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The Integration of Industry 4.0 in the Processes of a Company in the Gas Sector through a Holistic Enterprise Architecture

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Abstract: Industry 4.0 is a rapidly evolving concept that has received attention in recent years and aims to achieve a higher and more efficient production rate through automation. Because its implementation involves the improvement of business processes, this concept is inextricably linked to Business Process Management. Business Process Modeling is a Business Process Management tool that can be used to describe an organization's processes in order to elaborate and improve them. As a result, models are widely used for the better comprehension of processes and as a first step in introducing new concepts, such as Industry 4.0, into an organization. Hence, a comprehensive framework of a modeling architecture is required for an organization that desires a holistic transmission to new concepts based on its needs, operations, and structure. In this paper, a holistic enterprise architecture, along with an instance of it, which is proposed in a company that manages the high and medium-pressure natural gas network is presented, encompassing the appropriate models for the recording and detailed presentation of business processes and how Industry 4.0 principles and applications could be incorporated to them.
Keywords: **Industry 4.0; Modeling Architecture; Enterprise Architecture; Gas Sector; Business Processes**

I. INTRODUCTION

The term Industry 4.0 (or fourth industrial revolution) refers to a technology-oriented idea that is primarily focused on the manufacturing industry, but can be adapted and applied to any value chain organization [1]. Companies are attempting to implement a variety of innovative solutions in the context of Industry 4.0, including Information and Communication Technologies (ICTs), Cyber-Physical Systems (CPS), and the Internet of Things (IoT) [2]. The utilization of Business Process Management (BPM) tools to integrate Industry 4.0 principles into business processes could help and simplify their improvement [3]. The method of Process Modeling is used by BPM to contribute to Industry 4.0, providing stakeholders with appropriate methods to control intelligent manufacturing processes and smart factories efficiently and effectively [4]. Business process models examine and analyze the behavioral elements of systems and are typically developed in an early stage of requirements designing [1]. For the integration of the Industry 4.0, through the suitable information systems, in the processes that are modeled a complete enterprise architecture should be developed. The enterprise architecture frameworks integrate strategies, business activities, and information systems by providing a representation of current organizational capabilities and enabling desirable results [5].

The usefulness of the development of enterprise architectures for the integration of Industry 4.0 in the processes of organizations is emphasized by the literature [6], [7], [8], [9]. In the recent literature there are also studies that present architectures for the incorporation of Industry 4.0 in business activities. For example, completed 5-level architectures are proposed by [10], [11] for the adoption of Industry 4.0 in manufacturing environments where real-time data collection and management is required for operations control. According to [12] an architecture utilizing human knowledge for data input in smart factories can be developed. In [13] a vertical integration architecture to collect data and transform it into useful information for the system is proposed. The TOGAF (The Open Group Architecture Framework) approach is proposed by [14], [15] and [16] as the architecture in which the Industry 4.0 integration should be based, and RAMI 4.0 (Reference Architectural Model for Industry 4.0) by [17] and [18] which represents the IT systems, hardware and communication protocols specific for Industry 4.0 integration in the functions of the companies. The RAMI 4.0 approach is also used by [19] who add a new dimension of security and human interaction with the system. Furthermore, a 5-layer meta-architecture is proposed by [20] taking under consideration all the basic ingredients of the Industry 4.0 implementation in business processes (business layer, application layer, technology layer, operations layer, external interface layer). A meta-architecture is also presented by [21] including the views of big data, cloud computing, IoT and blockchain.

In addition, PERA (Purdue Enterprise Reference Architecture) for industry 4.0 is used by [22] as a framework for the construction of adjusted architectures such as the one proposed in this study. Enterprise architecture development provides companies with important information and useful details on how to align their strategy with their business processes in order to achieve the desired objectives [23]. Moreover, an architecture for the modeling of predictive maintenance and its automation, through the utilization of Indus-try 4.0, is proposed by [24]. ARIS (Architecture for Integrated Information Systems) architecture is also suggested by [25] and [26] for the digitization of processes.

Finally, [1], [27], [28], and [29] utilize UML-based models, which are a large category of process modeling techniques used as a Business Process Management tool. Consequently, both dynamic and static techniques are used to configure models and architectures. BPMN, on which this paper's architecture is based, is described as a solid and adaptable solution for both static and dynamic modeling methods [1, 27].

Concerning the gas sector, that is the sector of the company for which the architecture was developed, there are very studies which point out the usefulness and the benefits of Industry 4.0 and IoT in the operations of the companies. Specifically, the contribution of the re-mote control of oil and gas platforms and infrastructures has been studied, through a developed model [30]. In addition, a high-level architecture has been proposed for the application of cyber-physical systems and the assurance of the security of gas networks in Europe [31]. In addition, there are many publications regarding the management and analysis of big data for oil and gas industry gathered by the IoT sensors [32]. The identification of the gas sector processes that are eligible for transformation, through Industry 4.0 applications, is also provided by the literature [33]. Furthermore, there are proposed enterprise architectures combining models for processes, products/services, data collection, networks, and Industry 4.0 integration [34], and suggesting the usage of IoT in the whole value chain of the oil and gas organizations [35]. Finally, more general enterprise architectures for the linking of oil and gas companies core processes with technological solutions and information systems are proposed based on Zachman framework [36], on TOGAF [37].

The aim of this paper is the development of a Business Process Modeling Architecture prototype, and specifically the better explained with instances extension of the architecture proposed by [38] which will be used to describe methodologies and guidelines for the design and combination of Business Pro-cesses and Industry 4.0 in an organization, called DEDA, that is re-sponsible for the operation of Greece's middle and low-pressure gas distribution networks and desires to transform its processes following an Industry 4.0 framework. Initially, the methodology that was utilized for the development of this architecture is presented. Subsequently, the description of the proposed architecture, including the views that will meet the organisation 's objectives and particular diagrams for depicting how the incorporation of Industry 4.0 and the analysis of a process was carried out, is presented. This architecture is based on ARIS and its encompassing methods, following at the same time the structure PERA, as a guide for the Industry 4.0 and information systems integration. Owing to its simplicity and generic nature [39], which facilitated the fitting with the company's needs and mentality, the levels of PERA architecture were chosen as the base of the adjusted meta-architecture of this case, developed as a next-step emerging framework according to PERA principles. The combination of PERA and ARIS led to the development of a new meta-architecture based on the needs of a specific organization operating in the natural gas sector. The combination of ARIS and Industry 4.0 for the gas sector is the first time that is presented in the literature based on the recent aggregated reviews about enterprise architectures, including or not Industry 4.0 contribution [5, 18, 40, 41, 42]. In addition, the architecture of this paper tries to achieve the interlacement of physical (manual), semi-automated and automated activities (Industry 4.0) through information systems, as these dimensions is significantly to be combined for the success of every organization [43, 44].

II. METHODOLOGY

For the development of the proposed architecture the steps that were followed are presented in Figure 1. Initially, the basic modeling methods and integrated architectures presented in the literature and reported by academic sources, as well as business users were searched and identified. This search helped to understand the evolution of this scientific area, while also helped to convey ideas to DEDA about the views that could be taken into account for the design of the architecture that will be formed. The architectures that were taken under con-sideration in the first step were the most widespread and adopted modeling architectures, the Zachman Framework, the FEAF (Federal Enterprise Architecture Framework), the TOGAF, and ARIS. The Zachman Framework is organized in grid form including roles and queries, categorizing and organizing the components of the business that concern both the management of the business and the development of information systems [45]. FEAF is an architecture that started from the governmental and public sector for the integration of the in-formation system in the processes and has, on the one hand a classification for business models and on the other hand a methodology (pro-posed process) of building the architecture of an organization [46].

