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A methodology to manage organizational procedures through ontologies

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ABSTRACT The current organizations maintain relationships with actors, who intervene in the execution of key processes, presenting problems in the correct administration of the organization's procedures and the administration of a shared jargon, increasing the costs related to the procedures. The objective of this article is to present the MONPRO methodology, which supports the management of organizational procedures through the creation of specific ontologies of the organizational domain (including employee jargon and natural language), which allows a person with knowledge in computer science, without being an expert in ontology, create it. MONPRO is composed of five phases. The activities in each of them define a series of formats and diagrams that lead the ontology developer to break down the procedure and obtain the necessary resources to build the ontology. To test the methodology, the "Presentation and Defense of the Doctoral Thesis of the Carlos III University of Madrid (Leganés campus), Spain - UC3M" procedure was used. The results can, in general, have a positive impact in reducing costs for a company by their no longer requiring to hire experts to develop procedure ontologies, decreasing by approximately 43.8% the consultation time on procedures and establishing a common organizational language regardless of the jargon of a particular employee. In general, this research offers organizations the opportunity to improve operational procedures, giving their employees access to the standards of the organization using a natural language and its own jargon, increasing the quality of procedures.

INDEX TERMS Management of organizational procedures, ontology creation methodology, organizational jargon, organizational ontologies.

I. INTRODUCTION

Organizations today, digital in the main, are faced with the challenge that the information systems that support them do not take account of the fact that the different actors which interact with these information systems speak different languages or jargon, due to their formation, location of residence, social status, and culture, among others. This brings a series of problems, mainly in communication [2][3][4], which often lead to causing information systems not to function as they ought to, with this effect occurring both in academic [5][6][7] and industrial organizations [8][9].

As a result, solutions have been developed that, in particular knowledge domains and taking account of very specific problems, address the problems of communication with information systems through the use of ontologies. These ontologies have proven to be useful in alleviating the problem of jargon diversity when it comes to supporting the interaction of different actors with the information systems. Now the problem has moved to the cost and the difficulty involved in the creation of such ontologies, so that the different actors, either internal or external to an organization, properly use the procedures defined by the organization and which they are responsible for. This is very important for organizations since the good use of organizational procedures ensures the quality of the products and services the organization offers.

The challenge addressed in the present work is twofold: on one hand, to try to minimize the cost of developing the ontology a methodology for the creation of ontologies is proposed that supports the management of organizational procedures, while on the other, the problem of the construction and instantiation of the ontology is solved in an easy and efficient way, so that the different actors can use it transparently and in their natural language [10][11].

The following sections contain a description of the MONPRO methodology, its instantiation in a particular

procedure called "Presenting and Defending the Doctoral Thesis in the UC3M", implementation of an online system for the actors of the procedure, in such a way that they can obtain answers from the ontology created by natural language, and finally, the evaluation carried out to validate the capacity of the proposed methodology to create ontologies of organizational procedures and their support for operational decision making. To develop MONPRO, Niño was used as a reference [1]; This study defined a methodology for the creation of models.

II. STATUS OF THE QUESTION

Over the years, a great variety of methodologies for the construction of ontologies has emerged [12][13] [14][15][16][17][18][19][20],and some of them, based on the proposal by [21], have tried to structure knowledge in different areas, including the organizational context [11], allowing the latter, for example, to model an organizational ontology that adapts to the needs of organizations. However, a disadvantage of it is that it needs the intervention of experts to create instances of the proposed ontological model and does not provide for a transparent and practical use for the actors both internal and external to the organization, i.e. the final users of the procedures through the ontology.

A number of methodologies were found that work with organizational processes, such as the ontology for software maintenance based on management of software maintenance projects with a business process point of view [22][23] and the ontology for project management that encompasses the main processes, concepts and relationships of project management [24]. All these methodologies are oriented to the conceptualization of the processes and not to the procedures, which are closer to how to do things in the organization.

Other work related to the perspective of organizational processes are: A methodology for generating process models that consists of two phases, the conversion of a text to a process and the generation of ontology the structured and semantic process model called process ontology [25] and the generation of knowledge through a process-oriented ontology which improves the ontologies related to the topic, because it involves the responsibilities of manufacturing engineering and its planning [26]. This article focuses on the explanation of the planning process. Both studies exclude the step by step for the construction of the ontology and do not contribute to the development of the procedures but to the processes.

The methodology of Natalya and Deborah [21], one of the first to perform ontologies, is worth a mention. Because of its simplicity, practicality and ease of application, it forms the basis for the MONPRO approach, which seeks to allow people who are not experts in the development of ontologies and who have computer skills, to be able to apply it by obtaining an ontology for the management of organizational procedures in companies.

In summary, there is not yet a solution for solving the problem in natural language of the interaction of internal actors in the organization or external users of the procedures. That will be the challenge addressed in this work.

III. MONPRO METHODOLOGY

The methodology proposed in this paper is called MONPRO and consists of five phases, as shown in Fig. 1.

MONPRO has the following phases:

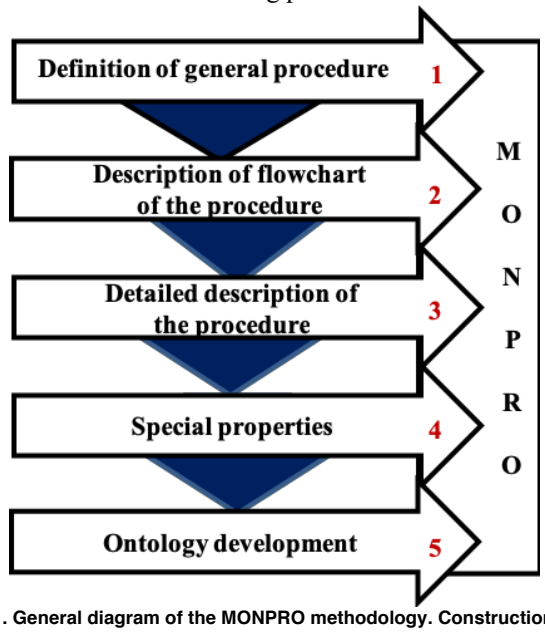

Fig. 1. General diagram of the MONPRO methodology. Construction of an ontology of organizational procedures in five phases.

1) **Definition of general procedure:** activities such as the description of the specific domain, use of the ontology, the documents associated with the procedure, the general concepts associated with the procedure and the consideration of other existing ontologies.
2) **Description of flowchart of the procedure:** this is a phase particular to MONPRO, which presents the specification of the activities of the procedure, the description of the direct relationships of the activities of the procedure, prior and consequent relationships, and activities parallel with each other, defining of the users and the general description of the domain.
3) **Detailed description of the procedure:** carries out activities such as the type of questions and answers to be solved by the ontology, definition of procedure concepts, basic associations of the conceptualization, detailed description of the concepts, relationships between concepts, hierarchy of concepts, and the relationship of properties.
4) **Special properties:** the rules to be considered and the important restrictions for the operation of the ontology are established here.
5) **Ontology development:** in which concept-individual association, label-individual equivalence, label-

relationship between concepts equivalence, implementation and its rules are made.

To exemplify the use of the MONPRO methodology, a specific case of ontology defined in the context of the Carlos III University of Madrid (Leganés campus), Spain, was used. The procedure called " Presentation and Defense of the Doctoral Thesis at UC3M" was used, which aims to "*Describe the necessary procedure for the presentation and defense of the doctoral thesis at UC3M, establishing activities, responsibilities and actors for the presentation, defense, deposit and evaluation of doctoral thesis".*

For MONPRO, an organizational procedure necessarily has activities, documents, formats, responsible users, relationships and descriptions, flowcharts and may or may not have instructions Fig. 2, Fig. 3.

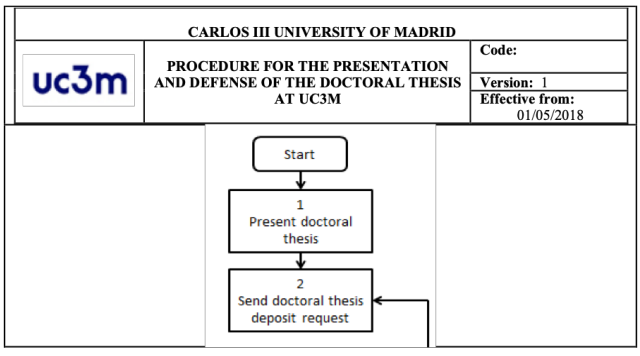

Fig. 2. Procedure for the Presentation and Defense of the Doctoral Thesis at UC3M. Part of the flowchart of the detailed procedure is shown.

Making the understanding of MONPRO and its monitoring at the time of implementation easier, in most of the activities of the defined phases small formats have been created that must be completed in order to be more precise and obtain the best results of the ontology it is desired to create.

