https://dx.doi.org/10.22161/ijaers.611.12 **ISSN: 2349-6495(P) | 2456-1908(O)**

Inventory Process Cost Reduced With RFID, Simulation and Open Source Technologies

Cristiano Manhães de Oliveira[1], Patrick Jhullyan dos Santos Ribeiro Soares[2], Gudelia Moreales[3], José Arica[4], Italo Matias[5]

[1,2,3,4]State University of Northern Rio de Janeiro (UENF), Brazil
[5]Ucam(Campos dos Goytacazes), Brazil

Abstract*—*One ofthe possibilities for companies to seek cost reductionis through the improvement of their processes. RFID (Radio Frequency Identification) can make this possible for its traceability of company assets, as well as the development of IoT projects, which are characterized by the generation of large amounts of unstructured data. RFID is widespread worldwide and research on the subject has grown in Brazil. However, the implantation of this technology, in Brazilian companies, faces its associated costs. Based on those arguments, this paper presents the development of a system based onRFID technology and open source tools (NodeJs, Python and MongoDB), as well as simulating RFID antennas in a virtual environment (Rifidi). Indeed, it is possible to reduce the costs on the development of the system, since it was not necessary to purchase any equipment or software licensing.
Keywords*—Data Engineering, Data Science,Internet of Things,Inventory Management, Radio Frequency Identification.

I. INTRODUCTION

Nowadays, humanity has lived in a technological advancement never seen in history. In this context, the Internet of Things (IoT), Internet of Objects aims to allow the full connection between the real and virtual worlds [1][2].

IoT is the mix of technologies such as radio-frequency identification (RFID), sensors, Global Positioning Systems (GPS) and mobile devices. Figure 1 shows a relation among those technologies associated with IoT.

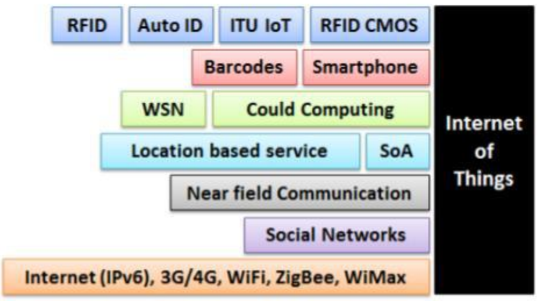

Fig.1 – Technologies related to IoT. (Source: [3])

As shown in Figure 1, IoT can be represented by a set of technologies such as RFID, ITU (International Telecommunications Union), CMOS (Complementary Metal-Oxide-Semiconductor),WSN (Wireless Sensor Networks), SoA (Service oriented Architecture), NFC (Near Field Communication), Social Networks, etc.

IoE, as shown in Fig.2 compasses Internet of Everything, whereas IoT is only composed of "things". Besides that, IoE also extends to business and industrial processes [1].

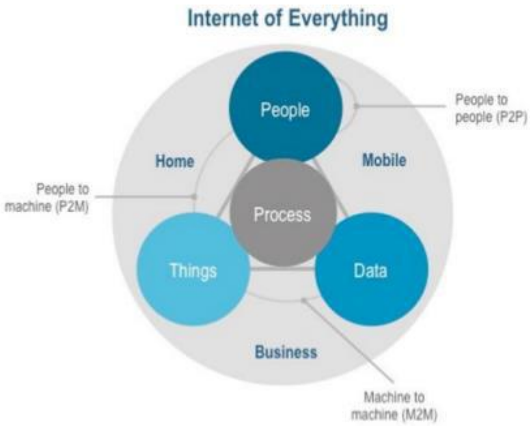

Fig.2 - Internet of Everything (IoE) [1].

Also, cities may use IoE along with 'Big Data' processing systems for controlling road traffic flow, monitoring agricultural growth, education and healthcare, making it as 'Smart Cities' [1].

IoNT concept (Internet of Nano Things) arises when nano-sensors are embedded in several objects through the use of nano-networks [1], it was introduced by [4], using nano-antennas based on graphene operating atTerahertz frequencies [5].

https://dx.doi.org/10.22161/ijaers.611.12 ISSN: 2349-6495(P) | 2456-1908(O)

IoNT provides access to data from locations impossible to detect, or inaccessible instruments, previously due to the sensor size. This allows new data to be collected, new findings and better diagnostics [5].

The IoT has led automation to the next level, enabling optimization process, device control with minimal human intervention, improved monitoring of large amount of data [6]. It has become increasingly comprehensive when applied in areas such as: SmartCities, Smart Homes and industry 4.0 [7].