The same logic is also followed in TOGAF which is mainly based on modularization, standardization, and already existing, proven technologies and products [47]. Finally, ARIS aims to integrate IT technologies into the company being improved, using a "Control - Design - Implementation" cycle [48]. It also satisfies the need for information systems tools and methods that support Business Processes. Even if all the architectures are well-established and could support the development of DE-DA business modeling, ARIS was selected as it has several significant advantages over the others. The first advantage is that it can support all the views that are necessary for the modeling with the ability of choosing alternative methods (about 200) to fill them. In addition, it supports the Industry 4.0 view that was the main reason for DEDA for the modeling of processes and the configuration of a holistic business architecture. Finally, the architecture framework and the accompanied tool can support internal, external and collaborative processes, while at the same time has the ability to evolve the recorded processes that in automated.
As a second step, the definition of the views that will be taken under consideration by the company - user (DEDA) was carried out, taking into account its strategic directions and its available resources and skills. The choice of the operating system views to be analyzed led to the next step which was the selection of the architecture framework on which the customized architecture that will be formed for DEDA will then be based. This framework includes the basic principles and tools that allow the design of an architecture. As a fourth step, the se-lection of the methods that will be used to cover the business views was made, while as a final step, the selected methods were tested and structured in order to ensure the coherence of the shaped architecture through the correlations of their objects.

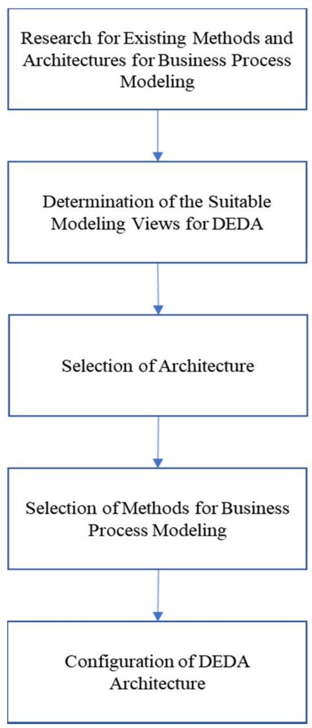

Figure 1. Methodology of architecture development.

III. PROPOSED ARCHITECTURE

A. Development of the Architecture

The first step for the configuration of the proposed architecture is the understanding of the role of BPM in Industry 4.0 implementation in a gas company. BPM is the higher level (Level 6) of the "pyramid" that is structured according to PERA principles and depicts the vertical integration of Industry 4.0 in business processes, as shown in Figure 2, and encompasses modeling, execution, and business process control. The Actual Processes of Organization Operation makes up the lower level (Level 0). Level 1 includes all necessary equipment for direct interaction and coordination with actual processes, whereas Level 2 includes SCADA or other data collection system (based on the needs), which gathers data from Level 1 equipment utilized in actual processes. Level 3 encompasses Equipment System and Maintenance Management, which is based on the aggregation of the data of SCADA or other data collection system. Level 4, Products Lifecycle Management (PLM), serves as a link between Levels 3 and 5, since it develops products based on requirements from Level 5's ERP and CRM systems while also monitoring low-level production.

The concept of security is critical at all levels of a company's architecture for a gas distribution network, and it takes different forms at each of the pyramid's six levels. For example, security is crucial on both a physical (e.g., covering the risk of physical asset destruction) and an informational and net-work level (e.g., preventing a cyber-attack). Similarly, knowledge must be managed in various ways in the different levels of the pyramid (e.g. explicit knowledge concerning executional processes is expected to be found in the lower levels of the pyramid, possibly in the form of analytical procedures and work instructions, whereas more tacit knowledge is found in the higher levels, possibly in the form of management good practices and shared experiences).

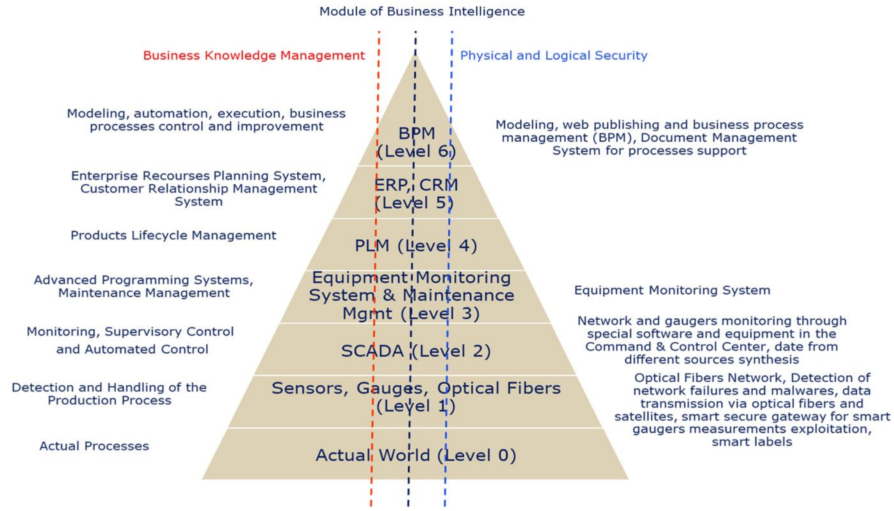

Figure 2. The “pyramid” of Industry 4.0 implementation levels.

Based on the needs of the organization, in which the proposed architecture was implemented, the views of the system analysis have been detected and categorized as follows:

1) *Organization View:* Encompasses the organizational structure of the company according to employees’ positions and its allocation in departments.
2) *Process View:* Consists of the processes, subprocesses and activities of the organization.
3) *Information Systems View:* Depicts the information systems used by the company as well as the applications included in them and their interconnections
4) *Industry 4.0 and Internet of Things View:* Analyzes how sensors, actuators, and communications networks are used to automate semi-autonomous processes.
5) *Documents/Files View:* The recording and categorization of important documents and files for the business processes operation are included in this view.
6) *Rules/Legislation View:* Refers to the business rules and legislation that impact organizational processes and should be recorded.
7) *Risks/Controls View:* Includes risks listing according to their cate-gory and their implications in business processes.
8) *Products/Services/Customers View:* Includes the analysis of products and services provided by the examined organizations and the approaches on the basis of which its main customer categories are served, too.

ARIS was chosen as the modeling architecture and, more precise-ly, the meta-architecture modeling framework to be utilized, based on the views that are provided and should be covered based on the organization's analysis. ARIS was selected not only because it entirely incorporates the perspectives that must be included in the analysis, but also because it is clear, and its supporting software was easily accessible by all employees. The views of ARIS are shown in Figure 3, together with the methods (diagrams) utilized in each view. Organizational, Data, Processes, Functions, and Products and Services are the views of ARIS. The representation is carried out through the House of ARIS, which depicts the interconnections between different views. Through specific modeling methods, these views correspond to specific levels of the PERA architecture. Network Diagrams, Network Topology Diagrams, IoT Object Definitions Diagrams, IoT Context Diagrams, and Information Carrier Diagrams are utilized in particular at Levels 1, 2 & 3 where the Industry 4.0 principles are implemented in company processes. For the representation of the information systems requirements, structure, and function in Levels 3, 4, and 5, Application System Type Diagrams, Application Collaboration Diagrams, Requirements Tree and Requirements Allocation Diagrams, Customer Journey Map and Customer Journey Landscape (for CRM), Product Service Tree, and Information Carrier Diagram are used.

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Value-added Chain Diagrams, Enterprise Collaboration Diagrams (BPMN), Function Allocation Diagrams (FAD), Business Rule Architecture Diagram, Business Controls Diagram, KRI Allocation Diagrams, Risk Diagram, and In-formation Carrier Diagram are all representations of BPM at Level 6.

