence-oriented”, and “value add-oriented”), considered as KM enablers can be implemented asynchronously of each KM processes.

5 CONTRIBUTIONS TO PRACTICE

The potential contribution of this research, on the managerial perspective, is to improve how the IoT ecosystem generates value to users and organizations using a model of KM processes to support IoT ecosystems. From a research perspective, this discussion advance in the KM and IoT relationship.

Although we can cite lots of the benefits of using IoT, we also must understand the challenges arising from its use in a successful implementation. Therefore, it is essential to think IoT as an active ecosystem, integrated into any type of technology, and be supported by KM. The advantage of thinking a KM-IoT integrated model lies in the dynamics of the modern world itself. Several applications of IoT can facilitate and increase the quality of life to all society and higher competitiveness for the organizations.

On the practice contributions, IoT solutions can be implemented in two perspectives: data-centric and user-centric. The first perspective is related to the formation of an IoT ecosystem, which provides visibility and understanding of the problems and opportunities to the organizations to improve their operations or the monitoring of the daily activities to provide the possibility to make decisions and action. The second perspective is related to the formation of an IoT smart ecosystem to giving not only visibility or monitoring but also a dynamic environment to make decisions or actions in real-time or an interaction directly with the organizations and the users.

A proposed model was created to help organizations in general, and project managers in particular, to understand how to form and maintain an IoT smart ecosystem. However, the potential benefits of KM-IoT can not be measured yet as we envision higher connectivity and intelligence, not only in a single ecosystem but among different ecosystems in an interdependent connection. Knowledge is generated from the individual, move to the organization, move among organizations, move to the ecosystem, and end up among ecosystems. It comes back to individuals. Although each individual has different objectives, they can interact among diverse ecosystems, creating new capabilities. We also recommend assigning a solution integrator to coordinate the IoT solution and manage the stakeholders, which a project manager can do it with experience on a complex project and with business knowledge. Figure 16 summarizes the explanation of proposed IoT-KM in the IoT ecosystem model.

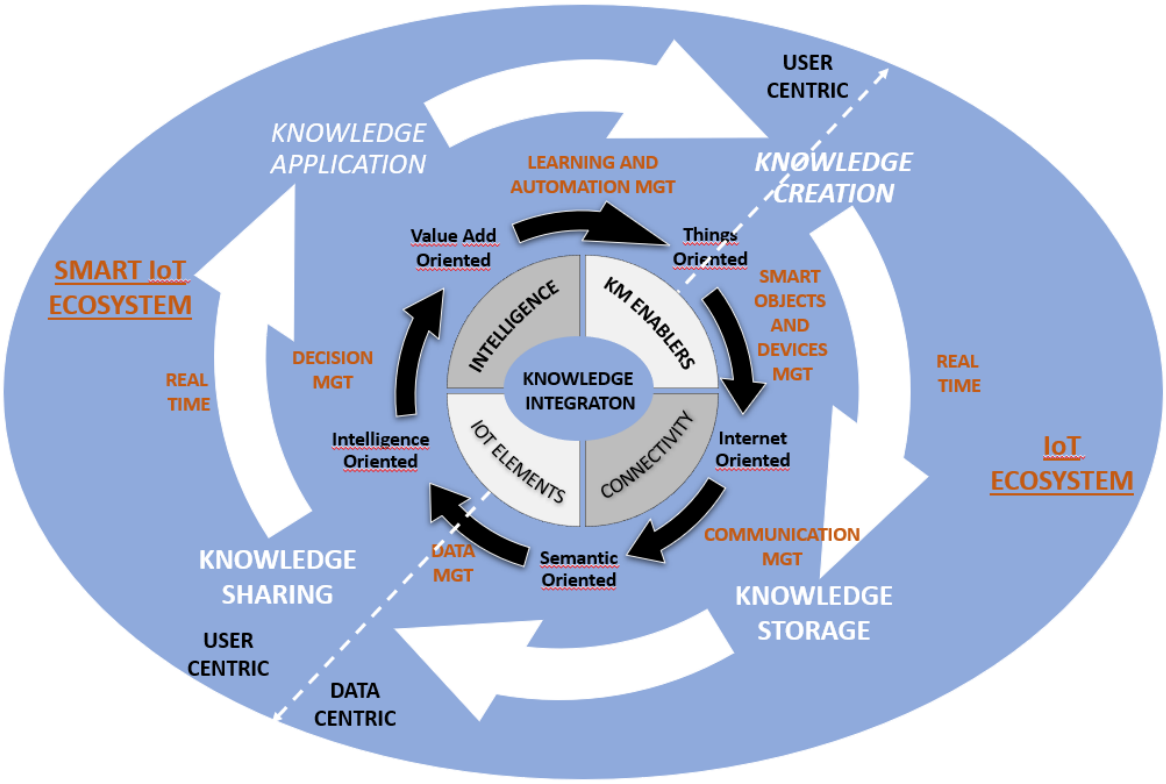

Figure 16 – Proposed IoT-KM in IoT ecosystems

Source: Elaborated by the authors, 2020

In the IoT ecosystem, Knowledge Integration Process supports the ecosystem formation and the integration of all elements. In Figure 16, it is represented by the blue color, divided into data-centric and user-centric perspectives. KM enablers (IoT technologies implementation) support the creation of an IoT environment, providing the connectivity of smart objects and human beings in real-time interaction. Thus, the black arrows represent the different visions (things-oriented, internet-oriented, semantic-oriented, intelligence-oriented, and value add oriented) based on IoT elements or KM enablers.