Experts estimate that devices connected to IoT will grow exponentially in the coming years, with 50 billion devices connected by 2020 and an average of 6.58 connected devices per person [8].

The Gartner Hype Cycle (GartnerHypeCycle) is a structured and qualitative analytical tool for trend analysis based on research and expert judgment [9].

Gartner's Hype Cycle shows the lifespan of a given technology, from the beginning through maturity, to its decline. This helps with business planning [10]. As shown in the report of July 2017 (Fig. 3), IoT has risen from its peak above, for example, BlockChain, with five to ten years to reach maturity.

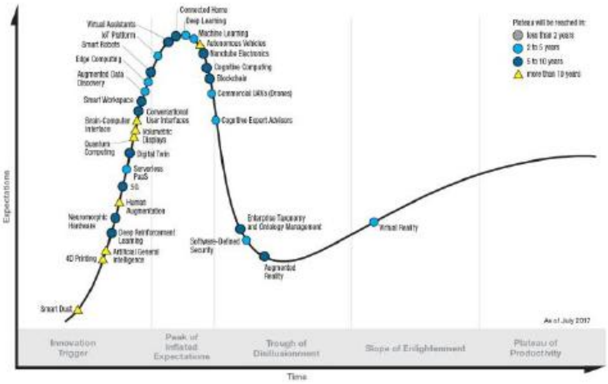

Fig.3 – Hype de Gartner Cycle [10].

BlockChain is a distributed peer-to-peer network where members can interact with each other without an intermediary. This lack of an intermediary makes it possible to perform transactions more quickly and securely between two or more people, and all that is possible through the use of encryption, which is a key feature of the BlockChain networks [11].

IoT has been gaining attention of organizations, with advances in wireless technology, smartphones and sensor networks. Because of this, more and more things, in network or smart objects, are being involved in IoT [3].

Organizations have paid more attention to cost reduction; this challenge often involves delivering products at the right time and at the desired location [12]. A better inventory management can help achieve this goal.

Inaccuracies or errors in the storage process are mainly responsible for loss of undetected items, offsets, outdated stores and inconsistencies between physical storage and records in Information Systems [13].

There are tools in the market that facilitate and make the information more accurate, besides increasing the speed of information flow, especially RFID [14][15].

RFID is an automatic identification and data capture technology that consists of a label or transponder or tag [16] consisting of silicon-based microchips [17] with a unique serial number single-digit (ID) containing information about a single item, a transceiver (or reader) and a middleware system [16]. It is based on the use of electronic waves as a way of communicating data to identify some elements, such as company assets, people and services [18], the operation of an RFID system is shown in Fig. 4:

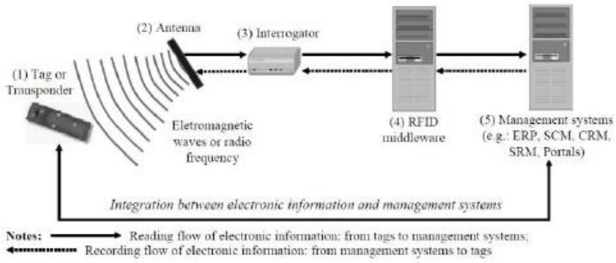

Fig.4 – RFID systems architecture [18].

This technology is widespread worldwide and research on this theme is currently growing in Brazil [14]. However, its use faces some barriers, such as high cost for implantation [19][15].

Therefore,the goal of this paper is the development of a system, based on open source tools (Python [20], NodeJS [21], MongoDB [22] and Rifidi [23]), for the improvement of processes related to inventories, with simulation of the RFID equipments, obtaining a reduction of costs in the development of this type of system.

This paper is developed as follows: the next section (Materials and Methods) it is explained the methodology used, then is shown on the system developed as well as the simulation performed and finally (Discussion and Results) are shown and discussed the results obtained.

II. MATERIALS AND METHODS

This paper methodology is divided into 2steps:

- System development;
- RFID simulation equipment.