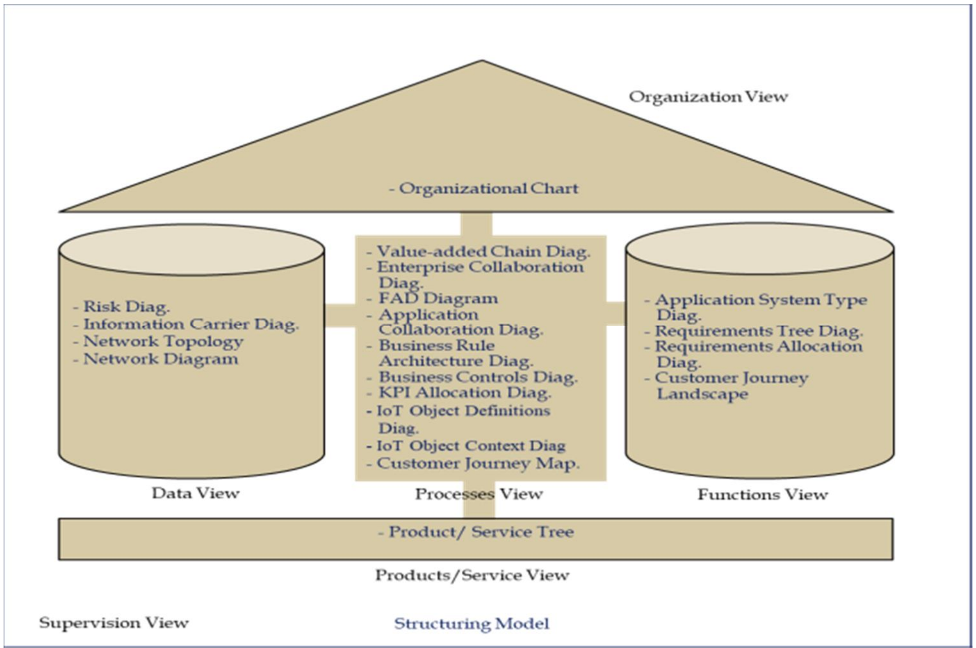

Figure 3. Used diagrams distributed in ARIS view.

In Figure 4 the methods of ARIS were redistributed to be adjusted in each view of the organization. In both Figure 3 and Figure 4 an extra Supervision View has been added, constituting the common plat-form of connection between the other views, in the form of a control panel.

Figure 4. Used Diagrams distributed in organization views.

In particular, the Organization view, is structured by the Organizational Chart configuration. The Information Carrier Diagram is used for documents and files recording and classification in the Documents/Files view. The Enterprise Collaboration Diagram, which is the core diagram of the recommended architecture, supports the Function view by depicting all of the organization's functions in BPMN form, in both "as-is" and "to-be." Function Allocation Diagrams (FAD), which connect BPMN to the diagrams of other perspectives, and Value-Added Chain Diagrams, which aggregate business processes at a high level, support BPMN diagrams.

The view of System Requirements is presented by The Requirements Tree Diagram determining the hierarchy of requirements, which subsequently analyzed using the Requirements Allocation Diagram. System requirements link "as-is" and "to-be" diagrams and are connected to business improvement initiatives.

The view of Industry 4.0 and IoT is one of the most significant views for the utilization of the proposed meta-architecture since it promotes the organization's transition to automation adoption. The structure of automations, including the function of sensors and actuators, is represented by the IoT Object Definition Diagram, which is complemented by the IoT Object Context Diagram, that describes the function of the automation in a process. Furthermore, Network Topology and Network Diagrams represent the automations' communication and interconnection networks, completing the Industry 4.0 view in business processes.

The view of Risks/Controls/Policies is analyzed as an integrated framework because of their correlation. The Business Rule Architecture Diagram depicts the business policies that must be followed by the organization. The Risk Diagram outlines the risk categories and risks that are associated with the organization's operations, which are measured by the KPI Allocation Diagram and confronted based on the recorded information encompassed in the Business Controls Diagram. The Ap-plication System Type Diagram is used to describe the view of Information Systems, which records all of the company's information systems and decomposes their structure and functionality utilizing Ap-plication Collaboration Diagram. The Product/Service tree is used in the final view of Products/Services/Customers to depict the products and services delivered by the company to customers. In addition, the path that is followed by the customers from the beginning to the end of their interaction with the organization, as well as an analysis of each step of the route parameters, are depicted by the Costumer Journey Landscape and the Costumer Journey Map, respectively..

B. Instances of the Methods

The proposed architecture consists of the main view of Processes which constitutes its core, based on BPMN diagrams representing business processes, framed by the other views which supplement a completed framework harmonized with the needs of the studied gas company, in order to depict every aspect of its operation (e.g., information systems, documents, risks) and achieve the adoption of Indus-try 4.0 principles in its processes. BPMN lanes offer better interaction between physical and electronic actors, too. That was the reason for choosing BPMN as the central architecture diagram. The transition was primarily depended on the matching of Industry 4.0 and IoT methods in BPMN diagrams along with the cooperation with the methods of the other views.

In this paper, specific instances of methods are presented in order to give an example of the structure of the architecture. The explanation of the objects that are used in the presented diagrams are presented in the Appendix. In particular, the methods that are presented for each view are:

1) *Organization view:* Organizational Chart
2) *Process view:* Enterprise BPMN Collaboration Diagram, Function Allocation Diagram (FAD) (with Risks-Controls), IoT Object Context Diagram

The example that was selected to be presented in this paper is a small part of the total architecture, but at the same time, the most important, as it depicts the core methods of the architecture for the correlation of Industry 4.0 and IoT with the business processes. The three methods of the process view that are presented show the interlacement of the automated activities (IoT sensors) with the semi-automated activities (monitoring of the collected data via the Control Room) and manual activities (physically checking of malfunctions), through in-formation systems.

Before the analysis of the example of the architecture, the presentation of the Organizational Chart of the company is very important. The Organizational Chart concerns the hierarchical structure of the company and was the first diagram that was configured in order to define which Departments and Employees participate in the processes. In Figure 5 the Organizational Chart of DEDA is presented in Departments level, which was also the level that was used for the modeling of processes the most of the times (apart from specific exceptions).

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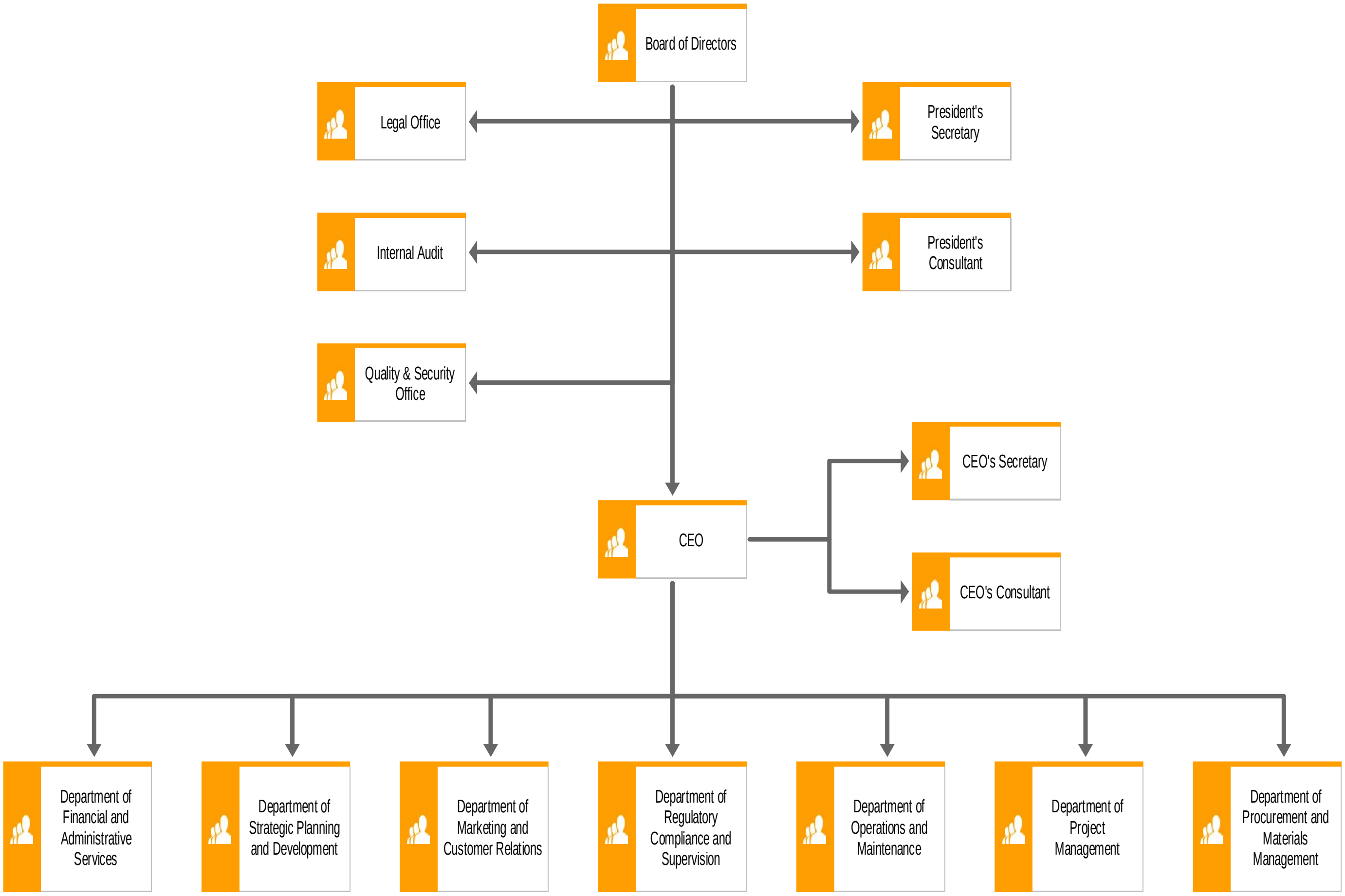

