# State of the Art

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### IoT-FM: an integrated approach inside maintenance management of service equipments

#### Abstract

*Today innovation seems to be carried out through digitalization processes which tends to computerize every object. However innovation doesn't find concretization in reality if in a process physical and economic transformation don't occur. IoT, thanks to its demonstrated feasibility among FM sector, shows interesting development in industrial maintenance practices as well. Therefore here possible transplanted innovations seems to be applied in maintenance field of service equipments, through the convergence of three elements: FM, in maintenance declination, IoT platform, with its related IoT architecture, and service equipment knowledge. The synergy of these three elements allows to create a new service which enable the better support for facility assets of organizations, which aim to manage efficiently their infrastructure. The creation of this kind of service will have strong consequences among the reconfiguration of organization models, BIM oriented approach, energy management and related life cycle assessment.*

#### KEYWORD

IoT, Platform, Proactive Maintenance, Predictive Maintenance, Service equipment, Facility Management

#### Introduction

As Facility Management (FM) concerns the management of integrated services, Internet of things (IoT), in its general connotations, looks as a technology of absolute innovation to support service provision. Actually IoT, through its components, allows to collect, storage and analyze data, which represent interesting steps of a methodology to be a source of strength for FM, as its data elaboration is foundamental into the integration of processes. The overall convergence between FM and IoT is currently proved on several applications. These are possible thanks a "facilitator", represented by a common platform, which makes feasible their linking in a broader perspective. Then IoT results a valid instrument thanks to its features, which best-fit FM inclination: openess, complexity, interoperability, scalability and dynamicity.

In particular, Facility Management is a "corporate discipline", according IFMA (International facility management association) which coordinates the "integration of processes within an organisation to maintain and develop the agreed services which support and improve the effectiveness of its primary activities" by addressing to "Space and Infrastructure" and "People and Organization" (EN 15221-1:2006). So far objectives of FM concern costs optimization and budget management, whereas IoT offers a wide range of procedures to achieve strategic, analitic and operative purpose, in different time-frame.

As research methodology, a systematic literature review of principles and theoretical frameworks of IoT paradigm has been conducted. This involves critical evaluation of IoT definitions, current technologies developed and manufacturing applications. In this operation many keywords have been used in the search process, like IoT, Platform, Proactive Maintenance, Predictive Maintenance, Service equipment, Facility Management. Google Scholar, Web of Knowledge, Elsevier, and Scopus have been precious search engines for connected papers.Second, given to the transverse nature of my investigation, a qualitative research approach based on service provider's most innovative products has been carried out. The information collected included which technology have been installed and which practices have been adopted after collecting and analyzing energy data.

This State of art aims to highlight which innovations are possible in maintenance practice with IoT application, by listing some current best cases. The paper here proposed is organized by presenting a general IoT architecture, usefull in company's purposes. Then few examples of IoT applications inside FM are presented, by proving the effectiveness of IoT sinergy. Last, scaling down inside FM discilipline, proactive maintenance practices strengthened by IoT deployment and energy management hints are described throught their prevailing implementations.

## 1) IoT current panorama

Internet of Things (IoT) is a term firstly coined by Kevin Ashton in 1999 in the context of supply chain management (Ashton, 2009) " to describe a system where the Internet is connected to the physical world via ubiquitous sensors".

Krotov (Krotov, 2017)defines IoT as "a network compromised of various nodes belonging to the technological, physical and broad socioeconomic environments" .

However IoT concept, as it can be easily understood from its name, comes from Internet 50 years ago's history, when "The Arpe Network", in December 1969, created its first 4 nodes' connection.

Nowadays, through evolutions of technologies for devices, network and communication, we assist to the actual Internet of Things, which is involved in the 4th Industrial Revolution (I4.0)(Lee et al., 2014). According to the latest Hype Cycle of newly emerging technologies, IoT was in one of the top three 'innovation trigger positions' in 2014, showing a tendency to grow towards the peak of the Hype Cycle (Burton and Willis, 2014). IoT provides a network where real-time data can be streamed back to a main hub. Each sensor and actuator placed on assets can be integrated to the network and provide an access to data previously difficult to gather. "Big Data" is the result of the large amount of dataflow collected from these assets.

Three factors are accountable for the "actual" IoT's State of the Art: devices, communication protocols and cloud-based resources.

Smaller devices, able to sense the environment in which they are dipped in, are experimenting new development's challanges thanks to the deployment of CMOS (complementary metal-oxide semiconductor) miniaturization and MEMS (Micro Electro-Mechanical Systems), which can sense acceleration,vibration,gyroscope,tilt,magnetic,heat,m pressure, temp, light, moisture, humidity, barometric parameters. These devices, then, have to be thought in a energy scavenging perspective, by the inclusion of primary batteries (not rechargeable) or secondary batteries (rechargeable set in combination with some form of energy harvesting: solar -15 $mW/cm^2$, Temperature Gradients - 80 mW/cm$^2$ with 1V from a temperature difference of 5K, Vibrations – 0.01 and 0.1 mW/cm$^3$ and acoustic noises – 3*10$^{\{-6\}}$ mW/cm$^2$ at 75dB- 9.6*10$^{\{-4\}}$ mW/cm$^2$ at 100dB).

The second trend responsible for today IoT involves the "Communication protocol". Lower power wireless communication technologies, nowadays, are more and more capable to work with low-power impacts over devices, so that they can live, survive, send informations without being linked to the electric power. The third evolutive input is represent by the Cloud service's advent. Actually cloud-based resources allow to process and to store a huge amount of data, not more to the edge of the network, but in proper data centers which is represented by the cloud.

These three trends have modified also user's IoT interface which increasingly involves the applications of smaller devices, providing real-time data toward the network's center (cloud), in a wide range of application fields, from wereable devices to industrial machineries.

Today IoT is even more pervasive in its applications and, especially, in the expected revenue or incomes which can be gained thanks to the IoT's implementation, above all in those Industry 4.0's sectors represented by vehicles (up to $750 Billion, with its autonomous driving and condition-based maintenance), factories (up to $3,7 Trillion with operations optimizations and health/safety), logistics and navigation (up to $750 Billion), retails (up to $1,2 Trilion with automated checkout) and work sites (up to $930 Billion with operations and optimization in security/safety). (McKinsey Global Institute, By 2025, IoT applications could have $11 Trillion impact, July 2015).

However not all IoT systems have similar characteristics. Infact a first IoT subdivision can be made among Internet of things'a consumer and Industrial Internet of things. This two categories involve IoT system with different requirements. Actually IoT-consumer requests "low cost", for scale-economy creation and for its spread, and "reactiveness". Whereas for industrial-IoT , "cost" is a relative issue, because profit is greater, but it demands high "reactiveness" in its systems.