CARLOS III UNIVERSITY OF MADRID

uc3m | PROCEDURE FOR THE PRESENTATION AND DEFENSE OF THE DOCTORAL THESIS AT UC3M | Code: | Version: 1 | Effective from: 01/05/2018

Item	Description of activity	Responsible	Support
1	**Present Doctoral Thesis** The Doctoral Student will prepare a doctoral thesis that should be edited and defended in Castilian Spanish or in languages normally used for scientific communication in its field of knowledge Note: In exceptional circumstances, the Rector, following the report of the School Managing Committee, may approve the editing and defense of the Doctoral Thesis in another language if there are academically justified reasons, ensuring on one hand the linguistic competence of the members of the Doctoral Thesis Assessment Tribunal and, on the other, its conformity according to the procedure that is established.	Doctoral Student Rector	UC3M Doctoral School Regulations, article 24

Fig. 3. Procedure for the Presentation and Defense of the Doctoral Thesis at UC3M. Part of the description of the detailed procedure is shown.

Below, each of the five phases proposed by MONPRO are presented, comprised of activities with formats associated with the development of each of these activities. For this article, only those considered relevant will be presented.

PHASE 1. DEFINITION OF GENERAL PROCEDURE

This phase includes the activities listed in Fig. 4, in which fields that must be completed to comply with the activity can be seen.

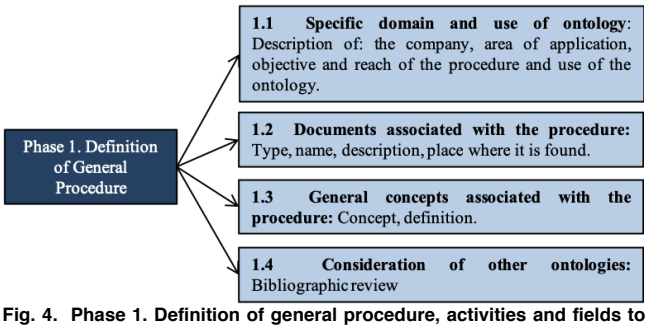

Fig. 4. Phase 1. Definition of general procedure, activities and fields to be resolved.

Activity 1.1. SPECIFIC DOMAIN AND USE OF ONTOLOGY

The specific domain of the ontology refers to the environment in which the procedure is applied. From this item, we seek to describe two important elements: the company in which the procedure was carried out and the area in which the procedure should be applied.

Activity 1.2. DOCUMENTS ASSOCIATED WITH THE PROCEDURE

This activity refers to those documents that make up the procedure either because they provide information, describe some of the activities, or are inputs for relevant information involved in the procedure, etc.. They can be of two types:

- **Legal documents:** constitute the legal basis of the procedure.
- **Related documents:** contain information that is received, processed, used as a basis, and/or is a requirement in defining the procedure.

Activity 1.3. GENERAL CONCEPTS ASSOCIATED WITH THE PROCEDURE

The concepts are definitions of terms that must be specified and that are directly related to the procedure and its activities.

It should be noted that the clearer the definition of the concept, the more understanding there will be of it, the area and the organization; in addition, other synonyms may be found that may not have been taken into account previously for the conceptualization of the procedure, which may be highlighted within the definition column.

Activity 1.4. CONSIDERATION OF OTHER ONTOLOGIES

This activity requires an analysis of other ontologies that exist to access the specific domain of knowledge represented in the organizational procedures. For this activity, the following must be taken into account:

- Review of the ontologies that have already been carried out in the organization.
- Bibliographic review to search ontologies of organizational procedures carried out in other organizations.
- Selection and alignment of the ontologies to be used, taking into account the general considerations already established for the particular procedure to which the ontology will be developed. This selection is made if favorable results were obtained in the reviews of the ontologies and the bibliography described above.

Applying this activity to the "Presentation and Defense of the Doctoral Thesis in the UC3M" procedure, the following is obtained:

On verifying the review of the existing ontologies in the UC3M, it was possible to establish that no ontology was found that represents the specific domain for the presentation and defense of doctoral theses. Additionally, after carrying out the bibliographic review to search for ontologies of organizational procedures that have been carried out in other organizations or institutions of higher education, no bibliography was found in this regard; therefore, the decision was made not to consider any ontology for this activity.

PHASE 2. DESCRIPTION OF THE FLOWCHART OF THE PROCESS

This phase includes the activities listed in Fig. 5, in which you can see the fields that must be completed to comply with the activity.

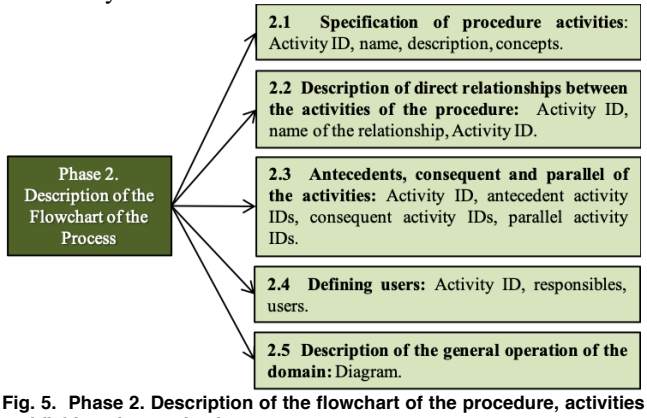

Fig. 5. Phase 2. Description of the flowchart of the procedure, activities and fields to be resolved.

Looking at projects related more to the objective of MONPRO [20] [23] [24], none takes into account the flow charts of the procedures to be represented in the ontology it develops. As such, this phase seeks to add a number of relationships not envisaged in other methodologies for developing ontologies, and that are exclusive of organizational procedures.

This phase will be developed showing some of the formats to fill out.

Activity 2.1. SPECIFICATION OF PROCEDURE ACTIVITIES

The activities represented in the flowchart of the procedure as rectangles are those that describe in a general way the functions to be performed step by step in the operations for which the procedure was defined. They contain concepts (nouns), which must be taken into account in the ontology through organizational jargon. The activity ID refers to the activity number in the flowchart and the concepts are all those nouns that appear in the description of the activity in the procedure.

Activity 2.2. DESCRIPTION OF DIRECT RELATIONSHIPS BETWEEN THE ACTIVITIES OF THE PROCEDURE

The direct relationships between the activities of the procedure are represented by the arrows in the flowchart that are described in the form of a conjugated verb. These arrows communicate two or more activities indicating the operational sequence with which these activities should be carried out. It must be taken into account that the end of one activity marks the beginning of the next, if it is not the last one.

Taking the case study, part of the Fig. 2 flowchart that allows this activity to be carried out is shown in Fig. 6.

CARLOS III UNIVERSITY OF MADRID

uc3m | **DESCRIPTION OF DIRECT RELATIONSHIPS IN THE ACTIVITY** | **Code:** | **Version:** 1 | **Effective from:** 01/05/2018

Activity ID	Name of relationship	Activity ID
1	The thesis is endorsed by the director	2
2	Set out in format No 1 "Authorization to carry out the deposit of the thesis" and the requirements established in the program are met	3
3	The publication has been received and the email "Thesis deposit request" sent	4
4	The deposit of the Doctoral Thesis has not been authorized	2

Fig. 6. Description of direct relationships in the activity. Application in the case study.

Activity 2.3. ANTECEDENTS, CONSEQUENT AND PARALLEL OF THE ACTIVITIES

In the flowchart from Fig. 2, the different relationships of the activities related in the graph can be observed through the arrows. It is necessary to identify which relationships are antecedents, indicating those activities that come before executing the activity in which you are engaged; consequent activities, those that follow the execution of the action, and which activities can be carried out in parallel.

An example of the way in which the format is completed can be seen in the Fig. 7, applied to the case study.

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uc3m | ANTECEDENT, CONSEQUENT AND PARALLEL ACTIVITIES | Code: | Version: 1 | Effective from: 01/05/2018

Activity ID	Antecedent activities ID	Consequent activities ID	Parallel activities ID
1	1	2	Not applicable
2	2	3	Not applicable
3	3	4	Not applicable
4	3	2	Not applicable

Fig. 7. Antecedent, consequent and parallel activities. Application in the case of study.

Activity 2.4. DEFINING USERS

Users are all those people whose requirements will bring them to interact with the ontology. To define them, it is necessary to review the description of the procedure. A subset of users is assigned in turn to the activities, establishing those responsible.

Activity 2.5. DESCRIPTION OF THE GENERAL OPERATION OF THE DOMAIN

A simple way to present the general functioning of the domain of knowledge to be represented in the ontology is using a scheme that shows the functions that the procedure that is to be supported must perform. One possibility is to do it through an adaptation of the UML Use Case Diagrams (Unified Modeling Language), or, failing that, a graph that contains the most important aspects and the relationship between the main activities performed by the procedure present in the flow chart, connected by means of arrows and containing the users who will perform the function. To graph the general functioning of the domain, the conventions in Fig. 8 are used.

