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# A new decision support system for knowledge management in archaeological activities"☆

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ABSTRACT

The use of Information Technologies (IT) has today become an added value for appropriate decision making. This has contributed to improving the companies' strategies in the market. However, the full potential of these technologies in the relevant field of Archaeology has yet to be fully exploited. To contribute to reducing this gap, this paper presents a new and original design of a Process Maturity Framework for archaeological knowledge and data management which may be applied for high-level timely decision making, supported by an 'IT Governance' reference frame, in order to improve the quality and efficiency of the services provided by the Diagnostic, Prospecting, Monitoring and Excavation processes of the Preemptive Archaeology Program.

This new Process Maturity Model (PMM) takes the processes which are currently established in each phase of archaeological projects as its reference to improve information analysis, reports generation and support decision-making processes, as well as to manage and control the materials and context found in the field. This is achieved by emphasizing the use of the information required for future queries and projections, ensuring its' quality and integrity in order to generate reports more efficiently, whilst also allowing a more agile and timely decision-making process. Said information has been collected during the field and laboratory processes by analysing the proper application and management of the technology from an 'IT Governance' framework in companies which offer archaeological services.

The different phases of the implementation of the model designed, based in ITIL, since it is the most holistic of the current benchmarks in Technology Services Management, are shown by means of a hypothetical, yet real, application of the PMM in an Archaeology Consultancy firm. Thus, a set of basic parameters is initially established in order to implement a PMM. Then, a diagnostic on the processes and IT Service Management applied to each archaeological phase is performed. Afterwards, an evaluation of the current maturity level of the processes is carried out and, finally, the continuous improvement plan is described.



## 1. Introduction

A Capacity and Maturity Model (CMM) is a simplified representation of the reality. CMMs contain essential elements of effective processes [1]. In the 1930s, Shewhart carried out the first studies to reach 'process improvement' using his principles of statistical quality control. Those principles were refined as time passed and were updated with the intention of being applied to the software within IBM [2].

Maturity models are focused on improving the processes of an organization. They evaluate and analyse all the essential elements to take them from an immature process to a disciplined, mature and effective one. These key elements for evaluation can vary from company to company, depending greatly on the size, structure and activity of the company; thus it is not common to find two equal analyses, they are defined based on the company and not on any class of standards.

The use and application of an IT-based model will allow us to differentiate the current situation from the ideal situation, which leads us to propose a model incorporating the best practices of different standards. At the same time, it does not lead to evaluating which tools or methodologies we should apply within each organization. Focusing on the use of a Decision Support

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System (DSS) as the best alternative for the management of agile and timely information within the different processes, taking into account that different disciplines are involved in a transversal manner.

Currently, there are different models or guides that can help an organization to assess its real state of maturity in different aspects. Initially the Process Maturity Models (PMM) were designed for the software industry, but their application area is very diverse. Within Small and Medium Enterprises (SME) they can be used to assess the growth status of an organization or business processes and they allow constant monitoring at the moment of the organization's transit from the inconsistency of business processes to their optimum level of continuous improvement. Clearly they outline improvement strategies and identify the areas or factors where the organization should focus on. Although there are different models and adaptations to each specific process, within SME the recommended model for its evaluation is the Process and Business Maturity Model. It is adequate given the ease of implementation, does not require expert staff and has flexibility within their processes that allow an SME to evaluate the state of the organization within its four levels [3]. Hence it allows companies to assess the maturity of their business processes and the responsiveness of their organizations to process-based change [4]. Another remarkable example of the implementation of maturity models applied in the measurement of performance, evaluating the need to have adequate performance measurement systems to support business development through the availability of useful and reliable information leading to the correct development of improvement plans can be found in [5].

We will focus on the evaluation of technological processes within an Archaeology Consultancy firm. Although real, the application illustrated is in fact fictitious.

Archaeology in Colombia is a branch of Anthropology that bases its work on the interpretations that are made of the data collected in the field work and the previous theoretical investigations. There are four types of processes in the field within the preventive archaeology programs: Diagnostic (DG), Prospecting (PR), Monitoring (SG) and Excavation (EX), and crucial information is gathered in all of them to develop knowledge about the communities that preceded us. The materials found allow for hypotheses to be postulated about the changes of the human being, so their study, classification and value is of great importance and relevance, as are the decisions that are made regarding them and which enable their safeguarding, without affecting the schedule of civil constructions where the Preventive Archaeology Plan (PAP) is immersed [6].

In Colombia, IT Management within Archaeology Service Companies has been limited to the provision and administration of the infrastructure to support these processes, collecting the information that is used for the analysis and the formulation of hypotheses about the findings. Currently, the management and control of the information compiled during the processes defined within archaeological projects (material culture, soil analysis, topography, and specially both field and laboratory data) are done manually and are too time consuming. This makes it very difficult to rapidly unify all the information about the projects that are being carried out and the archaeological objects that are found.

Therefore this paper reports in an original way the results obtained during the activity of research and analysis of the processes of an Archaeology Consultancy firm, and is structured as follows: first, in the second section, the concepts of the archaeological phases and projects that have applied systems for information analysis are presented. In Section 3 the proposed methodology for the creation and implementation strategy of the maturity model is described. Section 4 is devoted to present the results obtained from the proposed maturity model and, finally, in Sections 5 and 6 the results are discussed and the main conclusions are pointed out respectively.

## 2. Preliminaries

The originality and novelty of the subject recommends a brief review of the main concepts and advances on the same, which is what the rest of this section focus on.

### 2.1. Archaelogical phases

The preventive archaeology programs are developed in the phases of Diagnostic (DG), Prospecting (PR), Monitoring (SG) and Excavation (EX). A description of the methodological guidelines that ensure that they meet criteria of technical efficiency, scientific quality, proper management of assets and social responsibility is presented below.