Here three novelties are highlighted. First new regards the industrial IoT scopus, no more into the interconnection of objects of factory, but into obtaining of great amount of data over a specific controlled process. Second novelty regards the interconnection of all the same company's factories with the final user. Third novelty regards the always more persistent "standardization" in sensors and network, passing from vertical single vendor's systems to open interoperability IoT systems.

**But What is IoT?**

It is difficult to define what IoT is, because it requires to solve multidimensional problems. However it can be classified through 4 major built-blocks represented by: "Things", "Connectivity", "Data" and "Analytics".

Al these 4 major IoT's components have to be designed, taking into account two stringent aspects: security (data privacy, information's safety, etc. . . ) and reliability/robustness (IoT's system have to be intrinsically robust and reliable in a hardware, data extraction protocol, back-end- analytics data's perspective). However what makes effective an IoT system remains the "management platform", use facilitator for 4 major IoT built-blocks.

From an economic point of view it is possible to identify the major IoT's investment areas. According a survey, led by ISA (International Society of Automation) and assisted by ON WORLD, popular targets of service providers' IoT components are: IoT platform, WSN (Wireless Sensor Network), Cloud-based systems, Mobile app development, Network integration of new solutions with older ones. This survey shows that today major providers' expenditures are registered in IoT platform, Cloud-based systems and connectivity, respectively 66%, 50% and 70% on the total amount and 31%, 14% and 7% of variation's growth from 2014. (ON World/ISA Survey, Nov.2016 - 180 industrial end users, systems integrators, and service providers ). Recent studies have predicted that the potential number of connected devices by 2020 is greater than 20 billion with more than 3 trillion dollars being spent on IoT. Large company have been taking advantages into IoT's adoption, by analysing the Everett Rodgers Diffusion of Innovation curve (Rogers, 2015). To underline the arising IoT trend, Vodafone Barometer Survey (201, c) shows the full take-off of this technology (Vodafone 2016). This is also confirmed by the UK Business Strategy White Paper (2017) (Etherton, 2013) which proposes huge investment into IoT technologies in order to promote them through manufacturing industries. Actually SCM World (2015) included case studies at General Electric (GE), Harley Davidson, CISCO and Chrysler which have implemented solutions based on smart objects's connection, by seeing positive results.

Things, in IoT perspective, are all those elements with sense-capability, typically sensors and actuators. These are designed starting from the identification of constraints (flexibility, integration, budget, machine-interface, programmability and interoperability) and service requirements they are addressed.

Connectivity indicates a functional IoT linkage between its elements, which can be connected by wired (ethernet, field bus technology, etc..) or wireless solutions. Nowadays Radio solution (RFID), among wireless family, are the most used. In 2016 providers's choice for IoT connectivity depicts 80% for wireless solution and 20% for wired solution(isa). Parameters to select what kind of connecitivity to address depending on: network size, network composition or network nodes ("mobile" - without cables - or "fixed" – with cabled or radio solutions), service quality constraints (service quality to be intended as "bit per seconds" I can obtain from my sensor), latency (to obtain the information to backend), integration issue (possibility to implement existing intelligent objects with new sense technologies) and budget. Wireless solutions, which today are the most popular, are demonstrating an actual race to smart objects. Infact there are three main manners to connect object in IoT's perspective. First way is by using standard "Mobile Cellular Networks" (RAN, Radio Acess Network, and CN, Core Network, evolution), with the integration of sensors with a SIM cards, to put out data from smart objects. Second way is represented by the use of IoT-Dedicated Operators (Long Range Low Power Network: LoRaWAN, SigFox, InGenu) which provide operability though properly for sensors. Third and most common way is represented by Hot Spots Networks, which are short range multilevels solutions like Wi-Fi, RFID and Bluetooth, which use Gateway, a data's traffic concentrator, to accept data from local environment and, through a new gateway's processed language, to transfert toward the backend servers.

Today many connectivity technologies, which map a fragmented scenery, can be assessed to perform the same operation. In order to solve this splintering, arised from the absence of standardization guidelines at IoT's early stages, gateway are deployed, with its multiplatforms and multiprotocols inclination.

Gateway's solutions are predominant today in IoT applications, as principal global trends. However we are witnessing too slowly to the convergence toward all-IP communication, through transfer information's protocols which are compliant with classic internet. Nowadays a series of entities (ISA, Industrial Internet Consortium, Open Connectivity Foundation) are pushing to create a set of defined and shared protocols, in order to create "critical mass" for advocating open standards, influencing standard development and creating testbed for specific verticals.

Among Mobile Cellular Networks (NB-IoT, LTE-M, etc...) today 5G application seems to be the most promising, thanks to its larger bands or "bandwidth" (mmWave access, Massive MIMO), to transfer many informations in high speed, "network densification", "slicing", ability to reconfigure network to create customised solutions, and "mobile edge computing" (MEC), ability to have in the network, but near the final user, a data center able to close the information processing's loop. These 4 major features make possible different applications such as collaborative robotics, autonomous vehicle, immersive reality/virtual reality, in the nearby future. Politecnico di Milano is promoting several use cases on future's IoT development, supported by MISE (Ministero Sviluppo Economico) which actually register 28 partners, 11 endorsers and 41 use cases.

IoT focus is on data. It is necessary that all these IoT system manage the primary resource represented by dataflow. Primary purpose. of platforms is to facilitate, in general, dataflow through "device management" (connecting devices to the cloud, configuring devices, updating formware, monitoring devices), "data management" (storing and retrieving data, managing events, visualizing and sharing data), "data analysis/automation" (statistical anlysis, data mining, machine learning) and "security/privacy".

The entities, which create platforms, contribute to the formation of "IoT ecosystem", composed by specialized items in specific areas (devices integration, connectivity, cloud service)

Data and Analytics built-blocks aim to manage data's quantity, to store information, to handle data's speed (latency), to create the reactiveness on dataflow. Current research trends are oriented toward Big Data-Enabled solutions, to manage what is called as "stream analytics", that is the ability to manage real time dataflows, taking partial decisions upon an amount of data. This data management is strongly linked with the "Edge Clouds" and "Fog Computing growth", thanks to the operations on infromation near the final user (extremely low latency calls for cloud "closer to the ground": Mobile Edge Computing (MEC) for cellular networks and Edge clouds and Fog Computing), according the application's requirements which have been used.

### IoT general architecture and main components

Here a current IoT physical framework is presented by highlighting its main components which enable IoT data elaboration: IoT gateway, IoT middleware, and cloud-edge computing.