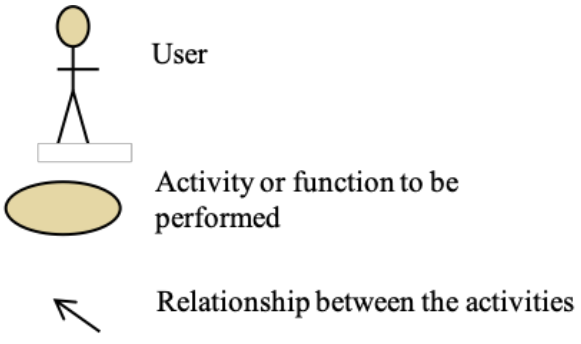

Fig. 8. Description of the general operation of the domain. Conventions.

Applying this activity to the case study of the "Presentation and Defense of the Doctoral Thesis in the UC3M" procedure gives Fig. 9, concluding that in presenting and defending a doctoral thesis, the doctoral student is in charge of the largest number of activities to be carried out within the procedure and the users who do least activities are the Program Director, the Tutor Director and the President of the Board.

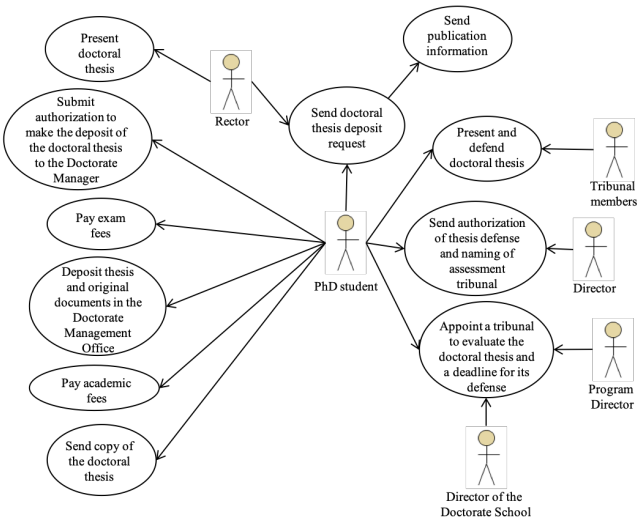

Fig. 9. Description of the general operation of the domain. Case study.

PHASE 3. DETAILED DESCRIPTION OF THE PROCEDURE

This phase comprises the activities related in the Fig. 10, indicating the fields that must be completed to fulfill the activity.

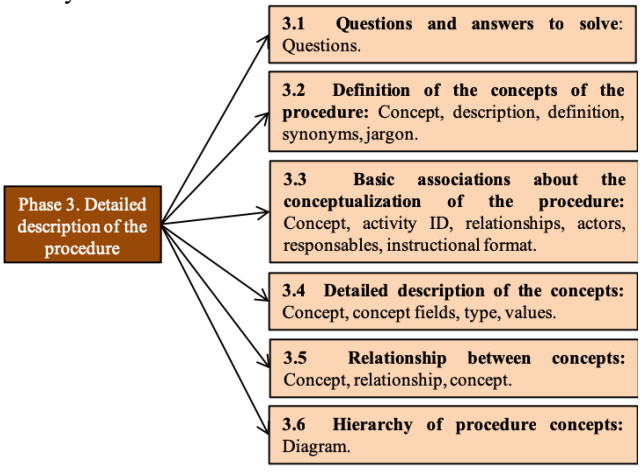

Fig. 10. Phase 3. Detailed description of the procedure, activities and fields to be resolved.

It specifies the conceptualization that is associated with the detailed description of the activities, as well as with those responsible and the supports that accompany the application of each of the activities of the procedure.

Activity 3.1. QUESTIONS AND ANSWERS TO SOLVE

In this activity, the majority of questions to which the ontology will answer will be described. Below is an example of questions that are common to any type of procedure in an organization; therefore, it is necessary to verify if there is any other question necessary for the organization to which an answer should be given, or another question that arises after a detailed definition of the concepts and relationships. For this activity it is necessary to take into account the following

- What steps does the procedure take?
- Who is responsible for a certain action?
- Who should perform a certain step?
- What is the required format for a certain activity?
- What steps follow a certain activity?
- What steps are taken before a certain activity?
- What requirements does a specific activity have?
- What documents should be considered as a basis for the procedure?
- What instruction should be followed?

Taking into account the case study, a sample of the questions to be solved would be:

- What activities does the thesis have to present and defend?
- Which actor is responsible for Activity 10, contact the doctoral student?
- What does the doctoral student do?
- Who is in charge of Activity 23, to archive the doctoral thesis?
- Which activity has Format 6 Manual Theseus?
- About Activity 11, send the authorization of the thesis defense and appointment of the evaluation board, what does it contain?
- Format 7, authorization of the thesis defense and appointment of the evaluation board, where does it appear?
- Where is the payment requirement needed?
- What needs to pay exam fees?
- What does Activity 6, to pay exam fees, require?
- Who approves the board?
- Where is the thesis disapproved?
- What is disapproved in Activity 20, leaving the doctoral program?

Activity 3.2. DEFINITION OF THE CONCEPTS OF THE PROCEDURE

This activity is responsible for extracting all the concepts associated with each of the detailed descriptions of the activities in the procedure. The fields to take into account when filling out the form are:

- **Concept**: This refers to the word included in the activity of the organizational procedure.
- **Description**: This is the set of all the activities related to the concept in the procedure.
- **Definition**: This is the conceptualization that is in the dictionary about the concept.
- **Synonym**: Word or words that have a meaning similar to the concept.
- **Jargon**: Jargon is the common language used in the organization to refer to the concept, regardless of area. For example, in the payroll area the concept may be called salary and in other areas it may be called payment, pay, wage, remuneration, bread, among others. The latter can be collected with questionnaires to the actors of the procedure about the concept and its jargon.

Activity 3.3. BASIC ASSOCIATIONS ABOUT THE CONCEPTUALIZATION OF THE PROCEDURE

This activity presents the basic associations related to the general conceptualization of the knowledge domain of the procedure; in addition, it integrates the actors and the people in charge who participate with the concept and the formats and instructions in which this concept can be found.

A description of the fields to be filled in this activity are presented below:

- **Concept**: This refers to the word included in the activity of the organizational procedure.
- **Activity ID**: Number of the activity to which the concept belongs.
- **Relationship**: These are the verbs with which the concept is related in the procedure.
- **Actors**: These are the different people who participate in the activity. They are also called users.
- **Responsibles**: They are the different people who are in charge of the activity.
- **Format**: Name of the format(s) to which the activity(ies) belong(s).
- **Instructions**: Name of the instruction(s) to which the activity(ies) belong(s).

Activity 3.4. DETAILED DESCRIPTION OF THE CONCEPTS

This activity contains the description of the basic concepts defined in the procedure and that are going to be represented in the ontology.

The explanation of each of the fields of the format is presented below:

- **Concept**: This refers to the word included in the organizational procedure.
- **Concept fields**: These are the attributes that the concept has. For example, the Doctoral Student concept has attributes such as a name, a student code and a NID (National Identity Document). For each field, the type and values to take are described. The latter make it possible to define basic facets to the properties (fields).
- **Type**: This may be string, numeric, date, character.
- **Values**: This may be any specific value or a specific classification of the concept.

Activity 3.5. RELATIONSHIP BETWEEN CONCEPTS

In this activity the concepts are related to each other, taking into account the verb with which the relationship between them is established.

To fill out the form, it must be taken into account that the relationship can be between synonyms and particular jargons, which are defined in the relationship column. Two common relationships are found here: must be (AllValuesFrom) and can be (SomeValuesFrom), which the user will place in natural language. Likewise, the concept of departure will be

the domain and the concept of arrival will be the range of the relationship.

Activity 3.6. HIERARCHY OF PROCEDURE CONCEPTS

Through a graphic adapted from a Class Diagram of UML, the relationship between the concepts that will define the ontology can be represented. The graph is made through the conventions presented in Fig. 11.

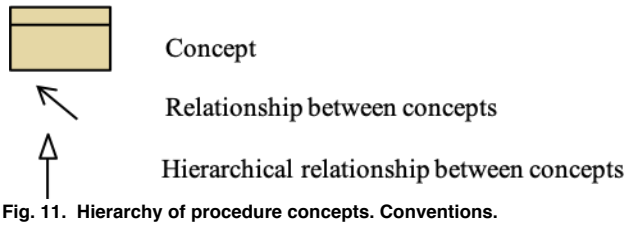

Fig. 11. Hierarchy of procedure concepts. Conventions.

In the case study of the Presentation and Defense of the Doctoral Thesis in UC3M, an example of the application of the activity is presented in Fig. 12.