Figure 5. Organizational chart of the company.

From the Organizational Chart, the Department of Operations and Maintenance participates in the process that is presented in Figure 6. In this process, the interaction of the Department of DEDA with an External Partner is presented, that's why the two participants are placed in separate pools. A BPMN diagram can depict in high level of detail the interaction participants involved. Every activity of this pro-cess can be connected with other diagrams of other or the same view for better understanding of the system. This example presents the "Detection of Gas Leak" process, and, in particular, the case in which both the need for remote valve closing and technician's presence are needed. The process is based on the data that are continuously collect-ed by the PZT (piezoelectric) sensors in the field and are transferred, with the help of LoRaWan protocol and an IoT middleware that trans-late the signals of sensors into data, in the Control Room and elaborated, through the Data Collection System. The pool of IoT middleware is not represented in the diagram for the simplification of the depiction. The Department of Operations and Maintenance systematically checks the data of the sensors (PZT and volume correctors) and, at the same time, checks if the correlation of the data that are coming from the volume correctors and the PZT sensors is normal. If abnormalities are detected or the system displays an alarm message, then the Department understands that there is a possible leak in the pipeline and gives an order to the Valve of the pipeline to cut off the supply of gas, through the system of the Control Room (the order is transferred via the IoT Middleware) and notifies the Technicians (External Partner) to go in the field and check for malfunctions, through the Operations and Maintenance System. After the fixing of the problem, the Department receives from the Technician, via the Operations and Maintenance System, the notification of the problem fixing. Subsequently, the Department gives again the order to Valve to open and allow the supply of gas and checks, from the Control Room, whether the data of the PZT sensors are normal again and after one hour checks the data from the volume correctors in order to ensure that the flow in the pipeline has been restored. Thus, this process manages to connect, through information systems, the automated collection of data by PZT sensors and volume correctors with the semi-automated orders to the technicians and the physical work for the fixing of the problem.

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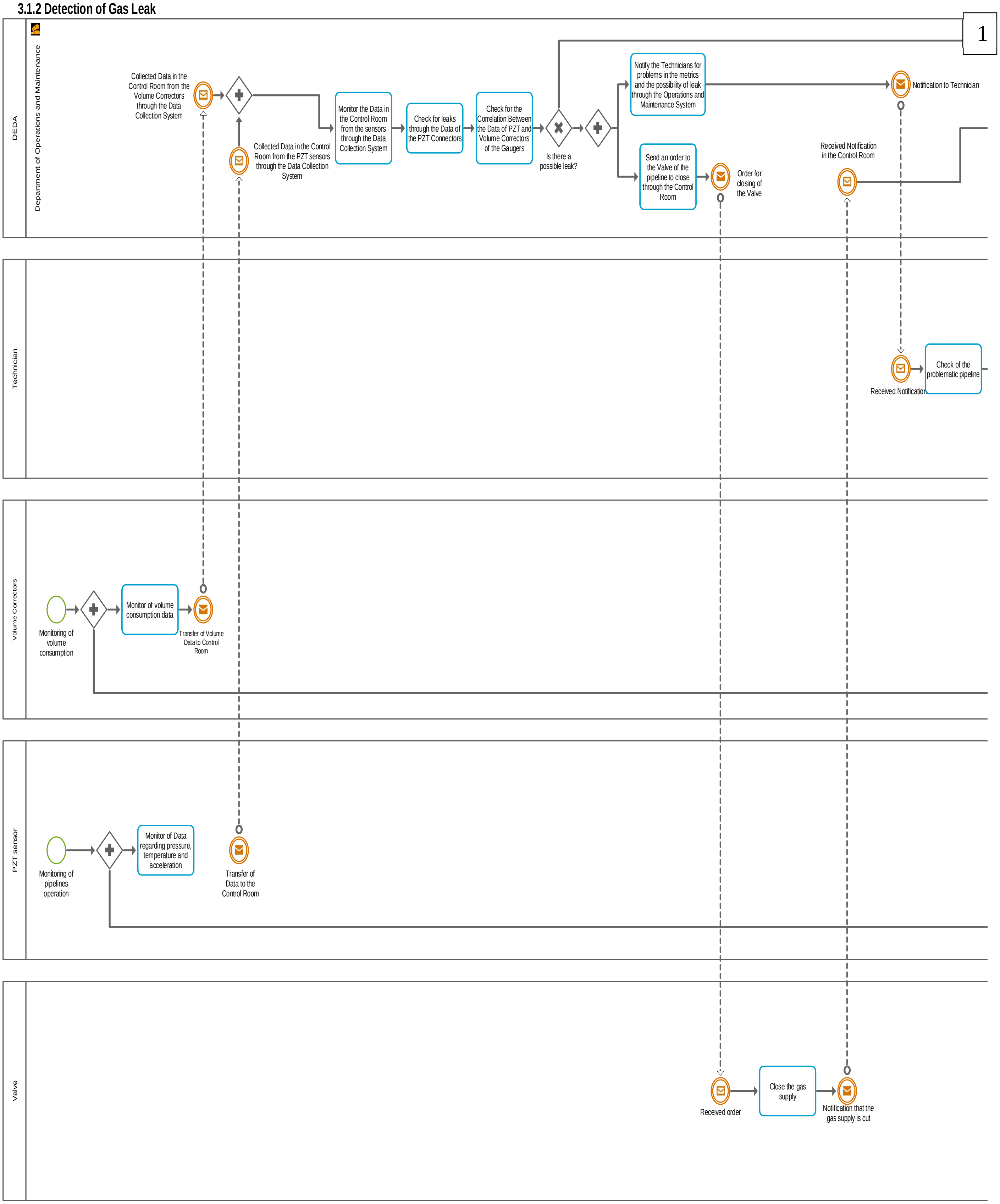
3.1.2 Detection of Gas Leak