IoT can be seen as the composition of three layers: perception layer, network layer and application layer, defined by China Mobile (Yan and Huang, 2009).

In perception layer information gained from sensor are collected. This information are elaborated and sent through some communication technology such as wireless sensor network, WSN radio frequency identification, RFID and final controlling element. Here major challanges of perception layer are represented by the optimization of low-power, miniaturization and low-price aspect of end nodes. The perception layer is composed by sensor node and gateway. End nodes sense data (temperature, humidity and image etc.) and then send it to a gateway in order to be elaborated through network layer. RFID is the major core technologies of the perception layer which allows to collect data through radio-frequency signal.

RFID allows to perform some characteristics such as reading in a long distance (a few meters to tens of meters), strong penetration ability (directly read information penetrating packing box), without abrasion, non-touching, anti-pollution, high efficiency (dealing with multiple tags simultaneously).

IoT perception layer needs to be improved through the adoption of global standards over its communication protocols. (Shen SuBin, 2009) (AA.VV., 2007). Major challanges in this layer are represented by low cost components in order to apply IoT on a larger scale, such us RFID tags and MZM module, and low consumption components in order to optimize network communication protocol to lower the communication consumption or adopting other energy supplement such as the polar energy and biotic energy. [NOME ARTICOLO]

Network layer is the IoT infrastructure which provide common service. It realizes the high reliable and safe delivery of the perception information through the function of common Internet (Sun Qibo, 2010). Common operations which occur on network layer are: data's memory, inquiry, analysis, excavation and comprehension, theory and technology of decisions and behaviors based on the data. Its applications are feasible thanks to current mobile telecommunication and internet. Here massive information is processed, both in short and in long distance, in the IoT management center, represented by clouding computing, platform, expert system, etc...

Application layer has the aim to discover service and take on service, which represents the final goal for IoT development, thanks to software development and intelligent control technology. Analyzed and processed perception data provide to the user specific service which are assembled in application layer.

### IoT Gateway

A gateway is a network node in which different protocols are processed, exchanged and joined with all IoT levels. In general any smart object which transforms signling and data can be a gateway. The most common gateway is a router which links a private network to the internet. Here in most IP-based networks, the only traffic that doesn't go through at least one gateway is traffic flowing among nodes on the same local area network (LAN)(Qian Zhu, 2010).

Generally, current IoT gateways use short-distance wireless communication protocol (i.e. Zigbee, Bluetooth, . . . ) to acquire the packet of information from the end-nodes, and use the 2G/3G or other network interfaces to send the data to Internet. As actual IoT's fast expansion occurs in a short time, this has been possible for lack of standardization protocols and guidelines. As a result, smart objects actually are designed in different modes by optimizing costs, reducing power consumption and fostering installation between end-nodes and network level. In this way, a transformation is needed when a packet of informations go fromn sensing level to application level.(Atzori et al., 2010)

So IoT gateway represents the bridge between the sensing level and network level, by becoming one of the most important component of IoT architecture.

In this sense PAN (Personal area network) can be an IoT gateway which supports transparent, secure and trusty communication among smart objects, in its two versions: wired (with computer buses such as USB and FireWire) and wireless (thanks to IrDA, Bluetooth, Wireless USB, Z-Wave and ZigBee). Although IoT architecture is not standardized, an IoT gateway represents the easy way to allow communication between different elements on the same horizontal level or along the vertical level. Infact gateway can produce protocol conversion between various sensing object's protocols (i.e. between Zigbee and Bluetooth) or transformation between the sensing domain level and network level protocols (i.e. between Zigbee and 3G)(Chen et al., 2011).

#### IoT Middleware

Between software and hardware, or end-nodes and application level, in IoT architecture is required an intermediate element represented by middleware.

Middleware provides services to software applications beyond those available from the operating system. It can be described as "software glue" (mid).

IoT middleware is a software-based element which works as an interface between IoT components, making communication possible among elements which otherwise couldn't be connected. In this way, middleware represents a facilitator instrument both at horizontal and vertical IoT level, which makes elements interfaceable. Middleware connects complex and already existing programs originally not designed to be connected. Its application allows linking of smart objects by providing a connectivity layer for sensors and for application layers which provide services.

Mulesoft, Oracle, RedHat and WSO2 are current companies which develop IoT middleware solutions. These products provide API management as well as basic messaging, routing and message transformation. More comprehensive IoT platforms include middleware along with sensors and networking components.

However, the large amount of IoT connectivity protocols and middleware are not facilitating connectivity among IoT devices and interpretation over collected data. This occurs because IoT middleware uses different programming abstraction and architecture for accessing and connecting to IoT devices. For example, adding an IoT device in a yet existing IoT architecture required expert Java programming expert in extending device's interoperability.

Several surveys on IoT middleware have been published (Razzaque et al., 2016) (Bandyopadhyay et al., 2011) (Chaqfeh and Mohamed, 2012). These surveys overview IoT middleware only from specific perspectives and none of them address the more recent trend of light-weight plug-and-play or cloud- based IoT middleware (Razzaque et al., 2016)

Currently three advanced middleware systems are shown in scientific literature: Service oriented architecture middleware, actor-based middleware and cloud-based middleware solution.

The main differences in the three middleware are the openness toward IoT architecture and IoT middleware's level where can be embedded. SoA (service oriented architecture) middleware is used in application level (servers or cloud). This middleware provides users the vision of raw data collected by IoT devices through Web applications. However it usually provides limited functionalities to users into the integration with other applications.

The actor-based style middleware provides the best latency and scalability for large-scale connected IoT end-nodes because this particular middleware can be deployed in all IoT level. Users can extend the computational units of actor-based IoT middleware by developing a pluggable actor from a central repository (Ngu et al., 2016). Both service and actor-based IoT middleware architectures may support any protocol standards. Differently in the cloud-based architecture interoperability among systems is obtained through the adoption of specific standards. Cloud-based middleware operation can be interrupt when the cloud provider ends the service, as shown by Google Nest which represent a first application in this sense. However cloud-based architecture requires users to trust the cloud provider to manage their data privacy.

### Cloud, Platform and Edge Computing

Cloud computing, often referred as "the cloud", is a backend element of IoT architecture, where calculation services and storage resources are deployed. The cloud is a term related to computer, information technology (IT) and software applications through a network connection, offered by data centers, using wide area networking (WAN) or Internet connectivity. IT resources can be assessed in the cloud: a software program or application, a service, or an entire infrastructure.

From a typological perspective cloud can be divided in: Software as a service (SaaS), Platform as a service (PaaS), Infrastructure as a service (IaaS), Public cloud, Private cloud and Hybrid cloud, according IBM definitions.