### 2.2. Diagnostic (DG)

This phase includes the collection of previously existing information, analysis and bibliographic interpretation, as well as dialogue with the inhabitants of the area and private collections. In this phase, the landscape elements that help to characterize the area archaeologically are also identified. This characterization is structured into three levels: low, medium, or high potential; according to the level of ancient anthropic activity that would be expected to be evident. This stage is optional and does not require the request for Authorization of Intervention from the Archaeological Heritage before the ICANH in Colombia.[1]

### 2.3. Prospecting (PR)

Prospecting is a technique that seeks to obtain the greatest amount of archaeological information from a given area, handling a level of specific analysis capable of creating and/or testing hypotheses [7]. The methodological tool, of a non-destructive nature, is fundamental in the identification of archaeological evidence.

Different types of Prospecting are applied according to the investigative criteria. Extensive, intensive, extensive plus intensive prospecting, probabilistic sampling and directed sampling. Each one is defined according to the size of the area to be surveyed. Within each process, specific areas are selected in which surveys based on statistical patterns are carried out [8].

The factors that are not directly controlled by the archaeologist are generally related to the natural characteristics of the terrain and the archaeological records [9]. The fundamental issue to be addressed is the degree of certainty to identify whether there are archaeological contexts and being able to perform thorough analyses. While it is true that the results need not always be positive, the identification itself should be, especially the association of the corporate and scientific environments.

### 2.4. Excavation (EX)

The result of the excavation will consist in acquiring all the entities that are entered in the stratigraphic record. Within the excavation phase, the defined archaeological zone is intervened. The purpose of the archaeologist is to obtain associated contexts, i.e. a set of objects that are arranged in relation to each other, in such a way that they identify a social activity carried out in a given time [10].

[1] Decree 763(2009), artícle 55, paragraph 4°.

### 2.5. Monitoring (SG)

According to the infrastructure project that is carried out within the area of interest, the spoil removal works are monitored to complement or locate archaeological areas of interest that had not been identified in the previous phases. This process consists in the permanent support and supervision of the task of manual or mechanical spoil removal.

### 2.6. Computational Archaeology

> *"Archaeology, as the interdisciplinary science that it is, acquires from computing that which is related in order to achieve its objectives"* [11].

Computer science within the archaeological process is consistent with the research method and constant search that Archaeology handles. Computer science allows the use of different methods of collecting and analysing the data obtained in its various phases.

### 2.7. Computerization technologies

In recent times, IT have been used in different fields of knowledge to analyse information. Specifically, IT has been applied in archaeology to specific topics such as spatial position through cartography and 3D design of the materials found.

Certain tailor-made applications have allowed proper management of the information collected, such as ARIADNE [12] and ArcheoData [13]. Moreover, there have also been some conferences that have facilitated sharing all the technological developments in archaeology, such as the "Computer Applications & Quantitative Methods in Archeology" (Carpentiero and Cirillo, n.d.; [14]. In Spain, the Institute of Altoaragoneses Studies and the Regional Parliament of Huesca developed the 'Aragonese Cultural Heritage Information System' (SIPCA, in Spanish). A database was designed at the University of the Andes, in Venezuela, for the inventory of archaeological sites and movable and immovable archaeological heritage assets of the state of Mérida.

### 2.8. Decision support systems (DSS)

A decision support system is a Business Intelligence tool focused on analysing the data of an organization. Provides support for the decision-making process. A DSS is a tool that contains dynamic, flexible and interactive reports, manages very short response times, is integrated with any necessary system and has the entire history of the information [15].

The computerization process of the cultural goods sector has focused mainly on the aspects of cataloguing and those of geodetection. Within this process ArkeoKeeper arises, which focuses on the transversal management of information in the field of cultural heritage management, adding other disciplines on existing computer standards. ArKeoKeeper is a technical–scientific computer system dedicated to the integrated management of the subsequent activities of the Excavation phase [16]. ArkeoKeeper can be classified as a DSS with its basic structures that allow defining and expediting decision-making processes.

One of the uses of a DSS is in electronic commerce, despite being two lines that emerged in parallel, it has been identified that they can be complemented to bring greater advantages and added value to their customers. Some examples of this are auction sites, customer websites and virtual stores for employees. The DSS supports the activities of electronic commerce and facilitates the support for decision making [17]

Another alternative example is the use of DSS for the allocation of human resources to teams of software projects, the tool supports an assignment model that evaluates the profiles, roles and training of the team as a whole. Ampuero and de la Peña [18].

## 3. Methodology. A proposal for a Process Maturity Model for Archaeology.

### 3.1. Initial conditions to be validated within the consultancy firm

The PMM proposed below has been designed based on the guidelines provided by ITIL as the best practices focusing on continuous improvement, along with the model generated in [19].

Prior to starting with the proposed model, it is important to mention a series of recommendations that an Archaeology Consultancy should keep in mind to ensure that the model is applied with the highest possible quality. Consultancy firms should bear in mind that the recommendations are a guide used to assess and improve the DG, PR, SG and EX processes within the PMA:

- Have an infrastructure and a base technology platform: Computing equipment for each professional. Data network infrastructure (physical and virtual). Hardware platforms. Internet platforms. Data management and storage. Operative Systems (OS) platforms. Software Applications
- Have a quality management system certification, if the company has already incurred in these procedures. At the time of the evaluation it is guaranteed that the processes have already been reviewed and optimized and are focused on continuous improvement.
- Assemble a task force to carry out the implementation of the model, in which the general manager, the project managers and the personnel in charge of IT take part, as well as a consultant with a solid knowledge of ITIL, if possible with direct experience in its implementation.
- Train the personnel involved. It is unfeasible to depend on advisors in the long term, the success of the model as a tool for continuous improvement will depend on all stakeholders being unbiased in transmitting the benefits and evaluation methods of the three dimensions that make up the model.
- Involve the managerial, administrative and archaeological staff from the very start of the project. The implementation of the model ends in the application of an improvement plan that will affect all the stakeholders involved in the projects. If they are included from the very beginning, any resistance to change is minimized and awareness of the potential benefits is raised.