Companies can offer different types of applications and services based on each view or the conjunction of them, based on the IoT elements of KM enablers. Thus, the ”things oriented” vision can be supported by the applications and services related to smart objects and devices management, the “internet-oriented” is related to the application and services of communication management, the “semantic-oriented” is supported by data management application and services. Decision management applications and services support the “intelligence-oriented” vision, and the “value add-oriented” vision can be supported by the application and services related to automation and learning management.

However, a complete IoT environment is generated and maintained by knowledge creation until the useful knowledge application. Furthermore, a solution integrator can use the

Knowledge Integration process to coordinate and integrate all the IoT elements with the support of KM processes (knowledge creation, knowledge storage, knowledge sharing, and knowledge application), which is represented by the white arrows. The black arrows are asynchronous with the white arrows, and the synchronization can be dependent on the level of connectivity and intelligence to generate a smarter IoT environment.

Therefore, based on the model presented in Figure 16, companies can understand the relationship between IoT elements and KM that can aggregate value for the IoT ecosystems, to have better effectiveness in the IoT Application and Services project implementations. Besides, we point out the importance of having a solution integrator, which can be covered by the role of a project manager. Thus, the more active introduction of KM's assumptions helps practitioners in planning the implementation of these types of complex projects that can originate from public or private initiatives.

6 FINAL REMARKS

The objective of this study was to understand the relationship between the IoT and KM and analyze intelligence and connectivity when creating a Smart IoT ecosystem. The SLR revealed several studies focusing on the evolution of IoT concepts and the IoT ecosystem, and the interviews reveal several applications and services implementation in an early adoption curve, characterized by a data-centric perspective. However, there are challenges beyond the technical issues, as the need for a solution integrator and professional competencies to integrate all technologies and stakeholders.

We also confirmed a user-centric perspective, with an additional challenge to transform data into actionable knowledge. Thus, we saw opportunities to create the idea of "intelligence-oriented," which enables data, information, and knowledge to transform into intelligence and learning in real-time, supported by the analytics technologies. We also infer the need for "value add-oriented" vision, which enables the implementation of practical actions to aggregate value to the activities, as the automation process or actions.

Thus, we concluded that the main IoT elements necessary for building the IoT ecosystem foundation are composed of "things oriented," "internet-oriented", "semantic oriented", "intelligence-oriented," and "value add-oriented". We call these elements as KM enablers since they facilitate knowledge creation, storage, sharing, and application, and they are based on the IoT technologies.

Additionally, we determined that there are opportunities to exploit KM processes in the formation and development of Smart IoT Ecosystems, where human beings and the physical world are connected. Therefore, the integration of IoT elements can be coordinate with the support of KM processes and support of a solution integrator

Lastly, we demonstrated that "Connectivity" and "Intelligence" are both KM Enablers, that support KM in a highly dynamic environment. These are particularly important points given that continuous learning leads to the generation of actionable intelligence, which is necessary for an evolutionary network, such as a Smart IoT Ecosystem.

At the end of this research, the potential contribution can be stressed, on the managerial perspective, is how to improve the IoT ecosystem to generate value to users and organizations using a model of IoT-KM to support IoT ecosystems. From a research perspective, this discussion advance also in the KM and IoT relationships.

In conclusion, the IoT and KM can leverage each other for creating intelligent ecosystems by combining emergent IoT elements and KM processes for generating higher connectivity and higher intelligence. Therefore, this study also contributes to discuss the relationship between IoT and KM in a broader view. Some findings can contribute to future academic discussion. The results point to new ideas as the IoT “intelligence-oriented” and IoT “value add-oriented”, as well the IoT elements named as KM enablers, the importance of the factors as connectivity and intelligence to enable an IoT smart ecosystem, as we proposed in the model presented in this study.

6.1 LIMITATIONS AND FUTURE RESEARCH

As there are few discussions in the literature about the relationship between the IoT ecosystem and KM, future studies in this area of research are essential for overcoming the existing barriers and challenges.

As limitations of this research, we can cite the wide-ranging coverage of the research. Although the proposal was to understand the IoT Ecosystem comprehensively, the research could have been limited in a specific area or sector. This limitation also becomes a research opportunity, as researchers can focus on an ecosystem of smart cities, health, among others. The technical aspects related to the IoT ecosystem also represent a limitation. Thus, other researchers who have the skills to analyze the technologies and interactions with the information presented here can expand the discussions on the IoT Ecosystem and KM.