From a framework perspective cloud ca be split into four layers: datacenter (hardware), infrastructure, platform, and application (Bandyopadhyay and Sen, 2011). Each of them can be seen as a service for the layer above and as a consumer for the prior level. SaaS is linked to the provision of applications operating on cloud environments. In general applications allow to be exploited through a client or a web browser. PaaS is related to platform-layer resources (e.g., operating system support, software development frameworks, etc.). IaaS provides processing, storage, and network resources, enabling the consumer to control the operating system (Ray, 2015).

Moreover many types of clouds with different features have been highlighted in the literature A survey of IoT cloud platforms, as listed here (Bandyopadhyay and Sen, 2011). Their choice depends on the specific business scenario and their deployment has his own benefits and drawbacks:

1) Private Cloud is managed abd owned typicalli by a single organization;

2) Community Cloud is used by a specific community of consumers;

3) Public Cloud is performed in a open way by the general public;

4) Hybrid Cloud is composed by two or more different private or public cloud infrastructures;

5) Virtual Private Cloud is addressed for issues related to public and private clouds, thanks to the use of virtual private network (VPN);

(Integration of Cloud computing and Internet of Things: A survey)

### Platforms

Cloud IoT platforms allow the rapid development of intelligent infrastructures. Users may leverage intelligent providers' sensing and actuating infrastructures based on platforms. Current efforts into defining a high-level IoT platform have taken to the creation of several open source models which deal with the heterogeneity of

IoTprotocols (Mišić and Mišić, 2014)(Kantarci and Mouftah, 2014)(Distefano et al., 2012) – e.g., Software defined IoT (SDIoT).

IoT Toolkit (run by a Silicon Valley based organization called OSIOT)(201, a) develops a toolkit that allows to join several protocols available for end nodes, cloud and applications. Interesting examples include open source projects lead by private companies. For example, the open source project of NimBits (201, b) provides a set of software to be installed on private or public Clouds (mainly Google App Engine) to create a PaaS that collects data from things and triggers computations or alerts when specific conditions are verified.

Moreover several services are provided that allow to collect data from things and to store these data on the cloud offered by the service provider. These services typically provide an API and many example applications to elaborate data from sensors, which range from specific, proprietary things to open, and distributed ones (e.g. Arduino). Actually Intel promoted an initiative that provides a software library for Galileo/Edison platforms, compatible with arduino, and a private cloud where data can be stored by things based on Galileo/Edison platforms and accessed by applications through a public API.

## 2) IoT and Facility Management synergy

IoT is a strategic point which today is carried out by many industries, through sensors'support which makes assets as informative terminals, in order to perform monitor and control. In this way, assets can produce informations about itself and surrounding environment. IoT offers a wide range of opportunity to cover many aspects related to the extension of the Internet into the physical realm, through its widespread deployment of spatially distributed devices with sensing and/or actuation capabilities (Miorandi et al., 2012).

To highlight the current IoT's wave, it must be considered that EU is investing 192 millions on IoT research, as programmi Horizon 2020 and Large Scale Pilots prove, by following, in 2017, the world trend of 3 major industries's investments: Services ($66 billions), Transportation ($85 billions) and Manufacturing ($183 billions). Then according ReportBuyer 2017, between 2017-2021 EMEA (Europe, Middle-Est, Asia) market will show an average annual growth rate of 31,5%, passing from current $53,88 billions to $211,92 billions in 2021. Worldwide Semiannual Internet of Things Spending Guide di IDC underlines a world wide provision among IoT investments, ranging from $800 billions in 2017 to $1.4 trillions in 2021.

Manufacturing industries, between 2016-2017, which base their processes on IoT are increasing the presence on market of 84% whereas transportation and services organizations point out a growth of 41%, as claimed by Verzion IoT Market Report, largest communication technology companies in the world. Going deeper to the survey, in relation to Boston Consulting Group, market analyst, three sources of growth on service sector are represented by IoT application in security, maintenance and energy.

The "definition" of cloud is proposed in September 2011 by NIST (National Institute of Standard and Technology) through its Special Pubblication: "Cloud Computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction". This definition has been implemented with the one of "IoT cloud" which stands for "a platform offered by a service provider as a hosted service which facilitates the deployment of software applications without the cost and complexity of acquiring and managing the underlying hardware and software layers". So far definition of "IoT cloud platform" can be formuled as: "a platform offered by a service provider as a hosted service which facilitates the deployment of software applications without the cost and complexity of acquiring and managing the underlying hardware and software layers to hinder a model designed to facilitate the information society, enabling advanced services by inter- connecting (physical and virtual) things based on, existing and evolving, interoperable information and communication tech- nologies through ennoblement of ubiquitous, convenient, on- demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction that leverage the need and heterogeneous connectivity issues of the user centric things in well defined fashion"(Ray, 2016).

IoT integration inside FM discipline is enabled thanks cloud deployment, which provides valuable applications in many service domains. It facilitates data flow between end-nodes, data analytics, visualization and IoT cloud services. Trend of IoT cloud platform suggests that its design is today oriented in favor of device management, data management, monitoring management and application management, by serving a multitude of service domain.

IoT cloud platform allows a more distribuited data processing. Infact, thanks to the implementation of innovative Big Data calculation, such as M2M (Machine-to-Machine), it is possible to monitor and control services, like in viticulture applications occur(Suciu et al., 2015). Here alerting message is elaborated inside cloud system after that Big Data calculation are processed. Actually many IoT cloud providers are implementing their platform into the market for specific IoT based services (Ray, 2016). However a strong need for standardization and integration is claimed among IoT cloud applications (Babu et al., 2015).

Today IoT applications among service sector are successful possible. These trends are embodied by several uses among industries which adopt IoT and provide services. Provision of sensors for service allows communication to any facilities. For instance, Philips Healthcare recently develops an IoT solution called e-Alert, which is a hardware/software solution, that virtually monitors the machines' performance. When Philip's e-Alert system detects a failure, it sends a text message to the informative system so that repairs can be made before serious damage occurs.(e-a) Moreover SAP HANA, an in-memory data platform to accelerate business processes, proposed by SAP, German-based European multinational software corporation, represent an innovation among technical facility management sector with IoT deployment, as it analyzes large volumes of sensor data (such as temperature, vibration, or rotation speed) and issues an alert long before a machine or plan failure.(han) Dell Inc., one of the most famous multinational PC producer, has developed a proactive maintenance IoT system with the partnership of SAP, Kepware technologies and Software AG. This is a software/hardware solution centered around the Edge Gateway 5000, which collects, analyzes and acts on real-time data from machine sensors, generating dynamic predictions. Kepware's KEPServerEX provides connectivity solution for elaborating diverse data sets from PLCs, RTUs, meters, and SCADA, foundation for PdM applications. KEPServerEX feeds the data to Software AG Big Data Streaming Analytics Platform running on the Intel AtomTM processor in the Edge Gateway. This ensures that perishable data are sent to the cloud where dynamic calculations occur. Cloud, then, is interfaced with SAP HANA, which provides integration in asset management system with reporting, generating alerts, and automating maintenance dispatching.