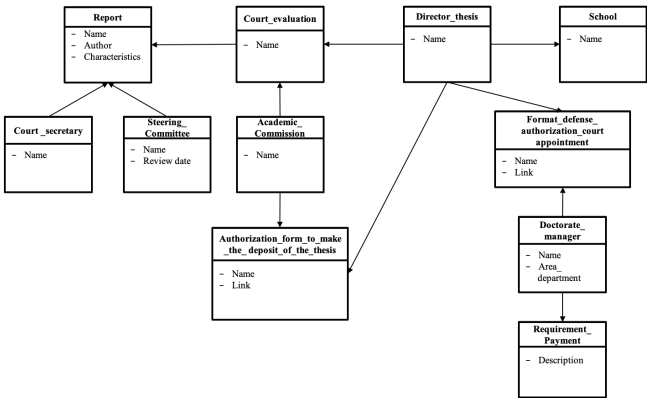

Fig. 12. Hierarchy of procedure concepts. Application to the case study.

PHASE 4. AXIOMS OF SPECIAL PROPERTIES

This phase comprises the activities related in the Fig. 13, in which the fields can be seen that must be completed to fulfill the activity.

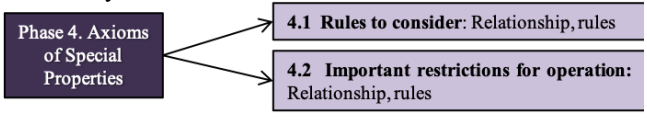

Fig. 13. Phase 4. Axioms of special properties, activities and fields to solve.

In addition, the special aspects of rules (axioms) to be considered and important restrictions for the operation of the ontology are established.

Activity 4.1. RULES TO CONSIDER

This phase establishes the special rules that must be considered with respect to the concepts and that help answer the questions that are asked in Phase 3. This part is equivalent to defining the axioms (rules) and some facets (restrictions) in an ontology.

These rules are made up of relations composed of two or more words (propositions). For example, a rule may be defined as follows: is_part_of (x, y) where instructive (x) and format (y). The instanced rule is: is_part_of (instructive IExample, format FExample), that is, in natural language: "the instructive IExample is_part_of the format FExample".

In order to reduce the complexity of the methodology, in the format the user is asked to be diligent in natural language, since in the construction of the ontology it must be done in the formal language.

Activity 4.2. IMPORTANT RESTRICTIONS FOR OPERATION

This item presents important aspects about the restrictions, both for the concepts and for the relationships between them, which must be taken into account in the ontology. Some examples are:

- All activity of the procedure must be approved by the head of the area of knowledge domain.
- Do not do an activity if the previous one is not finished.

PHASE 5. DEVELOPMENT OF ONTOLOGY

This phase comprises the activities related in Fig. 14, in which the fields are shown that must be completed to fulfill the activity.

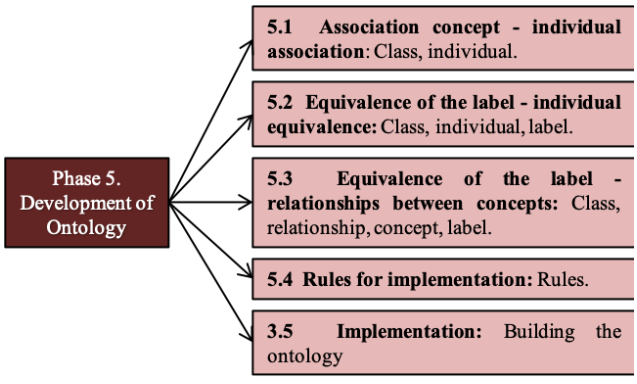

Fig. 14. Phase 5. Development of ontology.

In this phase, implementation of the ontology is carried out, facilitating its construction by people who are not experts in its development.

For the particular case study, Protégé version 5.0.0 (Build beta -17) was used for the implementation.

Activity 5.1. ASSOCIATION CONCEPT - INDIVIDUAL ASSOCIATION

In this activity the concept is associated with the individual, identifying the classes and their respective individuals, facilitating the development of the ontology.

Activity 5.2. EQUIVALENCE OF THE LABEL - INDIVIDUAL EQUIVALENCE

In this activity, a conceptual equivalence of the individual with the corresponding label is enabled. In the Protégé tool, the label refers to an annotation of the individual / instance, thereby facilitating its management.

Activity 5.3. EQUIVALENCE OF THE LABEL - RELATIONSHIPS BETWEEN CONCEPTS

This activity allows a conceptual equivalence between the relationships between the concepts and the corresponding label.

Activity 5.4. RULES FOR IMPLEMENTATION

The rules for implementation are those rules that were identified as necessary to be included in the construction of the ontology.

These rules are the ones that will allow us to adjust the way of making queries to the way in which the information is stored in the ontology.

An example of the rules applied to the "Procedure Presentationing and Defenseding of the Doctoral Thesis at UC3M" procedure, is presented below:

- Every concept is unique. It should not be repeated, even as a synonym. As an example, we have: *The doctoral student concept and its synonyms would be pupil, doctor, teacher. For the example, there should not be another doctoral student concept nor any synonym that goes by the same name*.
- Every concept and synonym must be defined without spaces, since the algorithm handles simple non-compound words. As an example we have: *index_impact*.
- Depending on the questions that the ontology must answer, defined in Phase 3 Activity 1, there must be a rule that can answer each of the questions. As an example we have: *Who conducts Activity 23, file doctoral thesis? For this question it is necessary to establish a rule that in natural language would be concept-relation-concept*.
- The same relation or property of a concept can be reused in another concept, as long as said concept is not synonymous with the new concept. As an example we have: *the doctoral student submits the thesis, the program management submits the thesis*.
- If a property of the concept is related to the same concept, it cannot be synonymous in another property of that concept. As an example, we have: *the property there_must_be of the relation of the doctoral student with the thesis_deposit, where there_must_be is related to the passage of two years to carry out this relationship*.
- The way to consult the question will be: concept - relation, concept - concept, relation - concept. As an example, we have: *doctoral student submits_to, doctoral student thesis_director, submits_to executive*.
- All the concepts are normalized for a better management. Example: they become lowercase.

Activity 5.5. IMPLEMENTATION

In this activity the ontology is built in a tool that allows the development of ontologies. For the case study, Protégé version 5.0.0 (Build beta -17) was used.

For the particular case of the UC3M and the Presentation and Defense of the Doctoral Thesis procedure, each of MONPRO's activities and phases were followed, obtaining the ontology presented in Fig. 15. To facilitate visualization of the ontology, it was made available in HYPERLINK "http://facfiet.unicauca.edu.co/Hiproor/AppWeb" \t "_blank" facfiet.unicauca.edu.co/Hiproor/AppWeb.

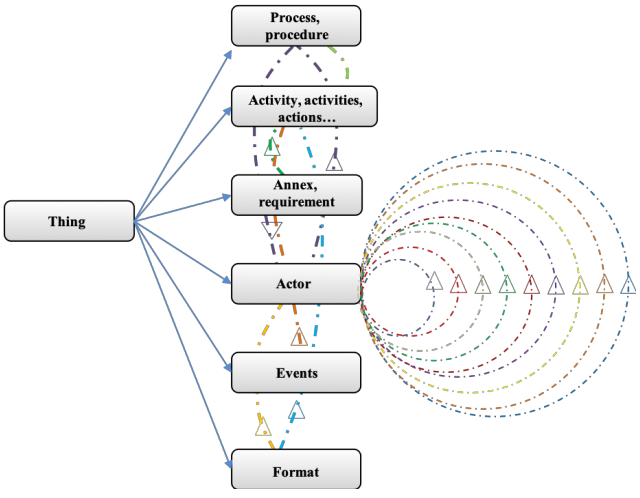

Fig. 15. View of global concepts of ontology for the Presentation and Defense of the Doctoral Thesis at UC3M procedure

Part of the contribution of this project is the final modeling of this ontology, at least in its general concepts, since the instantiation of it is achieved through each of the MONPRO phases, previously defined, which consist of certain activities where forms are made to be completed. These are taken into account for the implementation of the ontology, since they allow us to identify concepts, relationships among them, definitions, hierarchy, etc. thus facilitating the creation of the ontology in Protégé. The basic steps for the creation of the ontology were:

- Define the basic aspects, called annotations, in the ontology. These aspects include the title, the creator, the description, the version information, the modification date, license, web address of availability of the ontology.
- The creation of the concepts carried out through the definition of *classes* in Protégé.

- The creation of the individuals or instances, known in Protégé as *individuals by class*, for which the concept is selected and the name of the individual is added.
- The creation of *data property*, where the attributes of each individual are defined.
- The creation of the *object properties*, which establish the relationships between individuals defining domain (category/class) and rank (category/class).
- The *label* creation, labels from which are used in the ontology to associate synonyms.

Each of the modules of the resulting ontology in Fig. 15 group the concepts and individuals of the same class.

Because the concepts, relationships and axioms used in the example were based on standards of procedure definition, it can be suggested that the ontology constructed with MONPRO could become a generic ontology to instantiate any procedure in an organization, where users perform a process of adaptation and instantiation of their own concepts and jargon; but, to affirm this, it would be necessary to carry out more tests with several types of organizational procedures, something that lies beyond the scope of the present work.