### 3.2. Description of the proposed model

Considering the choice we made regarding the reference frame (ITIL), we will adapt the metrics defined in the 'Continuous Improvement of the Service' to our PMM, which is composed of three dimensions, Processes, Services and Technology. Each dimension has the following characteristics:

- The 'Process' dimension, whose objective is to provide an IT management that includes policies and a framework (ITIL). It is defined by a set of activities that specify what the archaeology consultancy requires in order to achieve its objectives. Measure the performance and quality of IT service management processes.
- The 'Service' dimension is composed by all those services that the IT area offers to its customers-users and that support a specific activity of the business, whether they are management or support related. It also refers to all means that can generate value to the corporate community and, at the same time, facilitate the operation to obtain the results of the processes. It allows us to validate the performance of an 'End-to-End' service.

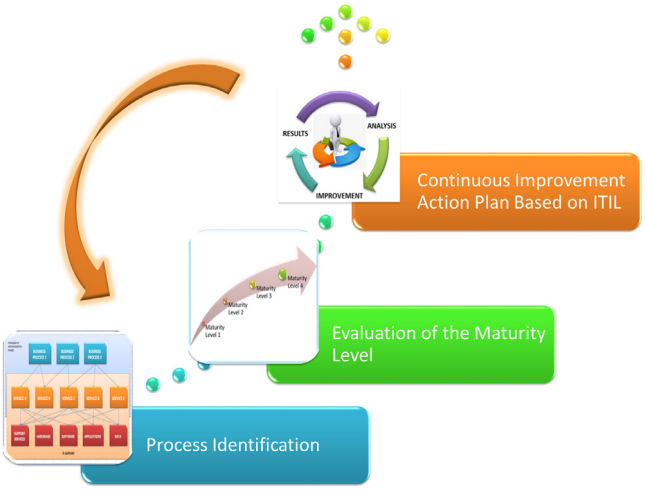


**Fig. 3.1.** Description of the Process Maturity Model.

- The 'Technology' dimension refers to the use of computational tools, information systems, infrastructure, processes, people and third parties in which all services are supported.

As can be seen, the model has a multidimensional approach that shows the interaction between the three dimensions: processes, services and technology; and which are necessary to align the changing IT services with the needs of the business. Additionally, it allows the identification and implementation of activities for continuous improvement, focusing on the quality of IT services within the DG, PR, SG and EX processes and improving their efficiency and effectiveness. Its objective is the delivery of value to the consultancy firms from an IT focus, ensuring the satisfaction of the Archaeology department and the administrative part. The latter is reflected in the availability and continuity of the services along with an increase in the consultancy firm's competitiveness through the application of more efficient and precise techniques, thanks to technology.

The proposed methodology initially selects the business processes that currently have a higher level of maturity, along with their subprocesses and activities, as shown in Fig. 3.1. For each process, the services (business and support) are identified according to the service categories predefined by the model and the technology used to provide them.

We will use the crossing of the three dimensions to measure the status of the Archaeology consultancy firm. On the one hand, we will validate the crossing between Processes vs. Services, which would allow us to identify the IT services that support the activities within each process to be evaluated and the degree of maturity. On the other hand, we shall evaluate the interaction of the three dimensions: Processes vs. Services vs. Technology: This would allow us to identify the degree of maturity globally, and also whether it is possible to guarantee the delivery of the services involved in each process.

For each dimension, a set of criteria is proposed to identify the level of maturity. A consultancy firm which has adopted all the practices included in a level is considered to have reached that level of maturity.

Finally, taking the information from the analysis on the interactions between the dimensions as the input, the results are evaluated in order to devise a plan of improvement actions based on ITIL. Thus, the consultancy firm, after developing the plan, will be able to measure its status again, turning this process into a cycle of continuous improvement.

### 3.3. Strategy to implement the Process Maturity Model

The PMM is designed to help the archaeology consultancy firms evaluate the level of maturity of the processes, services and the technology involved in the archaeological phases of the Preventive Archaeology Program in a three-dimensional way, and thus identify possible opportunities for improvement and put the most pertinent strategies in place with the goal of reaching the desired level of maturity in each process.

In order to implement this model, a number of stages were defined, based on the Service Life-Cycle presented in the ITIL (ITIL, 2011). These stages are presented below:

1. Initial Validation of the conditions to implement the model.
2. Maturity Analysis of the Process dimension.
3. Maturity Analysis of the 'Processes vs. Services' dimension.
4. Maturity Analysis of the 'Processes vs. Services vs. Technology' dimension.
5. Data Analysis of the three previous Maturity Analyses.
6. Design of a continuous improvement plan based on the ITIL's best practices.

## 4. Results: Hypothetical application of the Process Maturity Model in an Archaeology consultancy firm.

### 4.1. Consultancy selection

Once the PMM is established, a test was made regarding the relevance of the model on the Archaeological Consultancy firm 'GiArQ', a Colombian company with a long history of developing archaeological projects in Colombia. It is an organization that provides services to private and public entities, most notably to Ecopetrol, the company in charge of the extraction and commercialization of crude oil, both directly and through outsourcing companies working for Ecopetrol. The company name is hypothetical but does describe a real company, and is used to frame the requirements that are optimal for the application of the model.

This consultancy firm possesses numerous quality certifications and manages a comprehensive HSQE management system, which is why it was selected to implement the maturity model, since this guarantees that its processes have already been validated. In addition, this evaluation aims to demonstrate the efficiency of the use of ICTs in any medium to optimize resources and provide higher quality services.

The data hereby used are the product of professional archaeological work in the Project 'Boranda I y II, Rionegro, Santander [20], developed in a company with the previously mentioned characteristics.