Other IoT-oriented FM applications are shown by healthcare domain, by tracking staff, patients and objects, and monitoring patients'values through sensing (Vilamovska and Evi Hattziandreu, 2009).

Actually tracking, in its general meaning, allows to detect patient flow and to improve workflow in hospitals, by becoming an usefull instrument in a inventory process to be exploited in each FM fields.

So far a broad range of opportunities in different industries for IoT application is possible, such as healthcare, intelligent building (i.e. green building), product and brand management, retail and logistics management, people and goods transportation. IoT is expected to play an important role across Europe (e.g. Horizon-2020) (European Commission, 2013) and Asia (e.g. China's 12th Five-Year Plan) (Sung and Chang, 2013)(Rayes and Salam, 2016) during the next decade. IoT is expected to include 26 billion connected units, and incremental revenue generated by suppliers of IoT products and services are expected to exceed US$ 300 billion, mostly in services, by 2020 (Gartner, 2013). This will result in US$ 1.9 trillion in global economic value-added through sales in diverse end markets (Gartner, 2013). Many researchers have been active in healthcare restructuring that leverages IoT technologies in medical asset management (Lee and Palaniappan, 2014), optimizing medical resources (Valera et al., 2010), monitoring healthcare situations (Luo et al., 2012)(Castellani et al., 2012) (Istepanian et al., 2011), and increasing the use of home healthcare (Monares et al., 2014) (Pang and Tian, 2014)(Sebestyen et al., 2014).(Lee and Palaniappan, 2014)developed an RFID-based inventory management system (RFID-IMS) for tracking medical devices' utilization and managing their inventory levels using real-time data . (Shahamabadi et al., 2014) proposed a solution to establish a hospital wireless network (i.e. mobile network) using 6LoWPAN technology for healthcare monitoring in the IoT environment. (Xu et al., 2014)demonstrated a resource-based data model to store and access the IoT data to support decision-making in emergency medical services.

Logistic domanin which is managed by FM, according UNI EN 15221, appears to be invested as well by the IoT application, thanks to its quick processing technology based on RFID and NFC which allow to control supplychain, ranging from commodity design, raw material purchasing, production, transportation, storage, distribution and sale of semi-products and products, returns' processing and after-sales service.

Moreover it is possible to collect products'information, promptly, timely, and accurately so that enterprises or even the whole supply chain can respond to changeable markets in the shortest time, as performed by Walmart and Metro (Rao et al., 2009).

Intelligent informatics system (iDrive system) developed by BMW used various sensors to monitor environment in order to provide driving directions for drivers (Qin et al., 2013). Other operations during transportation and logistics, such as routes control, certain warning emission on container storing, can be enhanced by IoT as well (Gusmeroli et al., 2012) .

Furthermore, energy management which is one of facility manager's major issues is faced off through IoT integration, by avoiding energy waste and optimizing product life-cycle energy management. As data analysis is one of the most advanced technique in FM, thanks to its new calculation models (static attribute data acquisition, dynamic data acquisition and fuzzy environmental information perception)(*), data acquisition layer is crucial in gathering energy information. With IoT technology all components, machines and facilities in product life cycle can be all supported by IoT end-nodes, making possible to acquire more accurate energy parameters from item's status at any time (Tao et al., 2016).

Microsoft Corporation, one of the biggest global player in software field, are exploiting IoT application with its IoT platform Azure, through which many companies are taking advantages. Microsoft Azure is establishing itself as a public cloud platform of choice for industrial IoT solutions and Predictive Maintenance. According market report, more and more applications of predictive maintenance are shifting from on-premise to cloud setups – by 2022 about 70% of predictive maintenance setups are expected to be cloud-hosted. Besides the cloud infrastructure, Microsoft Azure currently has two "preconfigured solutions" which provide quick analytics engines: "predictive maintenance" and "remote monitoring".

Data dimension, which a "thing" can produce in few seconds, represent an important issue. For instance, a single autonomous car could generate as much as 100 GB of data every second. Simply collecting data doesn't bring added value if these data aren't properly processed. Mitsubishi and Vestas have been involved in a projectcalled Burbo Bank Extension, for IoT Wind Turbines deployment, by using Microsoft platform, in which more than 30.000 data collection per second were collected, producing more than 11.000 Gb Data per year, equivalent to more than 1 Billion e-mails, 60.500 hours of movie streaming or 2.750.00 hours of music streaming. 100 sensors here have been installed in each blade.

Security here arises from the endpoint, through the connection, to data, applications, and the cloud. Speed is performed in preconfigured solutions for the most common IoT scenarios. Openess represents the easily connection of any device, OS, data source, software, or service. Scalability allows the platform to grow effortlessly with millions of devices, terabytes of data, on-premises, in the cloud, in the most regions worldwide.

So far Microsoft Corporation has created Microsoft IoT Central, an IoT SaaS (software-as-a-service) solution that makes it easy to connect, monitor and manage IoT assets. Microsoft IoT Central lowers the barriers of entry for companies looking to revolutionize their business with IoT.

Thyssenkrupp, for instance, has created a strong connection among its asset and Microsoft platform, by creating MAX system, to perform a cloud-based predictive maintenance solution. Thyssenkrupp performs an IoT predictive maintenance by gather data from sensors and systems to create valuable business intelligence. This ha reduced elevator downtime by 50%. Applying the Internet of Things (IoT) to elevator maintenance, experts from thyssenkrupp and Microsoft spent two years developing MAX, the industry's first real-time, cloud-based predictive maintenance solution. MAX leverages the power of Microsoft Azure in order to create predictive maintenance service with the power to maximize elevator uptime. MAX works according this scheme: Data collected, Precise diagnoses, Predictive intervention. Machine data, such as door movements, trips, power-ups, car calls, error codes, etc., is collected from MAX- connected elevators worldwide. This data is sent to the cloud where unique algorithms analyze it for patterns and compute the equipment's operation and the remaining lifetime of components. Precise and predictive diagnostics are delivered to the technician in real time, indicating where intervention is required.

Moving from reactive troubleshooting to proactively preventing failures, MAX provides advance information about the wear and tear of elevator components, allowing to plan future costs and schedule disruptions.