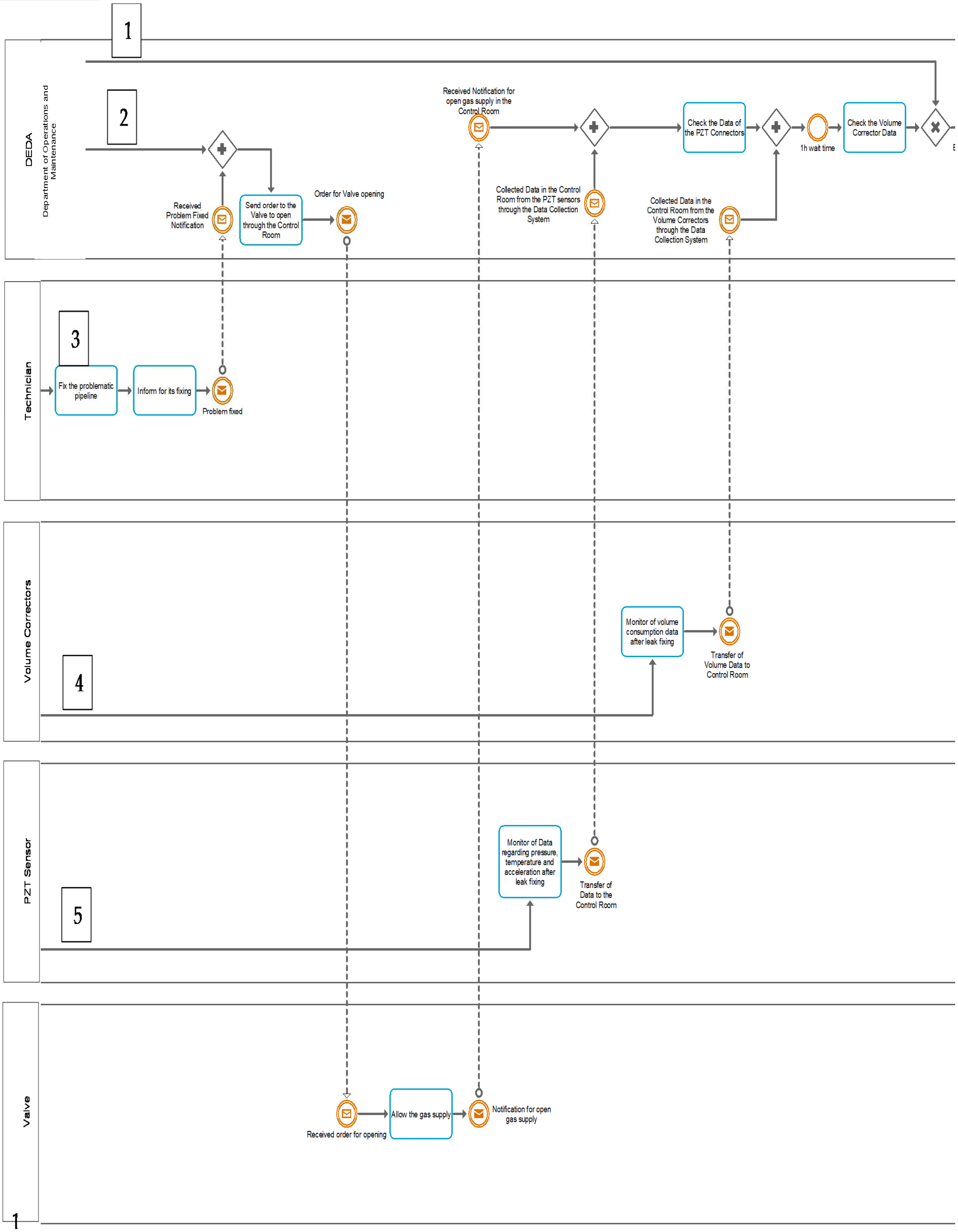


Figure 6. BPMN diagram of the "Detection of Gas Leak" process

For the better comprehension of the functions that are executed when the gas leak occurs, the BPMN diagram alone is not sufficient. For this reason, an IoT Context Diagram and a FAD were constructed to support the BPMN and to give further details regarding the process. The FAD gives an explanation of the specific important steps of the process, as shown in Figure 7, including the information systems that support the process, the location in which the processes take place, as well as, the risk and control actions that should be executed in case of danger. In addition, the PZT sensor (IoT object) presented in the FAD is further analyzed in the IoT Context Diagram, as present-ed in Figure 8. This IoT Context Diagram presents insights about the operation of the IoT network that cannot be presented in the steps of the BPMN. In particular, the pipeline is connected with the PZT sensor (IoT sensor) that can transfer data about the acceleration, the temperature and the pressure of the natural gas within the pipeline. These data are transmitted via a LoRaWan (Low-Power-Wide-Area) wireless network (as the signal may have to be transmitted to several kilometers away), which act as the communication protocol and the final destination is the Data Collection System, from which the employees of the Control Room understand whether to send an order to the automated valve of the pipeline (IoT actuator), to close and cut out the flow in the pipeline in which the PZT sends a warning signal. For the transfer of the signal, it is also used a Data Transfer Security Protocol compatible with the LoRaWan network. The security protocol is of high importance for the communication among the IoT objects of the network and, especially, when these objects control the gas leaks and the flow of the gas in the pipelines that supply the entire country.

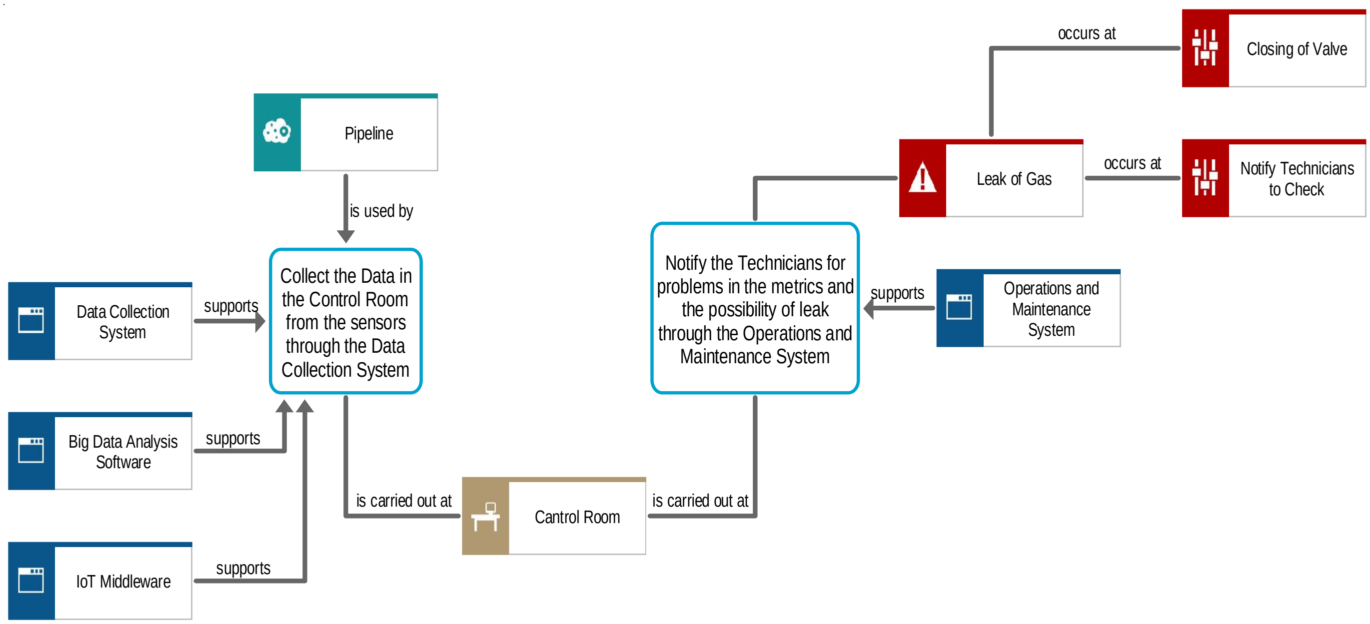


Figure 7. FAD analyzing two activities of the BPMN diagram

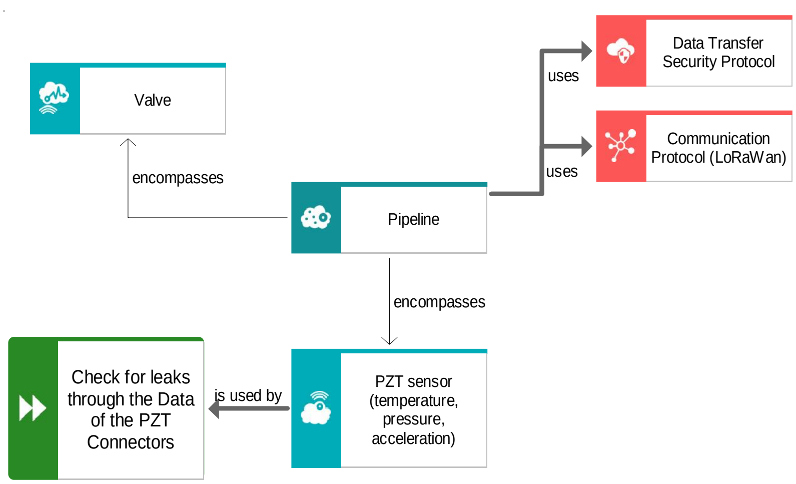


Figure 8. IoT context diagram depicting the function of a IoT object as part of the BPMN process.