The architecture of the developed system is shown in Fig. 5:

https://dx.doi.org/10.22161/ijaers.611.12 ISSN: 2349-6495(P) | 2456-1908(O)

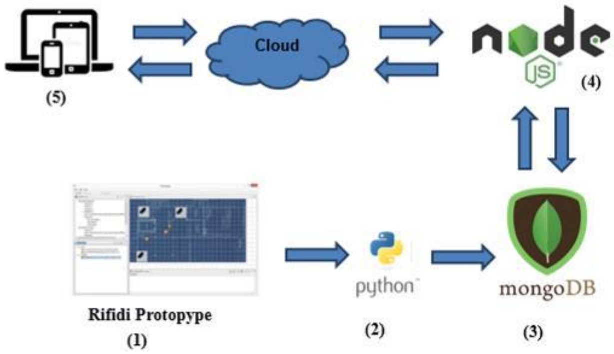

Fig.5 – Proposed system architecture

First, an interface was developed in Python (2), which reads the simulated data (Rifidi) (1) of RFID equipment. After reading the data, they are stored in a MongoDB (3) database. The web system was developed in a NodeJS server (4), which can be accessed through any mobile device (5), since the screen design must be responsive.

The code developed for the web environment was based on the MVC standard. Figure 6 shows this project directory structure:

Fig.6 – Folders structure of a web project ()

The starting point of the system is the "app.js" file, by which the system is initialized, as shown in Fig. 12, where the "nodemon" command is executed by the Ubuntu operating system terminal.

The web system, as previously said, the backend was developed in NodeJS and the front-end through Bootstrap (version 3.3.7), which made it possible to prototype responsive screens quickly. The following screen shows the login screen (Fig. 7), the dashboard (Fig. 8) and the Products register (Fig. 9):

Fig.7 – Login system screen

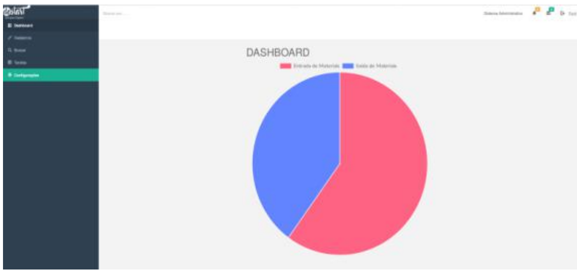

Fig.8 – Dashboard screen

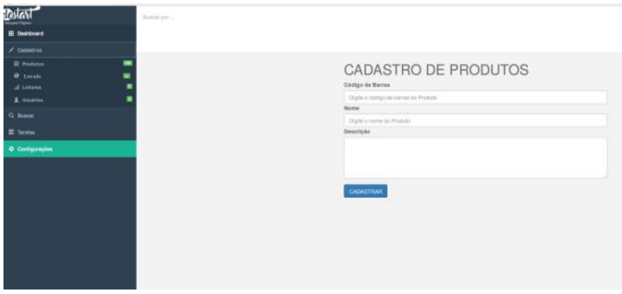

Fig.9 – Products registration screen

As previously explained, for the simulation of RFID devices in a storage environment, the RFID-prototyper system is used, as can be seen in Fig. 10:

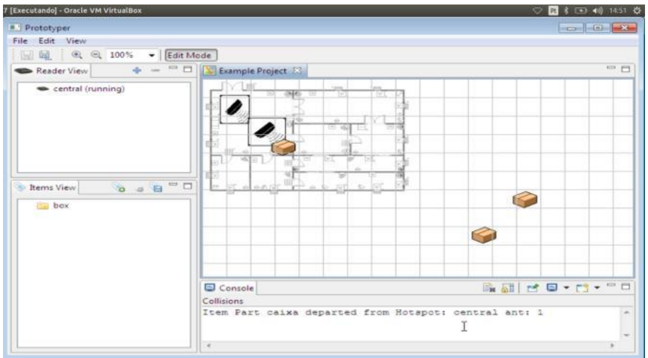

Fig.10 – Storage place simulated by RIFIDI-Prototyper

To implement this system, it was necessary to simulate another operating system (windows7), since RFIDI-

https://dx.doi.org/10.22161/ijaers.611.12 ISSN: 2349-6495(P) | 2456-1908(O)

prototype could only be executed through Java in version "1.6.0.29".

The connection with the environment in simulation, as well as the sending of the respective data was made through the Python language. The source code in Python can be accessed at:

github.com/cristianomoliveira/rifidi-python

An example of the resulting simulation data can be seen in Fig.11:

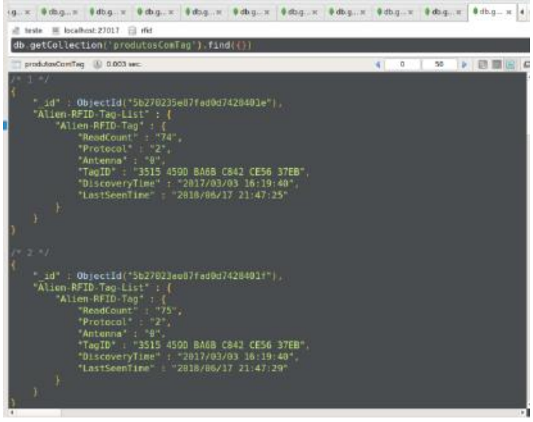

Fig.11 – Data obtained from simulation stored on MongoDB

III. DISCUSSION AND RESULTS

Table 1 shows a comparison of project costs, where open source tools were used, with other platforms, some of the costs are available in dollars, so they depend on the currency price, the conversion was done on 07/15 / 2018 with a US dollar quotation of R$ 3.89497.