Initially, for the implementation of the ontology, some rules were identified, highlighted among which are the following:

- Include unique concepts (classes), even if they are not repeated in the synonyms.
- The same relationship or object property can be reused with another object, as long as it is not synonymous with the same object.
- If an object property is related to a concept, it cannot be synonymous with another object property of the same concept.

The developed ontology is an OWL artifact containing 6 classes, 45 object properties, 28 data properties, 71 individuals and 933 axioms. The classes, some object properties and data properties are described below:

Classes

The different classes in the ontology represent all the knowledge related to the procedure: "Presentation and Defense of the Doctoral Thesis of the Carlos III University of Madrid", which contains the following classes in the ontology:

- Process, procedure: Information related to the procedure. The presentation_and_defense_of_the_doctoral_thesis instance is added.
- Activity, activities, actions, step, steps: Information related to the different activities that make up the procedure, for example: Activity_9_propose_defense_of_the_doctoral_thesis, Actividad_14_pay_academic_fees.
- Annex, requirement: Information related to the requirements that are part of the activities of the procedure, for example program_requirements, language_requirements.
- Actor: Information related to the different actors that are involved during the activities of the procedure, for example: PhD_student, tribunal, secretary, program_management
- Format: Information related to the different forms that must be filled out in certain activities of the procedure, for example: form_7_authorization_of_the_defense_of_the_thesis_and_nomination_of_the_evaluation_tribunal, form_10_report_of_international_expert.
- Events: Optional information in case the procedure is updated for some specific events.

Properties

For the ontology, 45 object properties were defined, for example: is_authorized_by, is_a_guide_in, is_required. These relate two classes in the ontology, such as: the property is_authorized_by relates the class form (domain) with actor (range) in such a way that the following is built:

- Form_7_authorization_of_the_defense_of_the_thesis_and_nomination_of_the_evaluation_tribunal carried out _by_program_management. It is also the case that the property is_required relates the class form (domain) with Activity ... (range), leaving for example: form_7_authorization_of_the_defense_of_the_thesis_and_nomination_of_the_evaluation_tribunal is_required activity_12_name_evaluation_tribunal. This produces a formal expression such as:
- Form_7_authorization_of_the_defense_of_the_thesis_and_nomination_of_the_evaluation_tribunal is_authorized_by the_program_management ∧ form_7_authorization_of_the_defense_of_the_thesis_and_institution_of_the_evaluation_tribunal is_requirement_activity_12_ name_evaluation_tribunal

For the object property is_authorized_by in the previous expression, it presents as domain and range form and actor respectively. On the side of the object property it is required that its domain is form and the range is activity. The ontology also includes object properties with symmetrical properties, for example, carries out, this can be seen in the following relationship: activity_12_ name_evaluation_tribunal carries out tribunal then tribunal carries out activity_12_ name_evaluation_tribunal is also true.

Axioms

The axioms are the rules that the ontology has, whose syntax is the following:

Antecedent ⇒ consequent

is_authorized_by (?x, ?y) ∧ is_required (?x, ?z) ⇒ carry out (?y, ?z)

then, according to the domain of the procedure, the forms must be authorized by different actors according to the activity in which they find themselves, for example the secretary, the tribunal, the program management, and so on. In addition, these forms are requirements of certain activities where they are related, so it can be inferred that the actor performs said activity where the form is required.

The example of the above with the instances of the ontology would be as follows:

Form_7_authorization_of_the_defense_of_the_thesis_and_invocation_of_the_evaluation_tribunal is_authorized_by the_program_management_ ∧ form_7_authorization_of_the_defense_of_the_thesis_and_nomination_of_the_evaluation_tribunal is_requirement activity_12_name_evaluation_tribubal ⇒ program_management performs activity_12_name_evaluation_tribubal.

IV. VALIDATION OF THE PROPOSED SOLUTION

Initially, a web application called HIPROOR – "Hola Procedimientos Organizacionales" (*Hi Organizational Procedures*) was developed as a proof of concept, which is in facfiet.unicauca.edu.co/Hiproor/AppWeb. In this tool an interface was made that interacts in natural language with the user through questions that the user makes in their own jargon about the procedures of the organization.

The application is capable of managing any instance of the ontology created in the case study. This means that if the ontology is taken as a basis for creating a procedure other than the example, it is expected that it can be consulted in this same application. The first tests of this application were carried out with an instance of the created ontology, but in the case of the "Create research group of the Vice-Rectorate of Research of the University of Cauca" [27].

The purpose of the web application is to take a question made by the user in natural language, translate it to SPARQL and make the search about the ontology to find the required answer. Then, the response is translated into a general format in natural language in order to be delivered and understood by the user. In addition, the application presents the possibility of assisting the user at the time of asking the question with three options: free form, autocomplete and formal approximation of natural language.

A view of the HIPROOR display is presented in the Fig. 16.

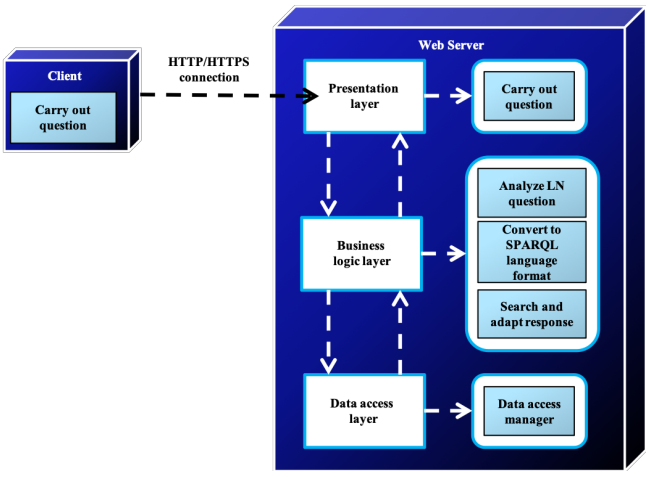

Fig. 16. Deployment view of the HIPROOR concept test.

To analyze the benefits of the methodology and the results that the application must provide, three different tests were defined:

A. Validation tests of the responses given by the ontology: This validation was carried out by two people who consider themselves experts in the "Presentation and Defense of the Doctoral Thesis at UC3M" procedure.

B. Performance test of the responses by the Information Retrieval System based on the ontology: This evaluation seeks to measure the answers provided by the ontology as an Information Retrieval System (IRS), in which the relevance of the information provided by the HIPROOR web application and its ontology is evaluated.

C. Support test of the decision-making process: This evaluation seeks to measure the answers provided by the ontology from its capacity to support operational decision making.

A. VALIDATION TESTS OF THE RESPONSES GIVEN BY THE ONTOLOGY

This test consisted in the selection of two expert users (the director of the Doctorate in Science and Information Technology and the Assistant of the Doctoral School), who made use of the HIPROOR search engine to request the responses to the five questions posed, in natural language, about the "Presentation and Defense of the Doctoral Thesis at UC3M" procedure. Once they have obtained the responses from the system, the experts define whether they are correct or incorrect, depending on the relevance of the response returned according to the question asked. One of the questions asked is: Which actor is responsible for Activity 10, contacting the doctoral student? The result of each question was recorded in a table by each of the experts, as observed in TABLE I, in which the "X" represents the result of the answers that the expert obtained from his query.

TABLE I
RESPONSES TO THE QUESTIONS ASKED BY THE EXPERTS

Question	Correct response	Incorrect response	Partial response	No response returned	Response time (seconds)	Observation
2	X				12	

To perform the search in HIPROOR, it was necessary to implement an automatic module that translates the natural language to a SPARQL search about the specific ontology created. For the particular case of the question asked in the TABLE I, we have:

```
PREFIX p1: <http://www.owl-ontologies.com/Ontology1334794121.owl#>
SELECT DISTINCT ?i1 ?i2 WHERE { {?i1 a p1:Actor}{?i2 a p1:Activity}Filter(?i2 = p1:activity_10_contact_the_doctoral_student)?i2 ?p1 ?i1 . }
```

Once the validation was completed, the approval of the experts was obtained in that all of the responses given by HIPROOR when consulting the ontology were correct and responded to the requirements made in natural language through the jargon of each expert. An example of one of the responses provided by the experts is presented in TABLE II, in which the "X" corresponds to the response that the experts obtained from the questions asked to the ontology, which indicates that all the answers obtained were correct.

TABLE II
RESPONSES TO THE QUESTIONS ASKED TO ONE OF THE EXPERTS

Question	Correct response	Incorrect response	Partial response	No response returned	Response time (seconds)	Observation
1	X				11	
2	X				12	
3	X				12	
4	X				13	
5	X				13	

B. PERFORMANCE TESTS OF THE RESPONSES GIVEN BY THE INFORMATION RETRIEVAL SYSTEM BASED ON THE ONTOLOGY

For these tests, classical IRS evaluation measures such as precision, recall and harmonic mean were used that will allow establishing the system's capacity to provide relevant responses to the user.