### 4.2. Initial validation of conditions to implement the model

The minimal conditions necessary for a consulting firm to be adequate for the implementation of the model were validated, applying a previously proposed check-list, of the minimum requirements.

### 4.3. Maturity analysis of the process dimension

In order to carry out the Maturity Analysis on the Process dimension, the following steps were taken:

1. The information gathered from the processes (DG, PR, SG and EX) and the subprocesses was identified and recorded in the format "Maturity Analysis of the Process Dimension".
2. Once the subprocesses have been defined, the activities carried out in each of them were specified.

**Table 4.1**
Processes dimension. levels of maturity [19].

| Maturity level | Description | Grade |
|---|---|---|
| Execution of strategic activities | The archaeologist executes the activities of the subprocesses from group A. | 1 |
| Execution of complementary activities | The archaeologist executes the activities of the subprocesses from groups A and B. | 2 |
| Execution of desirable activities | The archaeologist executes the activities of the subprocesses from groups A, B and C. | 3 |
| Execution of IT-supported activities | Executes the activities of the subprocesses from groups A, B and C. All the activities are IT-supported and with their services clearly identified. | 4 |

**Table 4.2**
Analysis of results, diagnostic and improvement plan.

| 3-Dimension analysis | | |
|---|---|---|
| Result | Diagnostic | Improvement plan |
| 1 | Basic level with great opportunities for improvement. It needs to ensure the fulfilment of the customers' requirements, in order to secure the strategic objectives. | Design a strategic plan to standardize the services. |

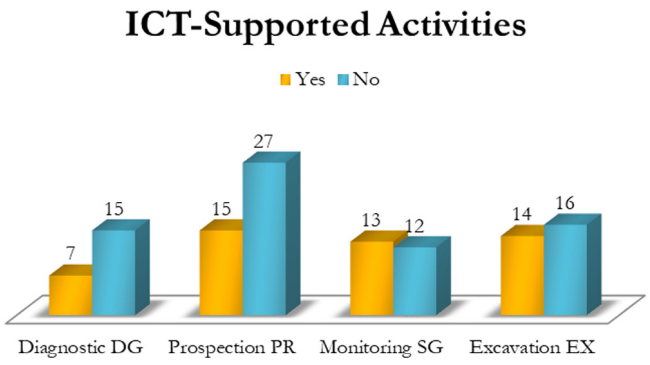


**Fig. 4.1.** Analysis of the activities with ICT support by process ('GiArQ S.A.S.').

3. The activities carried out by the consultancy firm were compared with those defined by the model in the format "Maturity Analysis of the Process Dimension". The objective was to determine what level the consultancy firm was at, based on the levels of maturity of the process dimension, shown in Table 4.1.
4. Finally, the proportion of activities that have ICT support within each process is analysed, showing that the percentage of activities without general support is higher than that of those that do have support. Additionally, the most affected process is PR, with 40% of its activities without ICT support, as Fig. 4.1 shows

### 4.4. Maturity analysis of the 'Processes vs. Services' dimension.

To evaluate the 'Processes vs. Services' dimension, the following activities were performed:

1. The IT service categories that support each of the resulting activities in the format "Maturity Analysis of the Process Dimension" were identified based on the service categories defined in the model.
2. The category of business service and support that is used in the execution of each activity was identified and included in the format of "Maturity Analysis of the Dimension of Processes vs. Services".
3. The services are recorded and then reviewed according to the support they have in each activity, in the format "Maturity Analysis of the Process Dimension". The evaluation is carried out to determine in which level the consultancy firm is placed.

### 4.5. Maturity analysis of the 'Processes vs. Services vs. Technology'

Once the maturity analysis of the 'Processes vs. Services' dimension was performed, the Technology dimension was included to make a cross-analysis among the three dimensions. This allowed to identify the level of maturity of the IT area to guarantee the provision of services in each process.

The level of maturity was evaluated from the perspective of the 4P's that participate in the provision of each service, in direct relation with each of the activities. This measurement was recorded in the "Process Maturity Analysis vs. Services vs. Technology Analysis" Format.

### 4.6. Results analysis from the evaluation of the 3-dimension maturity model.

#### 4.6.1. Processes dimension

After carrying out the validation of the activities executed in each process, it was determined that all the activities included in the "Maturity Analysis Format of the Process Dimension" were being applied. According to Table 4.1, Levels Maturity for the Process Dimension is located at the Consultancy firm in Maturity Level 3, because despite carrying out all the activities, not all of them have IT support.

#### 4.6.2. 'Processes vs. Services' dimension

Once the examination of the 'Processes vs. Services' Dimension was carried out, the final evaluation was performed for each process. It is important to bear in mind that in almost all the categories, except for Support and Quality of Service, levels of 2 and 3 were obtained, yet the final level of the Consultancy firm is defined as 1.

The scores obtained after the analysis of the DG vs. Services process are visualized in Fig. 4.2, PR process vs. Services in Fig. 4.3, SG vs. Services Process in Fig. 4.4 and finally the analysis of the EX Process vs. Services in Fig. 4.5.

When analysing the radar graphs, we can observe that within all the processes, the IT services that have been most structured are those related to general computer services and computer security. While the fact that the basic services are properly covered is a clear advantage, the same level of regulation and documentation must be achieved for all services.