Table 1 - Tools costs comparison

	Open Source		Proprietary software		
	Tool	**Cost (R$)**	**Tool**	**hosting cost (R$)**	**License (R$)**
Editor	Sublime	0	Visual Studio	0	0
Databases	MongoDB	0	SQL Server	103	0
Web Server	NodeJs	0	Windows Server 2016 Essentials	118	1,300
Cloud	-	19.25	-		-
Total (R$)	**19.25**		**221**		**4,300.00**

Table 2 - Comparison of labor cost with staff human resource

	Open Source		Proprietary software	
	Labour cost	**Cost (R$)**	**Labour cost**	**Cost (R$)**
	Developer (NodeJS)	5,975	Developer (Net)	5,700
Total(R$)	**5,975**		**5,700**	

The data in Tables 1 and 2 are estimated, made from queries conducted on the internet, on 07/15/2018. It can be observed that the hosting cost in the cloud generates a reduction of costs in the order of 94%.

The labor force did not suffer a breakdown of around 5% on the date of the survey, and may present larger changes of costs depending on the region of the country and the demand. The workforce related to the Python language was not calculated because the code developed for the project was small and it was made available.

Regarding software licensing, a few comments should be made. For example, in the case of Visual Studio and Sql Server, free versions may be used as shown above, but if purchased, licenses may have the cost around:

- **SQL Standard** - server + CAL - $ 931 (R $ 3,854.35);
- **Windows Server 2016 Essentials** (25 users e 50 devices) - $501 (R$ 1,928.85);
- **Visual Studio Professional** - R $ 3,460 (first year).

These licensing costs serve only a basic small business application, but because the project is related to IT, as discussed earlier, the volume of data is huge due to the large number of connected devices.

This can be bypassed if the project is hosted on a server in the cloud. Especially, this project uses a server with Ubuntu operating system, with the cost of $ 5 (19, 25).

If there is a need to increase the server resources, the relation of costs is shown in Table 3.

Table 3 - Comparison of labor cost with staff human resource

Memory	CPUs	Disc	Cost
2 GB	1	50 GB	$5 = (R$ 19.25)
2 GB	2	60 GB	$10 = (R$38.50)
4 GB	2	80 GB	$20 = (R$76.99)
8 GB	4	160 GB	$40 = (R$153.99)
16 GB	6	320 GB	$80 =(R$307.98)
32 GB	8	640 GB	$160 = (R$ 615.95)
64 GB	16	1.288 GB	$320 = (R$ 1.231.90)
128 GB	24	2.560 GB	$640 = (R$ 2,463.81)
192 GB	32	3.840 GB	$960 = (R$ 3,695.71)

In this way, a financial chart was developed for a project with a duration of 6 months for the development of the system, comparing an Open Source architecture and with Proprietary Software:

https://dx.doi.org/10.22161/ijaers.611.12 ISSN: 2349-6495(P) | 2456-1908(O)

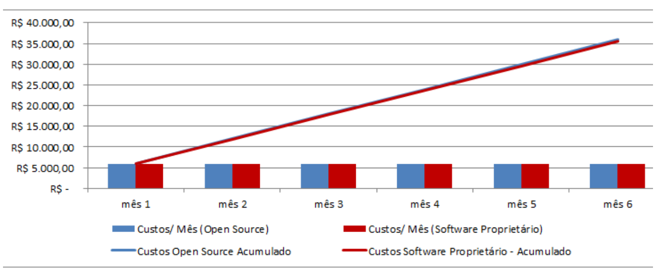

Fig.12- Costs only with labor and hosting.