It was decided to create an experimental design, which selects real users (PhD students) who want to know the procedure for the Presentation and defense of the Doctoral Thesis in UC3M, in order to compare the performance of consulting the procedure in the web application HIPROOR vs. the performance of consulting the procedure on the UC3M University web portal, just as a student who would like to know about this procedure would do.

1. DEFINITION OF THE EXPERIMENT

a) Object of study: The aim of the study is the web application called HIPROOR and its ontology as an ISR. That is why measures are required to evaluate the quality of the responses provided [28]. The traditional approach to evaluating such systems works on the notion of relevant and non-relevant documents [29]. For our case, a relevant document is a correct response and a non-relevant document is a not found or incorrect response. Relevance can be measured through:

- **Precision:** This refers to the fraction of retrieved documents that are relevant; it is calculated by the formula in (1).

$$\text{Precision} = \frac{\text{Number of relevant documents retrieved}}{\text{Total number of retrieved documents}} \quad (1)$$

- **Recall**: This refers to the fraction of relevant documents that are recovered; it is calculated by the formula in (2).

$$\text{Recall} = \frac{\text{Number of relevant documents retrieved}}{\text{Total number of retrieved documents}} \quad (2)$$

One characteristic of using precision and recall in IRS is that both measures tend to vary inversely with each other. As stated, and in accordance with the characteristics of HIPROOR, it was necessary to combine precision and recall through the weighted harmonic mean of both values, known as **harmonic mean F-measure**, as shown by (3)

$$F = \frac{(\beta^2+1)*\text{recall}*\text{precision}}{\beta^2*\text{recall}+\text{precision}} \quad (3)$$

β is a factor that shows the relative importance of coverage and precision. If coverage and precision are considered equally important, their value is 1.

b) Sample: Based on the case study of the "Presentation and defense of the Doctoral Thesis at UC3M" procedure, in order to analyze the performance of the expected responses, a sample of 20 PhD students was taken.

c) Variables:

- **Controlled:** The variables that were controlled for the present experiment were analysis capacity, abilities, age and the environment that we want to generate in order to be as homogeneous as possible; taking into account that doctoral students were selected as well as the users of the "Presentation and Defense of the Doctoral Thesis at UC3M" procedure of the Carlos III University of Madrid. This is the reason for defining the test in the same computer room, with the same configuration of the equipment and using the same internet connection.
- **Independent**: For this experiment the independent variables were the following:
  - B1: Search freely using HIPROOR, writing the questions as the user wants and in their own jargon.
  - B2: Search in HIPROOR using autocomplete, which starts from the definition of what the tool considers a question and from the first letters that are written taking into account the interrogative words (what, which, how, among others), the concepts (doctoral student, format, director, among others), relationships (own, delivery, among others), synonyms, jargon and

others; generates the complete words or phrases that can be searched in the ontology.
  - B3: Search in HIPROOR through the approach to natural language, where the user takes as a basis the standard definition that the tool has of what is a question with its respective structure.
  - B4: Search the information on the UC3M page. This variable would be the control group of the experiment since one of the current means most used to access information regarding the presentation and defense of doctoral theses at the University.
- **Dependent**: For this experiment, the dependent variables were precision, recall and harmonic mean.

d) Hypothesis formulation:

- **The research hypothesis $H_0(1)$**: The answers provided by the concept test associated with MONPRO, using natural language, are peculiar.
- **The alternative hypothesis $H_1(1)$**: The answers provided by the concept test associated with MONPRO, using natural language, are redundant.
- **The research hypothesis $H_0(2)$**: The MONPRO methodology allows the development of ontologies of organizational procedures.
- **The alternative hypothesis $H_1(2)$**: The MONPRO methodology allows approaching the development of organizational procedures ontologies.

2. EXPERIMENT DESIGN

The experiment was carried out with 20 users with whom four groups of five people each were formed. With this we obtained three experimental groups and one control group which are the reference for comparisons:

- G1: Experimental group with 5 random users. This group uses HIPROOR without any help, asking the questions as they wish (B1).
- G2: Experimental group with 5 random users. This group uses HIPROOR with the autocomplete where the user begins to write a word and the concept test completes it (B2).
- G3: Experimental group with 5 random users. This group uses HIPROOR with approximation to natural language, asking the question of how it was defined that a question should be formulated for the concept test (B3).
- G4: Control group with 5 random users. This group carries out the search in a traditional way through the web page of the UC3M (B4).

Three problems were defined from the "Presentation and Defense of the Doctoral Thesis at UC3M" procedure. It should be noted that one of the questions is a quick response in which many inquiries should not be made about the Procedure to be resolved and the other two have a greater degree of complexity in the search. The answers to these questions are given by:

- AC: The user answered the question and responded correctly
- AI: The user answered the question and responded incorrectly
- NAC: The user did not answer the question and it is correctly responded
- NCI: The user did not answer the question and is incorrectly responded

The TABLE III presents a compendium of the different answers that can be obtained as presented previously

TABLE III
ANSWERS TO OBTAIN

Response	Correct	Incorrect
Answered	cc	ci
Not answered	ncc	nci

The design of the experiment is based on the observations made on the different defined groups. These observations were taken to TABLE IV**.**

TABLE IV
OBSERVATIONS ASSOCIATED WITH HIPROOR

Group	Type of group	Search	Observation
G1	Experimental	B1	O1
G2	Experimental	B2	O2
G3	Experimental	B3	O3
G4	Control	B4	O4

a) Instrumentation: Data collection was done through the filling of a form that was given to each of the students participating in the test.

b) Definition of the problems to be solved by the sample: To determine the three problems with which the application and decision-making were evaluated at the same time, the criteria of those responsible for the "Presentation and Defense of the Doctoral Thesis at UC3M" procedure, with experts in it, were taken into account. For this article, the first problem will be presented.

Problem 1: Do you need to know what the necessary steps to carry out the *send authorization of the thesis defense and appointment of the evaluation board* activity are?

- Orientation 1: Identify the forms that must be completed to send authorization for the thesis defense and appointment of the evaluation board at UC3M.
- R1: Identify the form that the doctoral student must fill out.
- R2: Identify the form that the director / tutor of the thesis must fill out.

For this, the following should be taken into account:

- Identify all the forms that must be filled out.
- What form must the Doctoral Student fill out?
- What form must the Thesis Director/Tutor fill out?

The possible answers and their weighting are presented in TABLE V, which presents the weighting for each possible response alternative.

TABLE V
ALTERNATIVES OF RESPONSES TO PROBLEM 1

Option	Description	Weighting	Justification
1	No form required	0	Does not meet objective
2	The required forms are forms no. 7, 8, 9, and 10. The doctoral student should complete forms 7, 8, 9, and 10 while the Thesis Director/Tutor should complete forms 7 and 9 only	100	Objectives and restrictions are met
3	The required forms are forms no. 7, 8, 9, and 10. The doctoral student should complete forms 7 and 9 while the Thesis Director/Tutor should complete forms 7, 8, 9, and 10.	50	The objective is met, but the restrictions are not.
4	The required forms are forms no. 7, 8, 9, and 10 and the doctoral student should complete all of them	75	The objective is met, but Restriction 2 is not met.
5	The required forms are forms no. 7, 8, 9, and 10 and the Thesis Director/Tutor should complete all of them.	75	The objective is met, but Restriction 1 is not met.
6	There is insufficient information to make a decision.	0	Does not meet objective.

The valuations in TABLE V were provided by experts in ontology creation and decision making. It is intended to punish strongly if the ontology does not provide information on the procedures and also reward if there is information about it, which the experts consider to be relevant.

Two other problems to be solved by the different groups were likewise defined, giving a total of three set out problems.

3. VALIDATION OF THE RELEVANCE OF THE RESULTS PROVIDED BY HIPROOR

The data collection was done from the filling of a form that was given to each of the students participating in the test.

As HIPROOR is a particular system in IR response search, the measures were adapted to previous proposals for such measurements [29][30]. A sample of the tool interface is presented in Fig. 17. The technical solution chosen in this project was to implement a communication interface that uses natural language processing - PLN in the Spanish acronym, to interpret the requirements of the users of the system; subsequently, it transforms these requirements into a technical language, SPARQL (Protocol and RDF Query Language), which performs the inference of information in the organizational ontology, specially designed to consult routines and rules.

The proposed architecture allows adapting to any Spanish domain ontology implemented in OWL-DL, regardless of the number of its elements (classes, instances, object properties, datatype properties).