IV. DISCUSSION

The architecture that was developed according to the needs and the requirements of DEDA was used for the modeling, in the form of BPMN, of 52 AS-IS processes and 74 TO-BE processes, along with their supplementary diagrams, covering all the views and the methods that are described. The utilization of all the methods was very important as it gave the employees and the management team a completed and detailed picture of the already existing and the new processes, the functions of the information systems and the IoT technology that was added in the TO-BE processes. In particular, from the 74 TO-BE processes, the 24 encompass the view of Industry 4.0 and IoT and were mainly concern the operations and maintenance processes of the gas network (e.g., automated consumption measurement and pricing, automated detection of mal-functions and further actions for the avoidance of accidents). The integration of the Industry 4.0 view in the architecture and the connection of specific IoT diagrams with the processes was significant for the company, as it depicts and makes understandable the transition from a more manual way of working in a much more automated. At the same time, the basic strategic goal of the company that was led to the development of the models, that is making the operations and maintenance faster and less costly while the gas network is expanded, was fulfilled.

Furthermore, the proposed architecture managed to correlate the activities of the operations and maintenance department that are executed by humans in the field (manual/ physical) with automated activities that are executed by the Industry 4.0 sensors, actuators and network (e.g., data collection from sensors and actions like au-to-closing of valves), and with semi-automated activities (orders that are given to technicians for problems fixing), through information systems. Thus, the simplification of the processes is achieved as they are controlled by information systems which are the pillar both for the collection and transfer of data and information among the stakeholders of processes and support the functions of cyber-physical systems.

Finally, the development of an architecture that is based on the adoption of Industry 4.0, apart from the reduction of cost that offers to the company as it can be in-dependent of contractors for the continuous supervision of the gas network for mal-functions, results also in the assurance of more operations that are more sustainable and greener. Specifically, the standardization of operations and maintenance processes that achieved, incorporation Industry 4.0 technologies, led to the establishment of the remote supervision of the gas network operation and security, with structured plans for maintenance and automated activities that do not require the continuous and daily physical checking for technicians, neither for malfunctions nor for the recording of consumers consumptions. Consequently, the continuous utilization of vehicles for hundreds of kilometers of pipelines supervision is not further necessary and as a result the emissions of harmful for the environment gases are decreased to the lowest possible level, since the contractors will need to take actions and correct the malfunctions only when it is necessary according to the flow data that are gathered to the control room of the organization.

V. CONCLUSIONS & FURTHER RESEARCH

The modeling of an enterprise system in the Industry 4.0 era is a complicated and strategic task that faces several challenges in order to accomplish the holistic integration of various and frequently conflicting perspectives. The design of an integrated architecture based on the ARIS framework is presented in this paper, which takes into account the view of Industry 4.0 and Internet of Things. The design was developed for an organization that operates middle and low-pressure gas distribution networks, and it was based on the company's strategic goals and objectives. It is recognized that this is only the beginning, and that many more steps must be taken in the future.

The developed architecture has been verified according to the requirements of the company and is going to be fully deployed and validated, through a pilot project, in the near future.

However, it must be mentioned that the experience obtained so far has been positive, demonstrating that the goal of connecting the Industry 4.0 view with other organizational views at multiple managerial and operational levels has been achieved. As a further examination of the proposed architecture, it is important to examine its applicability to other organizations in the same or different industries after the pilot project which will be the final refinement of the models. In addition, the development of models, incorporating the view of Industry 4.0 for the oil and gas sector or for public utilities organizations, in general, with other architectures other than ARIS methods can be carried out in order to be compared with these of this study in terms of applicability and representation of all the necessary information.

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REFERENCES

[1] Petrasch, R., and Hentschke, R. Process Modeling for Industry 4.0 Applications: Towards an Industry 4.0 Process Modeling Language and Method. In: 13th International Joint Conference on Computer Science and Software Engineering (JCSSE) on IEEE, Khon Kaen, Thailand 2016, [DOI: 10.1109/JCSSE.2016.7748885].

[2] Lu, Y. Industry 4.0: A survey on technologies, applications and open research issues. Journal of Industrial Information Integration 2017, 6, 1–10.

[3] Nascimento, D.L., Alencastro, V., Gonçalves Quelhas, O.L., Gusmão Caiado, R.G., Garza-Reyes, J.A., Lona, L.R., and Tortorella, G. Exploring Industry 4.0 technologies to enable circular economy practices in a manufacturing context: A business model proposal. Journal of Manufacturing Technology Management **2018**, 30(3), 507-627[DOI: 10.1108/JMTM-03-2018-0071].

[4] Rehse, J.R., Dadashnia, S., and Fettke, P. Business process management for Industry 4.0 – Three application cases in the DFKI-Smart-Lego-Factory. it – Information Technology, **2018**, 60(3), 133–141.

[5] Abunadi, I. Enterprise Architecture Best Practices in Large Corporations. Information **2019**, 10, 293.

[6] Weill, P. and Woerner, S. Thriving in an Increasingly Digital Ecosystem. MIT Sloan Management Review, June 2015.

[7] Westerman, G., Bonnet, D., McAfee, A. Leading Digital. Harvard Business Review Press, 2014.

[8] Brynjolfsson, E. and McAfee, A. The Second Machine Age; W. W. Norton, New York, 2014.

[9] Zimmermann, A., Schmidt, R., Sandkuhl, K., Jugel, D., Bogner J. and Möhring, M. Evolution of Enterprise Architecture for Digital Transformation. In: 2018 IEEE 22nd International Enterprise Distributed Object Computing Workshop (EDOCW), 2018, 87-96, doi: 10.1109/EDOCW.2018.00023.

[10] Uriarte, A.G., Ng, A., and Moris, M.U. Supporting the lean journey with simulation and optimazation in the context of Industry 4.0. Procedia Manufacturing **2018**, 25, 586-593.

[11] Cicconi, P., Russo, A.C., Germani, M., Prist, M. and Pallotta, E.; Monteri`u, A. Cyber-Physical System Integration for Industry 4.0: Modelling and Simulation of an Induction Heating Process for Aluminium-Steel Molds in Footwear Soles Manufacturing. In: 2017 IEEE 3rd International Forum on Research and Technologies for Society and Industry (RTSI) on IEEE, Modena, Italy, 2017.

[12] Hermann, M., Pentek, T. and Otto, B. Design principles for Industrie 4.0 scenarios In: 49th Hawaii International Conference on System Sciences (HICSS) on IEEE, Koloa, pp. 3928-3937. HI, USA, 2016.

[13] Ullah, A.S. Modeling and simulation of complex manufacturing phenomena using sensor signals from the perspective of Industry 4.0. Advanced Engineering Informatics, **2019**, 39, 1-13.

[14] Shavaleeva D.N., and Salimova A.I. Enterprise Architecture for Industry 4.0: Proposed Solutions and Production Data for TOFAF-Based Modeling. Information Innovative Technologies Founders, **2019,** 1(1), 94-101.