**Table 4.3**
Estimated work days by specialist for the archaeological project.

| WORK TIME SHEET PROFESSIONAL WORK TEAM | 1 | | 1 | | 2 | | 2 | | 2 | | 3 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ACTIVITIES BREAKDOWN | Archaeology Director (Coordinator) | | Archaeologist 1 | | Archaeologist 5 | | Archaeologist 6 | | Archaeologist 7 | | IMS Specialist | |
| | Office | Field | Office | Field | Office | Field | Office | Field | Office | Field | Office | Field |
| PRELIMINAR ACTIVITIES WITH ECOPETROL | 3 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| DIAGNOSTIC (DG) | 4 | 0 | 4 | 0 | 4 | 0 | 4 | 0 | 4 | 0 | 4 | 0 |
| FIELD ACTIVITIES | 0 | 75 | 0 | 61 | 0 | 61 | 0 | 61 | 0 | 61 | 0 | 0 |
| ARCHAEOLOGICAL PROSPECTING (PR) | 15 | 22 | 26 | 11 | 26 | 11 | 26 | 11 | 26 | 11 | 8 | 0 |
| ARCHAEOLOGICAL MONITORING (SG) | 20 | 30 | 30 | 30 | 0 | 30 | 0 | 30 | 0 | 30 | 20 | 0 |
| ARCHAEOLOGICAL EXCAVATION (EX) | 20 | 20 | 30 | 20 | 0 | 20 | 0 | 20 | 0 | 20 | 20 | 0 |
| TECHNICAL SUPPORT DOCUMENTS FOR THE ARCHAEOLOGICAL MANAGEMENT PLAN'S REQUESTS | 27 | 3 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 2 | 0 |
| PROCESS ASSURANCE AND FINAL DELIVERABLES CONTROL | 4 | 3 | 4 | 0 | 4 | 0 | 4 | 0 | 4 | 0 | 0 | 0 |
| PROFESSIONAL WORK DAYS PER LOCATION | 56 | 78 | 36 | 61 | 36 | 61 | 36 | 61 | 36 | 61 | 14 | 0 |
| TOTAL PROFESSIONAL WORK DAYS | | 134 | | 97 | | 97 | | 97 | | 97 | | 14 |
| TOTAL FIELD WORK DAYS | | 78 | | 61 | | 61 | | 61 | | 61 | | 0 |
| TOTAL ESTIMATED WORK DAYS | 536 | | | | | | | | | | | |

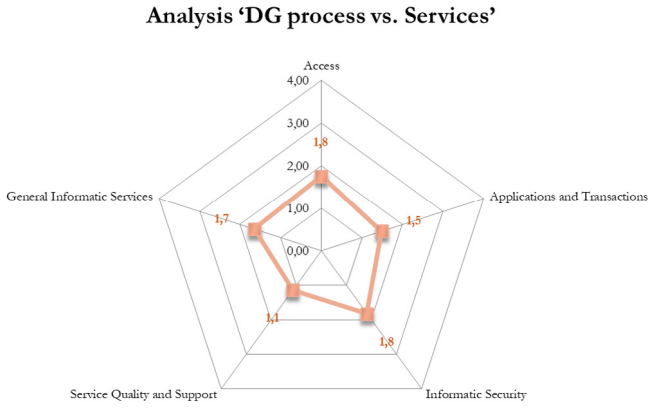


**Fig. 4.2.** Analysis of DG Process vs. Services.

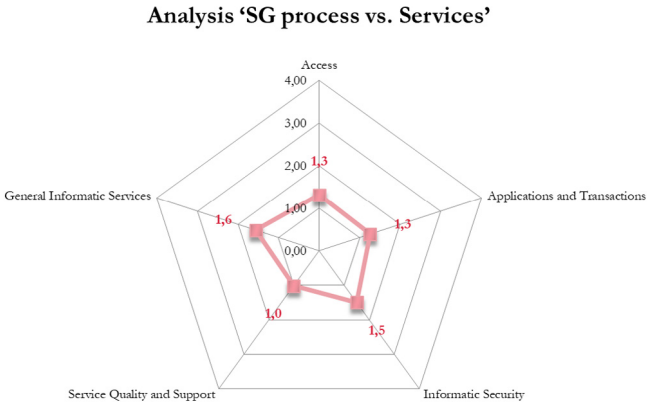


**Fig. 4.4.** Analysis of SG Process vs. Services.

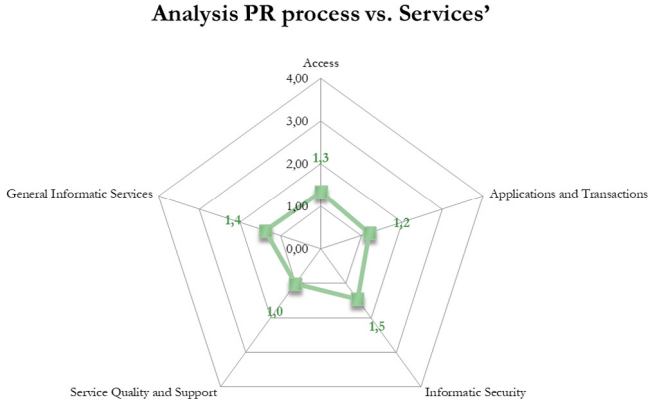


**Fig. 4.3.** Analysis of PR Process vs. Services.

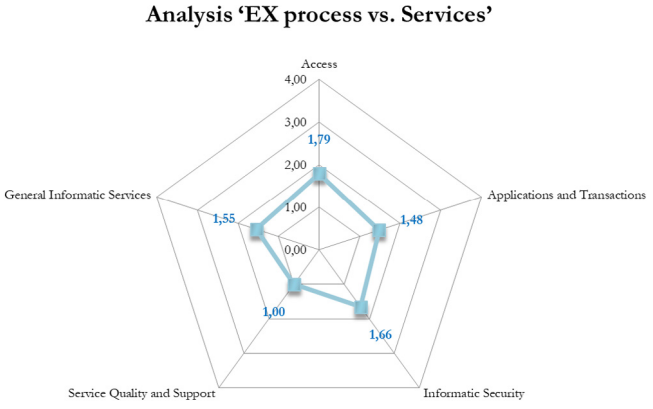


**Fig. 4.5.** Analysis of EX Process vs. Services.

*4.6.3. 'Processes vs. Services vs. Technology' dimension*

Once the assessment of the 'Processes vs. Service' Dimension for the DG, PR, SG and EX processes was carried out, the final evaluation was performed for each process. The final maturity level of the Consultancy firm is established as 1. The scores obtained after the 'DG vs. Services' analysis are given in Fig. 4.6, 'PR vs. Services' in Fig. 4.7, 'SG vs. Services' in Fig. 4.8 and finally the 'EX vs. Services' analysis in Fig. 4.9.