## 3) Maintenance implementation through IoT application

This paragraph aims to investigate how it is possible to take innovation in maintenance among FM sector, by the exploration of current maintenance's best practices inside industrial and manufacturing field.

Scientific literature shows a wide view on predictive maintenance's case performed over industrial equipments and machineries. Whereas little studies are highlited on service equipments'proactive maintenance, which represent a domain oversees by facility management.

Many maintenance modalities to be performed over components exist today, but there is no a general rule to carry out a particular maintenance practice, as these depend on the particular and changing problem faced off by facility manager. Nevertheless predictive maintenance appears as the one which is most suiteble to IoT thinking, together with condition-based maintenance, as it is founded on the same principles of dynamism, analyticity, efficiency and foresight. Infact, according UNI EN 13306:2010, preventive maintenance is an operation "carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item".

**Application of IoT concept on predictive maintenance of industrial equipment**

Current challenges in union between IoT technology and manufacturing systems is represented by communication between standard industrial equipments and platforms.

Industrial equioments use several serial protocols to communicate one with another by only sending one bit at a time. This is slower than parallel communication standards, but it can be used over longer distances.

Before the widespread of IoT, several techniques have been deployed in industry for maintenance analysis of industrial equipments. Condition-Based Maintenance has been a wide used merthod which consists of three main steps: data acquisition, data processing and maintenance decision-making. It is based on a maintenance program which implies maintenance decisions founded on the information collected through condition monitoring.

Nowadays in the manufacturing practices predictive manintenance has changed the role of maintenance function within industrial needs. In this context, new techniques for maintenance are proposed , basing on the fault prediction and IoT system.

Predictive maintenance with IoT implementation is addressed into the collection and analysis of data coming from assets, in order to provide the following benefits:

1) Identifying key predictors to determine likelihood of outcomes;

2) Optimizing decision-making by systematically applying measurable real-time and historical data;

3) Planning, budgeting and scheduling maintenance repairs;

In this sense, predictive Maintenance consists in continuously detecting the most significant machine or service equipments parameters, such as oscillations or temperatures, and in dealing with them appropriately through appropriate algorithms. The advantage of this method, linked to IoT, is the ability to acquire quantities that are difficult to measure or can not be measured directly. For instance, the presence of peaks in a spectral diagram can signal the presence of vibrations, which suggest that bearings have worn down. More than FM applications, Data science techniques are necessary for performing an effective proactive maintenace through Big Data elaboration. From data science application in proactive maintenance may occur different analysis. According SAP, which has developed a document titled "Data Science and Machine Learning in Internet of Things anche Predictive Maintenance", 5 categories of analysis typologies can be listed: trend, relation, segmentation, association and anomaly.

In trend category data behaviour over time is analyzed, in order to detect any process out of control and to estimate component lifetime. Relation category allows to research failure causes of a machinery, by conducting a fault tree analysis. Segmentation category indicates the possibility to cluster or clearly split data. In association category correlation among data are made in order to detect if a deterioration in performance of machinery and a breakdown are linked. Anomaly category shows which values result as unusual, to understand if they are errors or effective changes of a service equipments.

Predictive maintenance practices are associated with little data, because of their rarity, that are difficult to historicize. Here data analyst's competence allows to include these variable in a predictive analysis process.

According to a recent survey report conducted by the Aberdeen Group, "Best-in-Class" companies are increasingly utilizing IoT and Big Data to implement Predictive Maintenance models to address and improve their operational challenges:

1) Reduce unplanned downtime to 3.5% – Amount of unscheduled downtime against total availability;

2) Improve Overall Equipment Effectiveness to 89% , calculated as: Availability x Performance x Quality = OEE;

3) Reduce maintenance costs by 13%– Total maintenance costs including time and personnel;

4) Increase return on assets by 24% – Profit earned from equipment resources through improved uptime;

Although industrial maintenance reveals conceptual differences from FM's maintenance, it appears clear that their targets, that are machinery and plant systems, show the same fundamental operations: "work accomplishment powered by energy that, through a given process, is transformed by the system into another form, by exploiting a certain force and developing a certain power". Then both industrial and service equipments, when a maintenance manual is set up, display same failure variables, operative conditions and intervention's frequency. Morover communication protocols, architecture layers, hardware, software and middleware parts, gateways and end-nodes (sensors and actuators) have the same functionality in a general IoT's perspective, both for service and industrial equipments. Infact technologies, which seem to vary drastically, are mainly based on the same power source and devices' functionality. For example, a consumer machine such as an elevator uses different data transmission protocols comparing to the sensor units in an environmental sensor network. But differences occurs here just on IoT architecture's levels, rather than in a specific application field, such as service and industrial. The former may transfer data into the Cloud via WiFi directly, whereas the latter in general uses RFID for network communication, which sents stored data in a staging data node before it can be transmitted into the Cloud (Zhang, 2016). Dissimilarities are shown here just in level crossing among IoT architecture.

Last but not least, foresight techniques such as data mining, machine learning (artificial neural network, fuzzy logic) and text mining allow to strengthen maintenance and IoT paradigms, through parameters' forecast such as trend cycle, irregularity and data extrapolation, in order to create a systematic model. A forecasting model is that the activities responsible for influencing the past will continue to influence the future, as in maintenance practice occurs (Chase, 2013). The use of numerical methods, implemented through a predictive maintenance's software, guarantees to the user the ability to detect and evaluate data acquired by the machine. In this way the user has access to a wide range of ready-to-use features (i.e. for frequency analysis) while maintaining full flexibility in the implementation of their algorithms. Currently, analytics-driven predictive maintenance is achieving attention in many industries such as manufacturing, utilities, aerospace, etc., thanks to the expansion of IoT applications and the maturity of technologies that support storage and processing of Big Data.

Literature presents proactive maintenance's cases aim to analyze health status of industrial equipments. The most innovative nowadays trends show the creation of maintenance activities performed from analytics solutions that include both real-time machine condition monitoring and machine learning based predictive analytics capabilities. These allow to carry out: failure prediction, fault forecasting, failure detection and diagnosis, and recommendation of maintenance actions after failure.

In "IoT Company Ranking", survey carried in 2016 by IoT Analytics, market insights for the internet of things, a list of active companies involved in predictive maintenance with IoT is shown. The list is compiled starting from three indicators: monthly searches on Google in conjunction ith "predictive maintenance", 2016 newspaper and blog mentions in conjunction with "predictive maintenance" and number of employees that carry the tag "predictive maintenance" on LinkedIN in January 2017.