[15] Kornyshova E., and Barrios, J. Exploring the Impact produced by the Industry 4.0 on Enterprise Architecture Models. In: 13th International Conference on Research Challenges in Information Science (RCIS), Brussels, Belgium, 2019, pp. 1-6, doi: 10.1109/RCIS.2019.8877026.

[16] Kornyshova E., and Barrios, J. Industry 4.0 Impact Propagation on Enterprise Architecture Models. Procedia Computer Science **2020**, 176, 2497-2506.

[17] Paiva, M., Vasconcelos, A., and Fragoso, B. Using Enterprise Architecture to Model a Reference Architecture for Industry 4.0. In: Proceedings of the 22nd International Conference on Enterprise Information Systems (ICEIS 2020) 2020, 2, 709-716, DOI: 10.5220/0009194307090716.

[18] Pivoto, G.S., de Almeida, LF.F., da Rosa Righi, Rodrigo Rodrigues, J.J.P.C., and Lugli, A.B.; Alberti, A.M. Cyber-physical systems architectures for industrial internet of things applications in Industry 4.0: A literature review. Journal of Manufacturing Systems 2021, 58A, 176-192.

[19] Sharpe, R., van Lopik, K., Neal, A., Goodall, P., Conway, P.P., and West, A.A. An industrial evaluation of an Industry 4.0 reference architecture demonstrating the need for the inclusion of security and human components, Computers in Industry **2019**, 108, 37-44.

[20] Nowakowski, E., Farwick, M., Trojer, T., Häusler, M., Kessler, J., and Breu, R. An Enterprise Architecture Planning Process for Industry 4.0 Transformations. In: Proceedings of the 21st International Conference on Enterprise Information Systems (ICEIS 2019), Heraklion, Greece, 2019, 572-579, DOI: 10.5220/0007680005720579.

[21] Ilin I., Levina A., Borremans A., and Kalyazina S. Enterprise Architecture Modeling in Digital Transformation Era. In: Murgul V., Pukhkal V. (eds) International Scientific Conference Energy Management of Municipal Facilities and Sustainable Energy Technologies EMMFT 2019. EMMFT 2019. Advances in Intelligent Systems and Computing, 2021 Vol. 1259, Springer, Cham. https://doi.org/10.1007/978-3-030-57453-6_11

[22] Theorin, A., Bengtsson, K., Provost, J., Lieder, M., Johnsson, C., Lundholm, T., and Lennartson, B. An event-driven manufacturing information system architecture for Industry 4.0. International Journal of Production Research **2017**, 55(5), 1297-1311.

[23] Kitstios, F., and Kamariotou, M. Business strategy modelling based on enterprise architecture: a state-of-the-art review. Business Process Management Journal **2019**, 25(4), 606-624.

[24] Nordal H., and El Thalji I. Modeling a predictive maintenance management architecture to meet industry 4.0 requirements: a case study. Systems Engineering **2021**, 24, 34–50. https://doi.org/10.1002/sys.21565

[25] Tbaishat, D. Business process modelling using ARIS: process architecture Library Management 2017, 38(2/3), 88-107.

[26] Tbaishat, D. Process architecture development using Riva and ARIS: comparative study. Business Process Management Journal **2018**, 24(3), 837-858.

[27] Petrasch, R., and Hentschke, R. Towards an Internet-of-Things-aware Process Modeling Method - An Example for a House Suveillance System Process Model. In: 2nd Management and Innovation Technology International Conference (MITiCON2015), Bangkok, Thailand, 2015.

[28] Feldmann, S., Herzig, S.J.I., Kernschmidt, K., Wolfenstetter, T., Kammerl, D., Qamar, A., Lindemann, U., Krcmar, H., and Paredis, C.J.J.; Vogel-Heuser, B. Towards Effective Management of Inconsistencies in Model-Based Engineering of Automated Productions Systems. IFAC-Papers Online **2015**, 48(3), 916-923.

[29] Strang, D., and Anderl, R. Assembly Process driven Component Data Model in Cyber- Physical Production Systems. In: Proceedings of the World Congress on Engineering and Computer Science 2014 Vol II on IAENG, San Francisco, USA, 2014.

[30] Duque S.E., and El-Thalji I. Intelligent Maintenance Maturity of Offshore Oil and Gas Platform: A Customized Assessment Model Complies with Industry 4.0 Vision. In: Liyanage J., Amadi-Echendu J., Mathew J. (eds) Engineering Assets and Public Infrastructures in the Age of Digitalization. Lecture Notes in Mechanical Engineering, 2020, Springer, Cham. https://doi.org/10.1007/978-3-030-48021-9_73

[31] Gkotsis I. et al. Securing the European Gas Network, the Greek Business Case. In: Akhgar B., Kavallieros D., Sdongos E. (eds) Technology Development for Security Practitioners. Security Informatics and Law Enforcement, 2021, Springer, Cham. https://doi.org/10.1007/978-3-030-69460-9_21

[32] Nguyen, T., Gosine, R.G. and Warrian, P. A Systematic Review of Big Data Analytics for Oil and Gas Industry 4.0. IEEE Access 2020, 8, 61183-61201, doi: 10.1109/ACCESS.2020.2979678.
[33] Panayiotou N.A., Stavrou V.P., Stergiou K.E. Identifying Key Business Processes that Can Benefit from Industry 4.0 in the Gas Sector. In: Lalic B., Majstorovic V., Marjanovic U., von Cieminski G., Romero D. (eds) Advances in Production Management Systems. The Path to Digital Transformation and Innovation of Production Management Systems. APMS 2020. IFIP Advances in Information and Communication Technology, 2020, vol 591 Springer, Cham. https://doi.org/10.1007/978-3-030-57993-7_42
[34] Montanus, M. Business Models for Industry 4.0: Developing a Framework to Determine and Assess Impacts on Business Models in the Dutch Oil and Gas Industry, 2016. [accessed 26/10/2021] Business Models for Industry 4.0: Developing a Framework to Determine and Assess Impacts on Business Models in the Dutch Oil and Gas Industry | Semantic Scholar]
[35] Khan, W. Z., Aalsalem, M. Y., Khan, M. K., Hossain M. S., and Atiquzzaman, M. A reliable Internet of Things based architecture for oil and gas industry In: 2017 19th International Conference on Advanced Communication Technology (ICACT), 2017, 705-710, doi: 10.23919/ICACT.2017.7890184.
[36] Akoum M., and Blum V. Enterprise Architecture: A Pillar in an Integrated Framework to Measure the Internal Control Effectiveness in the Oil & Gas Sector. In: Baghdadi Y., Harfouche A. (eds) ICT for a Better Life and a Better World. Lecture Notes in Information Systems and Organisation, 2019, vol 30. Springer, Cham. https://doi.org/10.1007/978-3-030-10737-6_23
[37] Nisfiani E, Radja Brojas, M. and Hastomo, W. Designing an Information System Integration Enterprise Architecture with the TOGAF Framework in the Oil and Gas Business Unit Case Study: PT PWS. Seminar Nasional Teknologi Informasi dan Komunikasi STI&K 2020, 4(1), 289-301.
[38] Panayiotou N.A., Stergiou K.E., Stavrou V.P. (2019) Development of a Modeling Architecture Incorporating the Industry 4.0 View for a Company in the Gas Sector. In: Ameri F., Stecke K., von Cieminski G., Kiritsis D. (eds) Advances in Production Management Systems. Towards Smart Production Management Systems. APMS 2019. IFIP Advances in Information and Communication Technology, vol 567. Springer, Cham. https://doi.org/10.1007/978-3-030-29996-5_46
[39] Li, H. and Williams, T.J. Some extensions to the Purdue Enterprise Reference Architecture (PERA): I. Explaining the Purdue architecture and the Purdue methodology using the axioms of engineering design. Computers in Industry **1997**, 34(3), 247-259.
[40] Gonzalez-Lopez, F. and Bustos, G. Business process architecture design methodologies – a literature review. Business Process Management Journal **2019**, 25(6), 1317-1334.
[41] Zhou, Z., Zhi, Q., Morisaki, S. and Yamamoto, S. A Systematic Literature Review on Enterprise Architecture Visualization Methodologies. IEEE Access 2020, 8, 96404-96427, doi: 10.1109/ACCESS.2020.2995850.
[42] Gorkhali, A. and Da Xu, L. Enterprise Architecture: A Literature Review. Journal of Industrial Integration and Management **2017**, 2(2), 1750009-1-50.
[43] Hizam-Hanafiah, M., Soomro, M.A., and Abdullah, N.L. Industry 4.0 Readiness Models: A Systematic Literature Review of Model Dimensions. Information **2020**, 11, 364. https://doi.org/10.3390/info11070364
[44] Aliee, F.S., Kashfi, H., and Farahani, B. The Evolving Enterprise Architecture: A Digital Transformation Perspective. In: Proceedings of the International Conference on Omni-Layer Intelligent Systems (COINS '19). Association for Computing Machinery, New York, NY, USA, 2019, 179–183. DOI:https://doi.org/10.1145/3312614.3312651
[45] Zachman, A.J. A Framework for Informational Systems Architecture. IBM Systems Journal **1987**, 26(3), 276 - 292.
[46] Ferrugento A., Rocha Á. Evolution of Methodological Proposals for the Development of Enterprise Architecture. In: Rocha A., Correia A., Costanzo S., Reis L. (eds) New Contributions in Information Systems and Technologies. Advances in Intelligent Systems and Computing, 2015, vol 353. Springer, Cham. https://doi.org/10.1007/978-3-319-16486-1_35
[47] The Open Group. The TOGAF Standard Version 9.2 Overview, [Online], 2018, Available: http://www.opengroup.org/togaf [accesed: 23 Nov 2018].
[48] Scheer, A.W. Architecture of Integrated Information Systems, Springer – Verlag: Berlin, 1992.