Taking a closer look at the radar graphs, we observe that the use of technology in the IT services used in each activity, whether

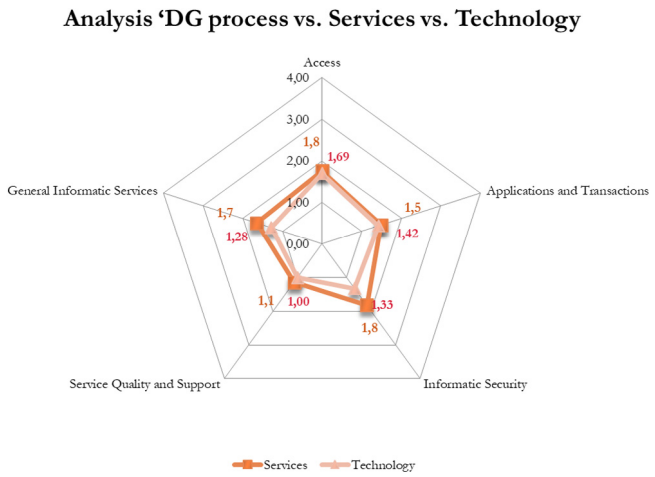


**Fig. 4.6.** Analysis of DG Process vs. Services vs. Technology.

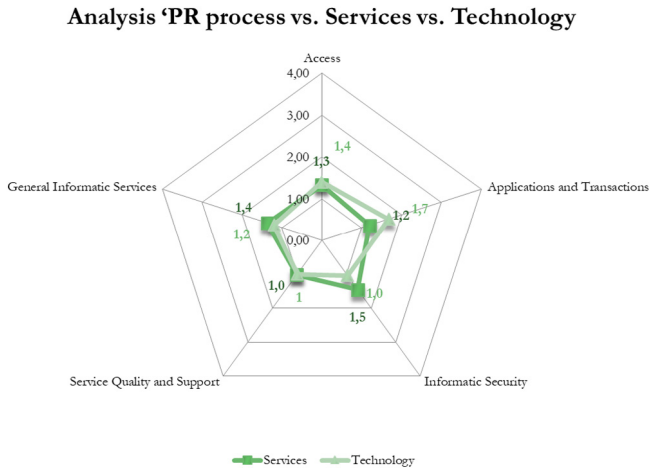


**Fig. 4.7.** Analysis of PR Process vs. Services vs. Technology.

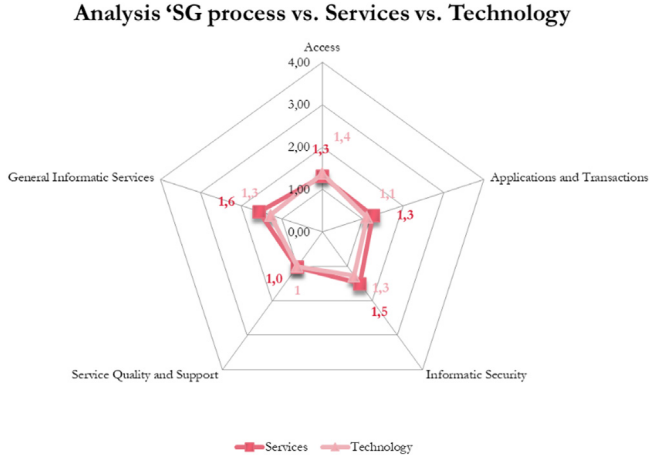


**Fig. 4.8.** Analysis of SG Process vs. Services vs. Technology.

it be support or business, is low compared to the defined and structured services that have the dimension of services.

After the analysis of the maturity level evaluation, we then show the relevant aspects and the points of improvement.