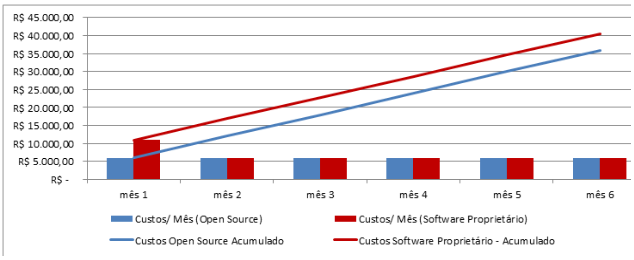

Fig.13- Labor costs, hosting and acquisition of RFID equipment.

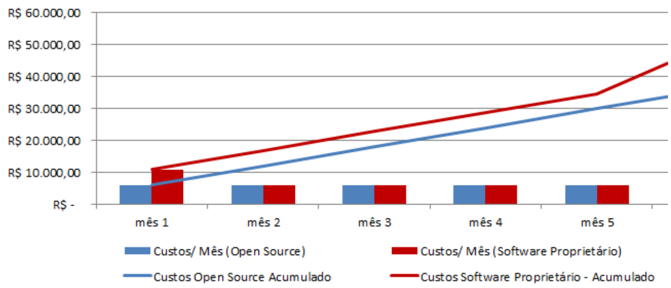

Fig.14- Graph of labor costs, hosting, acquisition of RFID equipment and licenses.

As can be observed in Fig. 11, comparing only the labor and the host costs, the difference is insignificant (increase of 0.1%), in which the Open Source project cost is higher related to the project. Proprietary Software, noting that this variation may change more or less depending on market demand and the region of the country.

Analyzing Fig. 12, there is an increase in costs at the beginning of the Proprietary Software project due to the acquisition cost of RFID equipment (R $ 5,000) at the beginning of the project, in which the Proprietary Software Project would exceed the other project in 11 , 53%, remembering that depending on the equipment to be purchased this variation may be higher or lower.

The last case to be analyzed is Fig. 13, where software license costs were added, i.e., acquisition of licenses: SQL Standart. Windows Server, Virtual Studio Professional.

Therefore, the cost of the Proprietary Software Project would exceed the other by approximately 27.9%. Remembering that the licenses of these servers were the most economical found such as Windows Server that is aimed at small businesses (only 50 devices).

MongoDB really proved to be efficient with regard to the storage of IoT project data. The negative point related to the use of this database would be the greater complexity, and difficulty in maintaining the code, when there are more relationships between the objects.

Because of this difficulty, in a team development environment, it is suggested that a code layer that consists of validating the data before its persistence is performed by an experienced developer.

IV. CONCLUSION

RFID technology is widespread worldwide, especially in developed countries due to its applications in many areas such as industry, livestock and health throughout the supply chain and on tracking of assets, people and animals. In recent years the technology has received new applications in Brazil, still few compared to the mentioned countries. Although the notable improvements RFID brings to organizations, the development of this type of system in the country it is considered a great obstacle for its high implementation cost of the equipment involved.

The proposed system was developed through open source technologies, which have been used by large corporations around the world such as: NodeJS, Python, Bootstrap, MongoDB. Those technologies have proven to be effective in the rapid prototyping of a scalable and robust system for the use of RFID technology, despite the considerable time taken to learn them.

Besides cost reduction achieved through open source technologies, another reduction was through the use of the RIFIDI-Prototyper system, since it was no longer necessary to purchase RFID equipment, such as antennas, which could make this project impossible to carry out. We reduced the total cost of the project in 27%.

The database was efficient on the storage of the large volume of data read by the antennas, which is common when it comes to IoT related projects.

The negative point on using MongoDB would be the greater complexity and difficulty in maintaining the code, when there are more relationships between the objects. A solution to this problem would be either the use of a specific library, or the use of a hybrid solution, i.e., objects related to sensor data could be stored in MongoDB, whereas other objects in another type relational databases.

Another point to emphasize in this research was the difficulty for the development of the bibliographical review for this paper, due to the great amount of articles related to the term RFID, since the technology was developed around the Second World War.

Data analysis, from the ones collected in Scopus database, we used R software along with Bibliometrix library, besides Gephi.

In addition to the possibility of accessing the system in mobile devices as a cell phone, it was noticed the need to access the system through desktop devices since the employee needs to wear gloves often, for that, a RaspberryPi 3 was used, in which the Linux, connected to a keyboard, mouse and monitor, thus keeping the cost reduction of the system.

Finally, for a future work, we suggest the development of other systems based on the same architecture approached here, related to smart cities with the persistence of data in the blockchain.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the financial provided by State University of Northern Rio de Janeiro, Brazil.