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APPENDIX

TABLE I.
Objects Dictionary

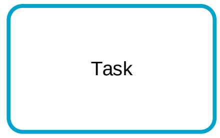
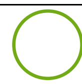
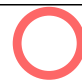
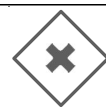
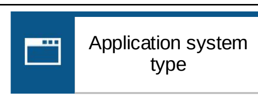
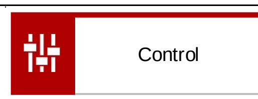
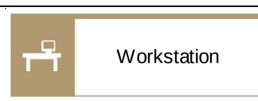
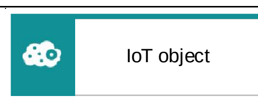
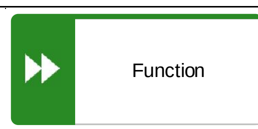
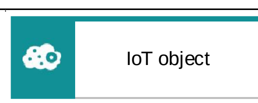
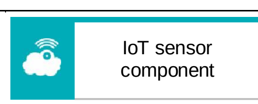
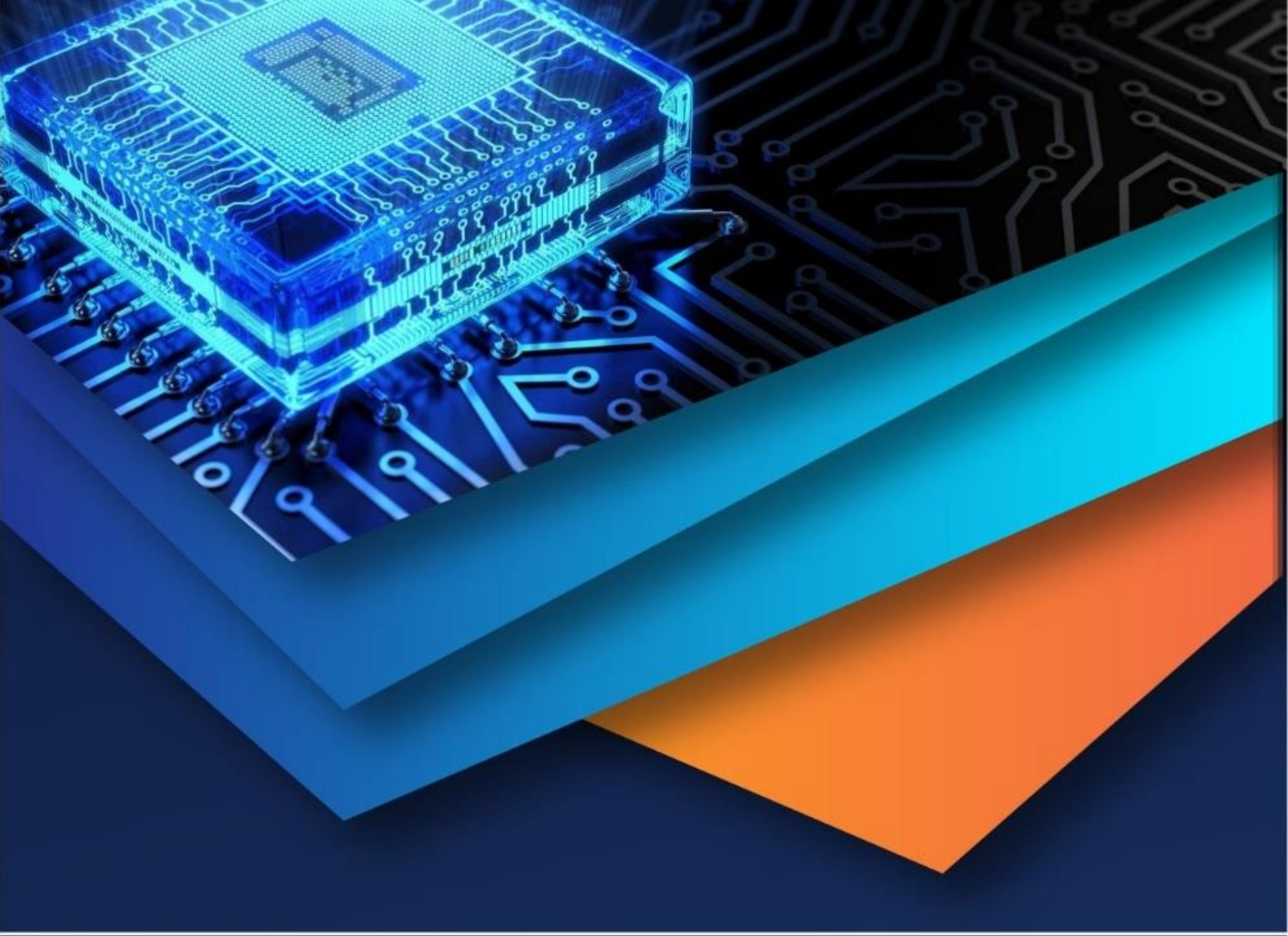
Diagram	Object	Object Description
Enterprise BPMN Collaboration Diagram	 Task	Depicts the activities that every participant executes in the process
	 Start event	It is the starting point/ trigger of the process
	 End event	It is the end of the process
	 Intermediate event	Depicts information, data or document sent among process participants during the process
		The first one is the XOR (exclusive) gateway, the second the AND (parallel) gateway, and the third the OR (inclusive) gateway
Function Allocation Diagram	 Application system type	Depicts the IS supporting the activities
	 Risk	Presents the risks connected with activities
	 Control	Shows how to mitigate risks
	 Workstation	Represents a specific place where an activity is executed
	 IoT object	Depicts specific equipment sensors needed for the insertion of automations in activities
IoT Context Diagram	 Function	Shows the steps and activities that should be followed by companies in order to implement DMAIC
	 IoT object	Depicts type of things that are elements of IoT
	 IoT sensor component	Depicts the sensors from which the data are collected

Diagram	Object	Object Description
	IoT actuator component	Depicts deices which take an action when specific data are provided by the sensors
	Security	Depicts the security protocol of the IoT objects communication
	Connectivity	Presents the protocol with which the IoT objects communicate and transfer data
Organizational Chart	Organizational unit	Depicts the performers of the tasks that should be carried out in order to achieve the business objectives (e.g., Departments, managerial positions)



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