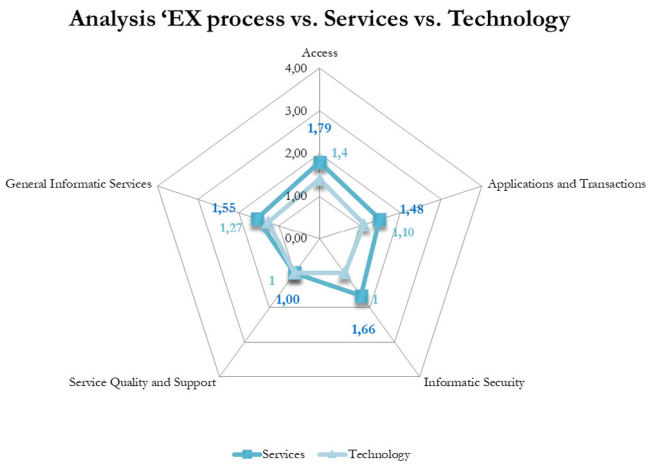


**Fig. 4.9.** Analysis of EX Process vs. Services vs. Technology.

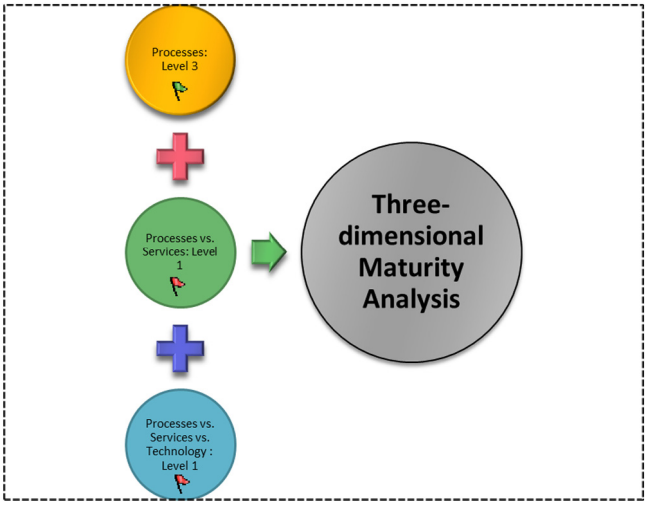


**Fig. 4.10.** Averages of the three-dimension maturity analysis.

**Table 4.4**
Estimated total cost of a 6-month archaeological project.

| Items | Colombian pesos (COP) | Euro (EUR) |
|---|---|---|
| Personnel | $ 211.496.181 | 64.066,78 € |
| Field trips | $ 296.517.359 | 89.821,53 € |
| Monitoring | $ 14.416.400 | 4.367,04 € |
| Complementary studies | $ 22.152.034 | 6.710,33 € |
| Consumables | $ 6.960.748 | 2.108,56 € |
| Total budget (before taxes) | $ 551.542.722 | 167.074,24 € |
| Taxes | $ 115.823.972 | 35.085,59 € |
| Reimbursable expenses | $ 20.610.094 | 167.074,24 € |
| Total budget (after expenses) | $ 667.366.694 | 202.159,83 € |
| **Total cost of the project** | **$ 687.976.788** | **369.234,08 €** |

The individual maturity levels were obtained based on the value assigned to the maturity level in the dimensional assessment. In conclusion, for the consultancy firm 'GiArQ', the final level of maturity of its three dimensions is determined as: Level 3 for Processes, Level 1 for Services and Level 1 for Technology, as shown in Fig. 4.10.

Therefore, for the consultancy firm 'GiArQ', the three-dimensional maturity analysis is 1, and thus the PMM allows us to identify the next step to implement, which is: (see Table 4.2).

**Table 4.5**
Reduction of times and costs by applying the proposed improvement plan.

| Activities | Time (in days) | | Estimated days after the Plan | Average daily cost | Cost Reductions |
|---|---|---|---|---|---|
| | Actual | Reduction with improvement plan | | | |
| Logistic Update | 3 | 2 | 1 | 112,9 € | 225,7 € |
| Data collection on the field | 20 | 7,5 | 12,5 | 112,9 € | 846,5 € |
| Material Classification | 7,5 | 7,5 | 0 | 112,9 € | 846,5 € |
| Daily and Weekly Reports | 30 | 20 | 10 | 112,9 € | 2.257,4 € |
| Photografic Record Classification | 9,37 | 9,37 | 0 | 112,9 € | 1.057,6 € |
| Non-Intrusive Methodologies | 356 | 356 | 0 | 112,9 € | 40.181,7 € |
| **Total** | **425,87** | **402,37** | **23,5** | | **45.415,5 €** |

*4.6.4. Improvement plan in the archaeological consultancy firm*

Once all the components have been analysed and all the dimensions evaluated, we then outline the improvement plan for the Consultancy firm, which must contain the following points to implement:

1. Define the services as a means to deliver value to customers/users by providing the results they seek to achieve without the need to take specific risks and costs.
2. Establish a Configuration Management System (CMS), define a tool and database to manage the configuration information of the ICT services. It should contain the Configuration Management Database: register hardware, software, documentation and any aspect relevant to the ICT provision.
3. Consider the implementation of self-help management tools. This is a functionality that allows users to help solve their own difficulties in a cost-effective manner. It could have an interface that includes elements such as Frequently Asked Questions (FAQ).
4. Have a workflow engine, which allows processes such as the life cycle of incidents to be defined and controlled.
5. Implementation of 'remote support': from the service centre it should be possible to take control of the user's desktop, allowing to correct any errors in configuration or investigate a problem.
6. Incorporate Business Intelligence and Reporting tools, as a way to maximize the benefits brought by the correct and efficient analysis of the storage data.
7. Develop and control a database of known errors to store all the details of previous incidents and problems and their respective solutions. This should be to enable to provide rapid diagnosis and resolution of future incidents and problems.
8. Integrate business service tools with IT service management tools, in order to support business functions in the consultancy firm. Apply tools to manage archaeological information at any point of a projects' execution, allowing for timely and efficient decisions.
9. Establish a ticket system that helps to structure the support activities within the consultancy in a flexible manner.

*4.6.5. Cost reduction*

The cost of the activities, referring specifically to the total work time of the internal resources of the consultancy firm, was measured per day/professional based on their current salary. The estimated time for the Archaeological Management Plan (AMP) was designated to each activity according to the resources available, as can be seen in Table 4.3; and the total cost of the project is shown in Table 4.4.

After the implementation of the improvement plan, an improvement in times and costs within the AMP can be evidenced. As daily activities become more efficient, they will provide reduced operational times which, when analysed within the global project, will translate into economic benefits, as can be seen in Figs. 4.11 and 4.12.

In the improvement plan, we have detailed some crucial points within the processes:

- Logistics update: Optimize logistics times by having a database of information on services and personnel needed.
- Data collection in the field: Upload data from a terminal directly in the field.
- Material Classification: Daily classification of the information generated by the project, instead of classifying all materials at the end of the project.
- Daily and Weekly reports: Generate daily and weekly reports from the information system.
- Photographic Record Classification: Daily uploads of the records into the system, reducing overall classification time.
- Non-Intrusive Methodologies: Costs Reduction in terms of time, resources and personnel in several processes by applying remote dating techniques, such as using the magnetometer for the detection of archaeological material without altering the soil surface (see Table 4.5).