Here IBM is presented as the major world predictive maintenance's practioner. IBM Predictive Maintenance and Quality, a software solution, is one of the key solutions enabled by its "cognitive intelligence engine" IBM Watson. It monitors and reports on equipment data, gathering from assets. Known examples for predictive maintenance implementations are Kone's elevators or DC Water's Hydrants. Kone recently launched its 24/7 Connected Services, based on the IBM solution.

Sap, a german software company, represents the second major firm which carries out predictive maintenance trought IoT application. SAP has implemented its solution "Predictive Maintenance and Service", through SAP Leonardo IoT Portfolio, for customers such as Kaeser Kompressoren or Siemens.

Siemens, which is an industrial automation specialist, has a different perspective on predictive maintenance than SAP and IBMl, through its automation system, which elaborate a large amounts of data, for establishing supervised machine learning algorithms. For the implementation of Predictive Maintenance at the NASA Armstrong Flight Center (cooling systems) for instance, Siemens worked with analytics services provided by US-based Azima DLI. In a further project, Siemens launched a 12-month Predictive Maintenance pilot with Deutsche Bahn in October 2016 to monitor the fleet of Series 407 ICE 3 trains.

Other industrial and service provider companies such as GE, General Electric, performs predictive maintenance through two moments: measurements and asset management. The former is managed through GE Digital, which covers the software and analytics part of predictive maintenance, by establishing the company in the condition monitoring hardware field. Whereas the latter is represented by GE's Predix platform to control. GE has, for instance, rolled out APM with BPs oil and gas production operations. Furthermore, GE Digital is advancing the concept of digital twin, an important basis to Predictive Maintenance analytics.

(Yang et al., 2007) created an Internet-based remote maintenance system for managing processes. (Feldmann and Göhringer, 2001) implemented an Internet-based diagnosis for a maintenance's monitoring system. (Iung et al., 2005) created toolbox to promote decision making over maintenance actions. (Mori et al., 2008) studied the operation's status of 8000 machine tools simultaneously worldwide to improve their maintenance's efficiency. With respect to IoT maintenance systems, (Gong et al., 2014) created a boiler remote monitoring system with IoT cloud platform's applications. (Wang et al., 2015) developed an IoT application for fault diagnosis and prediction, based on machine learning. (Alexandru et al., 2015) created a smart web-based maintenance system for a more automated manufacturing environment.

Based on AEI and RFID, IoT technologies have been widely used in the train dispatching and labor jobs management in GuangZhou EMU maintenance base. Technological solutions for the production-line and spare parts delivery have experienced pilot test with corresponding software like projects scheduling, process control, working processes monitoring, logistics management, etc. Engineering practice showed that IoT technologies benefit the efficiency upgrading of maintenance jobs flow control, the reducing of labor intensity and failure probability, especially the richness of productive information. Further steps will be made for attaining mature application through pilot test and technological solution improvement, while realizing comprehensive utilization of the real-time multi-source productive data of EMU base, establishing an intelligent architecture for EMU maintenance application. (Weijiao ZHANG)

Still on rail transport sector, Ansaldo STS, a society inside Hitachi Group Company, specialized in railway signalling and integrated transport systems for mass transit and freight rail operations, is performing an interesting IoT application in predictive maintenance and asset management. IoT for this company is an instrument to create value in service provisions. Value in services is here reached when data are collected and storage in an informative system which elaborates them into informations. The availability of new data is expected to bring benefits in multiple company's field such as: smart ticketing and intermodal mobility, human flow, passenger information and on board entertainment systems, security. IoT in Ansaldo STS allows to reach integrated rail operations by integrating information about intelligent traffic management system embedding rolling stock and crew management. Morover Iot application enables cost reduction by collecting real time information about asset status, by promoting predictive maintenance's strategy.

Actually asset management, inside FM field, oversees IoT wide applications. Here data collected from trains and railways are historicised and presented to the client, to analyze equipments'performance, nominal working conditions and behaviour's critical factors. This kind of informations permit to foresee failure rate. Ansaldo STS is passing from a preventive maintenance, based on dated surveys and number of operations performed, to a predictive maintenance based on big data. The scheduling of activities and the ticket activations is managed by the information system connected to the cloud. This concept is applied as well to IoT inventory management level: the group automatically orders the spare parts. IoT application, in Ansaldo's experience, acts also on technical services of trains (air conditioning system, electrical system and security system) which sends their data to a on board database. Depending on their alertness grade, data are elaborated inside cloud, when train can connect to the first useful station's network to undertake operations (mobile protocol). Moreover mos railways have equipped special trains (rowing fleet) with on board diagnostic equipment that run on the network to collect data regarding track, geometry, catenary status, etc. Rete Ferroviaria Italiana (RFI) has a fleet of diagnostic trains (Archimede, Talete, Aldebaran, Galileo e Caronte 1 e 2) for Conventional lines and High Speed Lines (Diamante) and is now planning to spend 65M Euro to upgrade this fleet. Whereas Société Nationale des Chemins de fer Français (SNCF) has a fleet of diagnostic trains that runs on the network and every two weeks is able to survey the entire High Speed Network.

However this kind of applications can face many problems. First of all, costs linked with data collection of obsolete trains is a relevant issue, as sometime assets and collecting data nertwork haven't the ability to exchange informartion. In this way a deep analysis has to be undertaken to undestand the convenience to install sensors or to substitute completely the assets. Then data must arrive with a certain reliability and a certain constancy to the cloud.

Farther Bosch group is investing in IoT systems through its 4 main divisions: mobility solutions, consumer goods, industrial technology and energy and building technology. This transformation involves the Bosch thinking to track goods'performance from manufacturing phase to end-user phase. Bosch produces sensors (end-nodes in IoT perspective) which represents the automotive basis, in which the group is a global player. Bosch sensors with Bosch IoT cloud allow to develop a scalable and flexible IoT, which is implemented through software and data analytics.

Moreover Bosch's ioT practice achieves service offer, which include training and counseling to integrate partners and customers in I"oT ecosystem".

Bosch IoT strategy contemplates "flexibility", as a main IoT feature, achieved thanks a distributed intelligence. This is possible for the deployment of the edge computing's application, in which calculations are not only carried by the central cloud. Edge computing allows to enlarge the IoT perspective beyond Bosch company's boundaries, by comprising clients, suppliers and final users. Value's production network becomes more and more pervasive, thanks to the IoT's adoption. This enable to follow life cycle's steps of all techinical equipments and components and permit to track the company workers'skill in a digital way, by collecting data and depicting realtime data. This is reached thanks to the "open standards" adopted by Bosch group, which promotes the interoperability in technologies'communication. Open standards, inside Bosch group are adopted in order to enlarge the partnership inside the company.