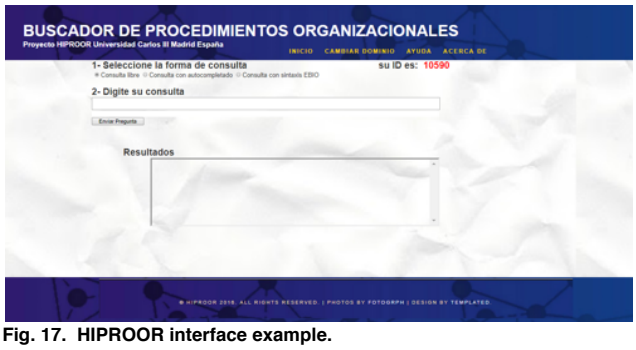

Fig. 17. HIPROOR interface example.

TABLE VI presents the final results applied to the four participating groups. It should be noted that the number of questions refers to the number of questions that participants had to ask in order to find the answer to the selected question.

TABLE VI
RESULTS FOR PRECISION, RECALL AND HARMONIC MEAN

Experimental group	Number of questions	Time used (minutes)	Precision	Recall	Harmonic mean F-measure
G1	34	3,872	0,925	0,833	0,855
G2	22	3,708	0,96	0,893	0,920
G3	19	4,508	1	0,866	0,920
G4	-	9,198	0,923	0,833	0,842

Fig. 18 shows the graph resulting from analysis of precision, recall and Harmonic mean in the test performed. The precision value in G4 can be seen to be very close to that obtained by the G1 group who made the search freely in HIPROOR, meaning that the minimum precision with HIPROOR was practically the same as that obtained with the current search method through the website made by G4. Something similar to what happened with precision can be observed, the minimum recall with HIPROOR was found to be the same as that obtained with the current search method through the website made by G4.

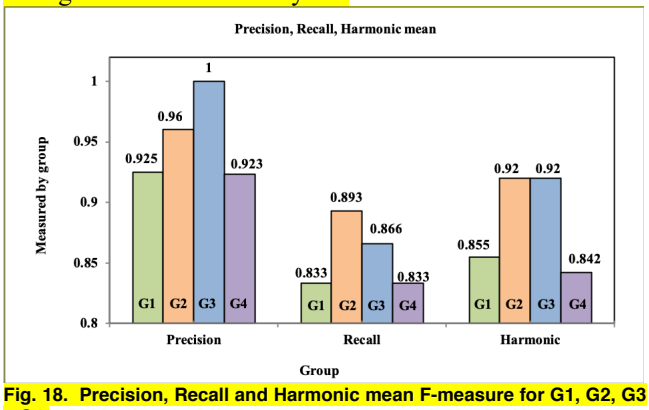

Fig. 18. Precision, Recall and Harmonic mean F-measure for G1, G2, G3 y G4.

Fig. 19 presents the graph resulting from the number of questions that each experimental group made in the test.

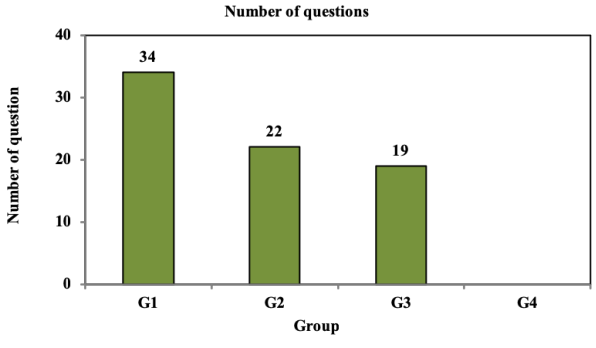

Fig. 19. Number of questions asked to solve the problem in G1, G2 and G3.

The number of questions asked is not shown for the G4 control group, since mentally the participants thought about a question and it was very difficult for it to be counted because as they were concentrating hard, they tended to forget to register whether or not they asked a question.

4. ANALYSIS AND INTERPRETATION OF THE RESULTS

The following can be established from the test results:

- Regarding control group G4, it can be observed that precision and recall were obtained very close to those obtained by G1 who searched freely in HIPROOR. On analyzing harmonic mean, the result is seen to be lower than those for G1, G2 and G3. With all this, it can be defined that the information search using HIPROOR is closer to optimal than by using the current method of accessing the information contained in the UC3M web page.
- As regards the G2 group, (users who consulted with the HIPROOR search engine with autocomplete help) and the G3 group (users who consulted using HIPROOR with help from natural language approximation), these had to ask fewer questions to solve the problems set out, with the G1 group, (HIPROOR without aids) requiring more questions to solve the problems.
- G2 and G3 produced percentages of precision greater than 95%, percentages of recall above 86% and harmonic mean F-measure values greater than 90%, indicating that, when carrying out the search with the help of HIPROOR, acceptable results close to 100% are obtained for enquiries by the user who has received support in formulating the questions, accessing the searches about the defined ontology in a more appropriate way with MONPRO. These percentages do not differ much from those obtained by the G1 group (as long as the terms used are written correctly); therefore, it can be determined that the system returns relevant responses to users and, consequently, supports searches in natural language using jargon particular to each user. This indicates very good results, since the percentages of precision, recall and harmonic mean F-measure exceed 83% in these types of consultation.
- Some G1 users had to ask a greater number of questions because they tended to write the terms that defined the search incorrectly (with spelling errors) and asked questions using concepts not found in the ontology, leading the search to be incorrectly formulated meaning there was no response, indicates that it is further necessary to add a type of jargon not covered by the ontology.
- Users in experimental groups G2 and G3 formulated the questions better by having the possibility of using the terms of the domain, increasing the number of responses answered correctly by HIPROOR.

C. SUPPORTIVE TESTS OFTO THE DECISION-MAKING PROCESS

Through this experiment, the aim is to measure whether the answers provided by the ontology serve to support operational decision-making. Since evaluating decision making is a complex area, this project performs an initial exploration of indicators to measure decision-making based on the information that the organizational actor has.

1. DEFINITION OF THE EXPERIMENT

a) Subject of study: the web application HIPROOR and its ontology in the field of IR-organizational IR, as support for operational decision making.

In the previous experiment, it was possible to analyze the result of the indicators of precision, recall and harmonic mean that are part of the information retrieval area. However, it is necessary to define indicators to measure support for decision-making which, until now, are not formally defined in the literature found [29][30][31] [32][33][34][35][36][37][38][39]. It is therefore necessary that the indicators to be proposed evaluate the quality of the decision made, supported in the technological solution provided and not in the definition of indicators that organizations use to make their decisions, taking into account some elements that have been established for decision making.

In the search for the state of the art in this regard, very few references were found [31][35] that attempt to evaluate the decision made formally; other references study the discipline of decision making with vague logic methods [38][39] and the rational decision-making model approach.

What could be observed from the sources consulted is that aspects such as process time, unstructured data, the use of innovation technologies in the processes and the training of the organization's employees are taken into account. Nevertheless, external indicators such as financial indicators, customer-related indicators and the market are not taken into account, since the case study is at a more tactical level than an operational or strategic level and is directed to how to perform the different activities required for the presentation and defense of the doctoral thesis at UC3M.

Furthermore, decision-making can be seen as a learning method [30], in which we can evaluate how wrong we were in the decision made, or how correct the final decision made was, allowing feedback to the decision-making process. This element is not taken into account for the case study and will be managed more as a control variable, focused on the group of individuals with uniform experience in this regard. Additionally, the approach is towards making individual and non-group decisions, which reduces the number of variables to be taken into account for the measurement in the indicators to be proposed.

b) Indicators proposed for the decision made: It is possible to make the evaluation of a decision in relation to how close to being the best decision or how correct it

was. Normally, a decision taken by a person [39] consists in the conscious evaluation of a set of alternatives $A = (a_1, a_2, a_3, \dots, a_i)$, in the presence of some objectives $O = (o_1, o_2, o_3, \dots, o_j)$ and some restrictions $R = (r_1, r_2, r_3, \dots, r_k)$, these being in many cases obligatory to accept any alternative or optional (priority) to better evaluate an alternative.

Possible states can be represented as functions, like this: $o : A \rightarrow O$; $r: A \rightarrow R$, defining that each alternative a_i of decision, obtains the levels to reach the objectives O and the degree of compliance with the restrictions R. Based on these variables, we have the following indicators:

- **Quality indicator. Decision-making mean (QDMM).**

The units of measurement depend on the nature of the objectives. For this particular case, the objective is to establish the degree to which a good decision was made, which can be measured by quality levels, best achieved by establishing a minimum scale of two levels and a maximum of five levels as shown in (4) , which shows a representation of the measured quality levels.

$$Cal_0 = 0\%;\ Cal_1 = 25\%;\ Cal_2 = 50\%;\ Cal_3 = 75\%;\ Cal_4 = 100\% \quad (4)$$

The unit of measurement is therefore percentage. Each alternative will thus obtain a Cali evaluation according to the evaluation made by an expert in the subject. The above percentages are an example; it is the leading expert who is able to attribute to them the appropriate value within the range of: $0\% \leq Cal_i \leq 100\%$.

For example, there are three alternatives to a given problem and, according to the above, the expert could assess them as shown by the TABLE VII.