## 5. Discussion

The origin of this proposal arose from the need to evaluate the application of technology within archaeological processes, in search of an integral analysis of said processes and their costs. To do so, the focus is on the study and proposal of improving response times, as well as on the opportunities that said information brings for decision making. By identifying the need to

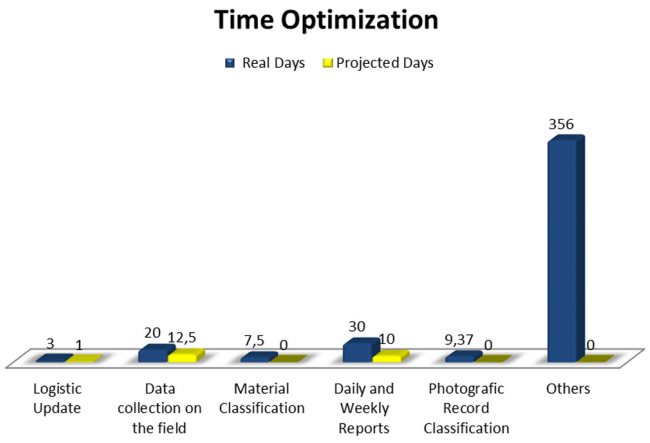


**Fig. 4.11.** Analysis of time reductions after applying the improvement plan.

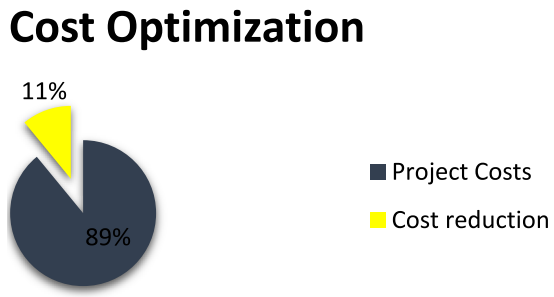


**Fig. 4.12.** Analysis of cost reductions after applying the improvement plan.

reduce costs within the projects, the aim is to demonstrate that it is possible to improve and reduce times and costs through the use of technology.

This initial proposal seeks to show the phases of the processes in which it is necessary to use technology, either information systems or tools that allow to speed up data processing.

The main problem lies in the absence of effective mechanisms to clearly define criteria for data management, processing and the generation of information, among others.

Although there are a series of processes within the consultancy firms where data management tools are applied, there are no standardized systems that allow to unify the processes, which would allow for timely decision making.

In the archaeological field, there are diverse approaches and data management models which can be applied in various scenarios as well as classification strategies, applications and methodologies related to the unification of data to produce and analyse information. However, no standards or guidelines were found that would allow the data collected by an archaeologist to be processed in the same way as that collected by another archaeologist in another company or project; this affects the integrity of the information between data management and report generation.

Thus, according to the results obtained we can analyse and discuss our model in terms of advantages and limitations as well as its practical implications. In this way, the proposed model explores the opportunity through a series of validations of the internal processes within the archaeology consulting companies, as well as the understanding of the different phases of the archaeological component.

The definition of the three dimensions made it possible to analyse each strategic point, focusing much more on the technology dimension, which allows for an evaluation of its' impact within the dimensions of processes and services.

The dimensions of processes allow for an analysis and evaluation of the impact of having well-structured internal processes. Within the proposal of the model it is possible to establish that by using the ITIL framework one can demonstrate the essential points for any company to effectively measure the performance and quality.

With regard to the application of the service dimension, it was possible to emphasize the importance of evaluating the concept of service, from whatever viewpoint established, since it must always be analysed in order to ensure the generation of value for the company.

Being a model with a multidimensional approach, we can consider analysing in any company the need to generate a plan for continuous improvement from three viewpoints. This enables us to continue at the forefront in the transformation of services, more specifically in the technological change we must face, and turn that into an ally for companies and for their growth.

The validity of the results allowed to highlight the role played by technology in the field of archaeology due to the savings observed in both the costs and the time within the execution of a project.

The result of the application of the model illustrates currents misconceptions regarding the use of technology and the need to integrate it into all processes that are carried out within the projects, right from the definition of the project through to the processing of the information, in order to achieve timely and efficient results.

## 6. Conclusions

Professional Archaeology cannot be a stranger to IT management. Its use has become fundamental for the analysis of the information obtained from an Archaeological Management Plan, applying the data analysis and management through the use of IT. This management is only as effective as the information that can be obtained from a longer and scientifically rigorous research. It is possible to obtain cleaner, clearer data with better projections in less time. It is also important to understand that making a comparative analysis of the time and cost of a project the archaeologist must wait for each phase to end to then make the report enabling the consultancy firm to decide on the next step. This implies a greater deal of work than if he or she had the information online, or if there were tools available that increase the probability of detecting findings and allow to make appropriate decisions in a timely manner.

The proposed PMM has allowed us to demonstrate the need for proper management of information technologies, for the implementation of an IT-governance that allows us to focus on the services provided in pursuit of business objectives. The long-term implications of the evaluation of IT processes are of the utmost relevance, since it will be on these evaluations that the continuous improvement plans will be based, always aiming to generate a value-chain in the decision-making process. Major archaeological projects ought to be the motor that, by their practice and experience, drives its implementation. All this implies the need to prioritize the protection of the archaeological information from the start of the project, thus ensuring its conservation and durability.

It is important that the improvement plan proposed as a result of the adoption of the PMM is included within the corporate standards and processes, to ensure its execution, as well as enhancing and facilitating the alignment between the IT objectives and the business objectives of the Consultancy firm.

As a final conclusion, we would like to add that, in addition to identifying general points when implementing the PMM, we have also evidenced the need to have an DSS that allows the

Archaeologist to use IT tools efficiently, as well as the inclusion of devices that allow the agility and efficiency in the input of information within said system. The applicability of IT tools cannot be deployed only at the organizational level, we must also analyse the possible uses in all the specific tasks across the phases of the project, where great savings can be made in terms of time, costs and resources.

As for further research regarding the PMM, it is proposed to integrate a holistic model that involves the key areas of the IT Governance specifically for the Archaeology consultancy firms.

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