In Powertrain Solution, the biggest division inside Bosch company, it is pursued the concept of flexible integration of machines. Here more than 5000 sensor-provided-machines can exchange knowledge. If a failure occurs inside a industrial plant, a knowledge management system can detect a break down and suggest, without any human intervention, a solution. This concept is linked to system's reconfigurability, based on the distribuited intelligence.

So supply-chain has been integrated in Bosch network. Digital life-cycle management, moreover, allos to comprehend when a particular product is becoming obsolete or when withdraw a products class to promote another one, thanks to advacenced data analysis's methods. In the informative system a product's hystory is uploaded, by representing it through a virtual real-time representation: each product is equipped with a sensor which tracks its quality and its production chain.

A case study (Parpala and Iacob, 2017) on predictive maintenance comes from the manufacturing field. Here maintenance practice is implemented thanks to the platform deployment which control an polishing and sanding machine for high gloss lacquered furniture components (painted MDF – medium-density fibber).

The machine can perform three movements: the motion of the conveyor table, with the fixed wood panel, the motion of the brush head in a transversal direction to the wood panel and continuous rotation of the brush. These three movements correspond to 3 communication standards on moto drivers. Data related to speed, functioning time of motors, working status of the motors and the temperature near the main motor are collected and sent to an open IoT platform, named Carriots. Hardware part (Arduino Uno board) is connected between the equipment and the IoT platform. If a Start or a Stop command is received, based on the protocol, IoT platform will receive the data. Arduino device is here chosen because it packs considerable power on a very small board and it provides many opportunities for automation, networking and data collection, even if Arduino is generally not so used in industrial application because of its low level voltage, robustness and safety.

Developing a predictive maintenance strategy means here to send usage alert via e-mail or other messaging services, basing on the achievement of temperature of 27 °C. Each time a defined threshold is reached, an e-mail alert is send to the user. So far other parameters can be added and different alerts can be defined. In this way on-line monitoring and predictive maintenance system can be performed for any type of industrial equipment.

## 4) Energy management implementation through IoT application

Energy management for society, in its general meaning, and for organizations, in its particular sense, represents a feasible challenge today faced off with IoT support and smart meters.

Actually. The energy future will be inexorably linked to the IoT. Wrote GeneWang, CEO and co-founder of People Power, a software company that enables smartphone-controlled management of connected devices, writes: "More and more devices, factories, lighting systems, buildings, transportation systems and smart cities and communities will be connected and controlled through the Internet. Brains in the cloud will optimize energy use to a larger and larger extent. More IoT sensors and devices will enable more control, and greater savings over time." Synergies between IoT and energy management are today seen by the organization as interesting and profitable points of research toward which being directed. General Electric (GE) in September 2015 introduced Predix, a cloud-based analytics platform that processes the massive amount of data produced by the IoT (st0). According (Shrouf et al., 2014) 4 steps are practicable to support IoT-based energy management in organizations. First step concerns the knowledge of production processes, current energy management and definition of targets. Second step involves the data collection through IoT technology and data analysis. In this phase service equipments and machines to be studied must be defined. Moreover monitoring devices, communication system, physical data storage have to be taken into account. Third step focuses on the integration between data and energy management tools, in order to define where improvement have to be set. Fourth step is related to strategic operation for improving energy efficiency. This process allows to the facility manager to select the most efficient configuration of service equipments.

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**RESEARCH QUESTIONS**

The object of the research arises from four research questions:

1) What is the possible healthcare management model for the IoT techniques in sensored service equipments?

2) What are the most suitable data management methods?

3) What are the parameters to be detected?

4) How to reconfigure organizational management models?

*Starting from these research questions the following objectives are met:*

1) Exploration of IoT potential inside facility management and discussing core technologies that can reshape healthcare technologies based on the IoT;

2) Research of IoT-based healthcare components to be managed and the definition of the parameters useful to control process;

3)Definition of theoretical models with IoT system approach suitable for management of maintenance equipment within hospital infrastructure;

4) Creation of a set of rules, covering all probable requests of typical hospital facilities;

5) Individuation of sensors and other devices to detect efficiency information or diagnosis at every stage;

6) Definition of general suitable platform useful for managing data for maintenance management of buildings;

7) Detecting and preventing systems failures or uses;

**METHODS AND TECHINIQUES**

Having regard to the proposed objectives, the research project intends to adopt the following working methodology:

1) Deep literature review and case-study analysis at the international scale of the current practice of healthcare buildings FM, focusing on maintenance planning and programming techniques;

2) Comparison between maintenance management models for technical equipments in buildings and relationships between different supply-chain operators;

3) Analyzing the theoretical and regulatory structure inside best practices and processes for healthcare facility management;

4) Monitoring of existing hospital facilities and their performance in order to the definition of requirements for data gathering, dynamic maintenance planning of plants;

5) Defining parameters (Input, output, supportive), indexes and rules to evaluate over time systems healthcare facility performance;

6) Proposal of innovative models for management of technical facility for IoT applications;

7) Definition of sensors apparatus;

8) Hypothesis of Iot systems case studies BIM Application;

9) Hypothesis of new organizational models of services: Analyses of FM structures organizational models in relation with their changes with regard on contracts, construction permits, project management and construction management;

9) Analysis of IoT applications which gather datafrom sensors with power, robustness, durability, accuracy and reliability;

10) Use of BIM systems for modelling and monitoring the information flow of hospital facilities;

## EXPECTED OUTCOMES

By responding to the previous objectives, it is expecting from this research to reach the following outcomes:

1) Definition of the characteristics of an advanced IoT-based support system with more stringent requirements and with run-time libraries, for a service-oriented approach (SOA);

2) Maximize asset visibility, utilization and performance while better managing regulatory compliance efforts. Increase hospital equipments availability, help reduce acquisition, operating and maintenance costs, and improve return on assets;

3) Creation of an innovative and unique IoT-BSMS (building service management systems) which gathers the potential of IoT technologies and artificial based intelligence (neural networks, fuzzy logic, genetic algorithms) with best practices management system;

4) Definition of parameters necessary for healthcare's management and its sensors of detection;

5) Creation of few FM models which adopt IoT and which are expected to reduce costs, improve the effectiveness of management processes and increase the reliability of equipment;

7) Creation of rules, which combine input and output parameters for decision support unit;

8) Identifying of correctly IoT optimum times for replenishing supplies for various devices for their smooth and continuous operation by the creation of items based on the logic of Sensing and responding, sensing and knowing, sensing and learning;

9) Definition of the characteristics of an advanced IoT-based support system with more stringent requirements and with run-time libraries, for a service-oriented approach (SOA)

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