REFERENCES

[1] Miraz, M. H., Ali, M., Excell, P. S., & Picking, R. (2017). A review on internet of things (IoT), internet of everything (IoE) and internet of nano things (IoNT). arXiv preprint arXiv:1709.10470.Perfect, T. J., & Schwartz, B. L. (Eds.) (2002). Applied metacognition Retrieved from http://www.questia.com/read/107598848

[2] Aydos, T. F., & Ferreira, J. C. (2016). RFID-based system for Lean Manufacturing in the context of Internet of Things. In Automation Science and Engineering (CASE), 2016 IEEE International Conference on (pp. 1140-1145). IEEE..

[3] Da Xu, L., He, W., & Li, S. (2014). Internet of things in industries: A survey. IEEE Transactions on industrial informatics, 10(4), 2233-2243.

[4] Akyildiz, I. F., & Jornet, J. M. (2010). The internet of nano-things. IEEE Wireless Communications, 17(6).

[5] Balasubramaniam, S., & Kangasharju, J. (2013). Realizing the internet of nano things: challenges, solutions, and applications. Computer, 46(2), 62-68.

[6] Tommy, R., Ravi, U., Mohan, D., Luke, J., Krishna, A. S., & Subramaniam, G. (2015, August). Internet of Things (IoT) expanding the horizons of Mainframes. In 2015 5th International Conference on IT Convergence and Security (ICITCS) (pp. 1-4). IEEE.

[7] Nukala, R., Panduru, K., Shields, A., Riordan, D., Doody, P., & Walsh, J. (2016, June). Internet of Things: A review from 'Farm to Fork'. In Signals and Systems Conference (ISSC), 2016 27th Irish (pp. 1-6). IEEE.

[8] Evans,D.(2011). The Internet of Things: How the next Evolution of the Internet Is Changing Everything. CISCO White Paper 1(2011): 1–11.

[9] Gampfer, F., Jürgens, A., Müller, M.,& Buchkremer, R. (2018). Past, current and future trends in enterprise architecture—A view beyond the horizon. Computers in Industry, v. 100, p. 70-84.

[10] Gartner(2018).https://www.gartner.com/technology/research/methodologies/hype-cycle.jsp.

[11] Christidis, K., & Devetsikiotis, M. (2016). Blockchains and smart contracts for the internet of things. IEEE Access, 4, 2292-2303.

[12] De Vicente, D. T., Garcia, M. J. M., Di, S. G., Santo, E., & Dias, M. (2010). AVL System Integration with RFID for the optimization of Cargo Transportation. WSEAS Transactions on Systems and Control, 5(6), 383-392.

[13] Bottani, E., & Rizzi, A. (2008). Economical assessment of the impact of RFID technology and EPC system on the fast-moving consumer goods supply chain. International journal of production economics, 112(2), 548-569.

[14] Oliveira, C. M. D., Soares, P. J., Morales, G., Arica, J., & Matias, I. D. O. (2017).RFID and its applications on supply chain in Brazil: A structured literature review (2006–2016). Revista ESPACIOS, 38(31).

[15] Soares, P. D., de Oliveira, C. M., Morales, G., Arica, J., Matias, I., Ferreira, A. S.,& Carneiro, V. (2017, October). Tracking of Materials and Equipment Used in Planned Maintenance Shutdowns on Offshore Platforms: An Approach using RFID. In OTC Brasil. Offshore Technology Conference.

[16] Musa, A., & Dabo, A. A. A. (2016). A review of RFID in supply chain management: 2000–2015. Global Journal of Flexible Systems Management, 17(2), 189-228.

[17] Adoga,I.,&Valverde R.(2014).An RFID Based Supply Chain Inventory Management Solution for the Petroleum Development Industry: A Case Study for SHELL Nigeria. Journal of Theoretical and Applied Information Technology 62(1): 199–203.

[18] Pedroso, M. C., Zwicker, R., & Alexandre de Souza, C. (2009). RFID adoption: framework and survey in large Brazilian companies. Industrial Management & Data Systems, 109(7), 877-897.

[19] Soares, P. D., de Oliveira, C. M., Morales, G., Arica, J., & Matias, I. (2017, July). International Joint Conference – ICIEOM-ADINGOR-IISE-AIM-ASEM. In Valencia, Spain.

[20] Python (2018). https://www.python.org/about/

[21] NodeJS (2018). https://nodejs.org.

[22] MongoDB (2018).mongodb.com

[23] Huebner, A., Facchi, C., & Janicke, H. (2012). Rifidi Toolkit: Virtuality for Testing RFID Systems. Seventh International Conference on Systems and Network Communications.