Therefore, future studies also should check if the model can be applied, mainly the new vision of "intelligence-oriented" and "value add-oriented", and how to implement a complex project such as in the IoT ecosystem. Furthermore, as findings of this study, we pointed the connection of findings with the theory of absorptive capacity cited by Gupta and Govindarajan (2000), which is defined as the capacity not only to acquire and assimilate but also to use knowledge. This theory is not the object of analysis in this research, but it becomes an opportunity for future research in IoT projects that contemplate the ideas presented in this research.

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APÊNDICE A – PROTOCOLO DE PESQUISA E COLETA DE DADOS

A) Instruções para o entrevistador:

Muitas pesquisas sobre IoT estão sendo realizadas com vários casos sendo implementados. Porém, ainda se discute muito sobre as tecnologias e não como gerar valor desses ecosistemas de IoT. Assim, objetivo dessa entrvista é comprender como a gestão do conhecimento pelos seus processos de criar, armazenar, compartihar, aplicar e integrar o conhecmento podem ajudar os ecosistemas de IoT.

Pesquisador: Erika Kajiyama Ikeda

Professor Orientador: Prof. Dr. Luciano Ferreira da Silva

B) Condições da entrevista

Nome	Idade	Função ou Posição na organização	Experiência em anos	Tipo de participação no ecossistema de IoT	Segmento de atuação	Duração da entrevista	Local (virtual ou presnecial

Quando? Janeiro a março de 2020
Quanto tempo? Até 60min.
Como será conduzida a entrevista? Gravada.

APÊNDICE B – ROTEIRO DE ENTREVISTAS

1. Empresa ou Segmento
2. Entrevistado (s):
3. Entrevistador:
4. Seções da entrevista:

( ) *Background* do entrevistado

( ) Itens a verificar

( ) validação dos itens percebidos

( ) Comentários finais

5. Introdução da entrevista

Você foi selecionado(a) para essa entrevista porque estamos fazendo um estudo que visa compreender como a gestão do conhecimento e IoT podem gerar inteligência e conectividade em ecossistemas de IoT.

Reforço que sua participação é voluntária e muito importante para nossa pesquisa. Os resultados serão compartilhados com o senhor (a) posteriormente, caso seja de seu interesse. Para auxiliar na análise do conteúdo da entrevista a mesma será gravada, sendo que o senhor (a) poderá solicitar a interrupção da gravação ou da entrevista em qualquer momento. A gravação será de acesso somente aos pesquisadores envolvidos no processo e os nomes e empresas citadas não serão repassadas ou publicadas em nenhum momento. A transcrição da entrevista será enviada para os senhores(as) para que sejam avaliadas e validadas.

6. Itens a serem tratados na entrevista:

a) Compreender como a gestão do conhecmento e IoT se relacionam.
b) Analisar com a inteligência e a conectividade podem criar um ecossistema de IoT inteligente

APÊNDICE C - TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Convidamos o (a) Sr (a) para participar da Pesquisa sob o título “Gestão do Conhecimento em Ecosistemas de IoT: Como gerar inteligência e conectividade”, sob a responsabilidade da pesquisadora Erika Kajiyama Ikeda, o qual pretende elaborar a dissertação com base na análise da literatura, e sua entrevista. A dissertação mencionada é requisito para conclusão do Programa de Pós-graduação em Gestão de Projetos, PPGP da Universidade Nove de Julho – UNINOVE. Sua participação é voluntária e se dará por meio de entrevista presencial com a utilização de perguntas abertas que terão como objetivo registrar sua experiência e percepção do tema embasado em seu histórico profissional. A entrevista tem uma previsão de duração méida de 1 hora.

Os riscos decorrentes de sua participação na pesquisa são inexistentes ou de baixíssima probabilidade, uma vez que o seu envolvimento na pesquisa se dará por meio de respostas verbais às perguntas. Além disso, para garantir que não ocorra nenhum constrangimento para com o entrevistado ou sua empresa, ambos serão mantidos em sigilo. É importante destacar que se o (a) Sr (a) participar estará contribuindo para um melhor entendimento sobre as decisões a respeito da priorização de projetos.

Se depois de consentir em sua participação o Sr (a) desistir de continuar participando, tem o direito e a liberdade de retirar seu consentimento em qualquer fase da pesquisa, seja antes ou depois da coleta dos dados, independente do motivo e sem nenhum prejuízo a sua pessoa. O (a) Sr (a) não terá nenhuma despesa e também não receberá nenhuma remuneração. Os resultados da pesquisa serão analisados e publicados, mas sua identidade não será divulgada, sendo guardada em sigilo.

Consentimento Pós–Informação

Eu,____, fui informado sobre o que a pesquisadora quer fazer e porque precisa da minha colaboração, e entendi a explicação. Por isso, eu concordo em participar do projeto, sabendo que não vou ganhar nada e que posso sair quando quiser. Este documento é emitido em duas vias que serão ambas assinadas por mim e pelo pesquisador, ficando uma via com cada um de nós.

Data: ___/ ____/ _____

___________________________________	___________________________________
Assinatura do participante	Assinatura do Pesquisador Responsável