TABLE VII
EXAMPLE OF EVALUATION OF ALTERNATIVES TO A PROBLEM

Function of option	Valuation
o(a1)	0%
o(a2)	80%
o(a3)	100%

The restrictions and alternatives must be able to be checked with ontology enquiries. This indicates that from a set of searches $S = (s_1, s_2, s_3, \dots, s_m)$ functions can be set $s: R \rightarrow S$ y $d: A \rightarrow S$. The above shows that the user, for each alternative-restriction, makes searches in order to determine the value of truth of the answers, i.e. true (T) or false (F). The alternative-restriction evaluates itself as true (T) or false (F), making the conjunction of all related searches. For the example described above, the user can obtain the decision logic presented in TABLE VIII.

TABLE VIII
EXAMPLE OF EVALUATION OF ALTERNATIVES TO A PROBLEM

Function of restriction or option	Related queries	Valuation	AND valuation
c(r1)	c1	V	c1^c5 = F
	c5	F	
c(r2)	c3	V	V
d(a3)	c4	V	V

According to the above, the nature of the relationship between alternatives and restrictions is presented as the result of a logical relationship of compliance or otherwise of restrictions, depending on the requirement (AND) or the preference (OR) of the restriction as presented (5), which presents the mathematical representation of what a restriction is.

$$o(a_i) = s(r_1)[\text{AND}|\text{OR}]s(r_2)[\text{AND}|\text{OR}]d(a_3), \dots [\text{AND}|\text{OR}]s(r_k) \quad (5)$$

For the previous example, it may be that restriction r_2 is mandatory in making a decision, since it is an indispensable condition to be fulfilled in taking any alternative. Furthermore, r_1 is optional for alternative a_2, which would indicate a relationship as shown in TABLE IX.

TABLE IX
EXAMPLE OF LOGICAL RELATIONSHIP OF RESTRICTIONS TO EVALUATE ALTERNATIVES

Function of option	Relationship of restrictions	Accept option or not
o(a1)	c(r1) AND c(r2)	F
o(a2)	c(r2) AND c(r3) OR c(r1)	V
o(a3)	c(r2) AND d(a3)	v

In accordance with the foregoing, alternatives must be rejected logically, in relation to their restrictions, remaining to be resolved whether a_2 or a_3 is more convenient, which should be related to the objectives to be met, since these may be of a different type; however, most of the objectives are classified as:

- **Maximize**: Make the best possible decision.
- **Fulfill**: Choose the first option that is minimally acceptable, satisfying in this way a goal or objective sought.
- **Optimize**: That which generates the best possible balance between different goals.

This classification is a mental process made by the user responsible for making the decision [29] consciously or unconsciously. From this process, you can build the problems and alternatives to present to the user.

Taking into account the example set to define the indicators, the user can select alternative a_2 in such a way that his decision is correct by 80% (TABLE VII), allowing us to establish how good was the decision made and, therefore, the information provided by the system for the user to select that alternative, indicating that if N problems are placed before users $P = (p_1, p_2, p_3, \dots, p_n)$ with its alternatives and restrictions, the users themselves evaluate the alternatives,

performing the process described above for each problem, obtaining a relation of them represented by (P_n) vs. $V(a_{ij})$ (selected alternative value i of problem j) as presented in TABLE X.

TABLE X
EXAMPLE OF PROBLEMS VS. ALTERNATIVES CHOSEN BY USERS.

Question	Value of select option
P1	80%
P2	100%
P3	50%
P4	70%

On averaging the values in TABLE VII, there is 75% quality in the decisions made, meaning that the system allows a good level of decisions to be made with respect to TABLE XI, representing a proposal for qualitative assessment of the decision made.

TABLE XI
QUALITATIVE VALUES OF THE DECISION MADE

Range	Qualitative value
$0 \leq x \leq 50$	Deficient
$50 < x \leq 70$	Acceptable
$70 < x \leq 80$	Good
$80 \leq x \leq 90$	Very good
$90 < x \leq 100$	Excellent

With the data obtained from the analysis performed, the Average Quality of Decision-making indicator is defined as shown in (6).

$$QDMM = \frac{1}{M*N} * \sum_{k=1}^{M} \sum_{j=1}^{N} O(a_{ij})_k \quad (6)$$

where M is the total number of users that solve N problems and $O(a_{ij})$ is the percentage value assigned to alternative i of problem j that user k has selected. The quality indicator fluctuates between $0 \leq QDMM \leq 100$, with 100 being the highest quality, meaning that the user selected all the correct alternatives. The value can be qualified with TABLE XI to define the capacity of the system in terms of support for decision-making.

- Efficacy indicator for decision-making (EfDM).

In making decisions, efficacy aims to establish how many problems were solved with the best alternative, which indicates the problems solved (P_{solved}) in which the alternative selected by the user was $O(a_{ij})$ =100%. Regarding the total problems (P_{total}), the efficacy indicator can be defined for decision making as shown in (7).

$$EfDM = \frac{P_{retrieved}}{P_{total}} = \frac{N*M-\sum_{i=1}^{M}\sum_{j=1}^{N} z_{ij}}{N*M} = 1 - \left(\frac{1}{N*M}\right) * \sum_{i=1}^{M}\sum_{j=1}^{N} z_{ij} \quad (7)$$

in which:

$$z_{ij} = 0 \text{ si } O(a_{ij}) \leq 100\% \text{ sino } z_{ij} = 1 ;$$

In order to obtain all the solved questions in a measurement by several users, the total questions (N) must be multiplied by the number of users (M). For the number of questions answered correctly, the number of alternatives answered correctly must be added, that is, $O(a_{ij}) = 100\%$.

The units of this indicator are dimensionless, since they are canceled in the quotient, so always $EfDM \leq 1$, which indicates that if the measurement is close to 1, the number of problems answered correctly is close to the number of total questions that must be solved; therefore, efficacy is close to 100% (to be able to establish different levels of efficacy, the final value of EfDM is multiplied by 100 establishing TABLE XII, a table of ranges, which defines the values for efficacy in the decision-making process).

TABLE XII
EFFICACY RANGES IN DECISION-MAKING

Range	Points	Qualitative value
$21\% \leq EfDM \leq 40\%$	2	Acceptable
$41\% < EfDM \leq 60\%$	3	Good
$61\% < EfDM \leq 80\%$	4	Very good
$81\% \leq EfDM \leq 100\%$	5	Excellent

- Time efficiency indicator for decision-making (TEfDM).

An important resource is the time used in decision making. A reference time per problem (t_{rp}), can be defined, given by the expert, which is what it would normally take a person to choose the correct alternative of all the (N) problems with the current resources of the organization. With this, the average time consumed by the user i can be calculated in choosing correct alternatives of the (N) proposed problems and being able to establish the efficacy regarding the time each user required to make the decision like this: t_r/t_{ij}; in this case, it inverts the quotient since the expected result is not to exceed the minimum time to solve the problems. As the system is used by various users, it is convenient to calculate the average of these times with respect to the reference time and thus obtain a value that depends less on the particular characteristics of a user, as shown in (8).

$$TEfDM = t_r * \sum_{i=1}^{M}\sum_{j=1}^{N} \frac{1}{t_{ij}} \quad (8)$$

in which N is the total number of problems to be solved by M users in the test; t_{ij} corresponds to the time required by user i in solving problem j, that is, from beginning to read it until selecting a solution option. The units of this indicator would be dimensionless. As the analysis of the indicator is done in relation to a value close to the unit, the classification presented in TABLE XIII is carried out.

TABLE XIII
TABLE OF EFFICIENCY RANGES IN TIME FOR DECISION MAKING

Range	Points	Qualitative value
TEfDM > 1	5	Very efficient
TEfDM = 1	3	Efficient
TEfDM < 1	1	Inefficient

Furthermore, it is important to convert this indicator into a percentage, in order to subsequently calculate the efficacy; in this way, as long as the indicator takes values of 1 or higher, the assigned value is 100% and if it is less than 1, the corresponding percentage is put down, since it would indicate how much time was consumed in relation to the reference time.

- **Effectiveness indicator of the system in decision making (EDM).**

The last indicator to be defined establishes effectiveness as the average efficiency and efficacy, where the EfDM indicator can be combined with the TEfDM as presented by (9).

$$\text{EDM} = \frac{\text{EfDM} + \text{TEfDM}}{2} * 100$$
$$\text{If TEfDM} > 1 \text{ then TEfDM} = 1 \quad (9)$$

The units are dimensionless since their components are also dimensionless. The restriction is placed to express the effectiveness as a percentage, since when effectiveness is above 1 the resources were used efficiently; later it is averaged with efficacy, which is also in percentage form. The 100 is a scale factor to express the effectiveness in percentage, which indicates that the closer the system is to 100% the more effective it is and thus the decision-making performed. That is, the decision-making process is more correct and with the maximum performance of resources (time), the closer it is to 100%.

- **Conclusion and scope of the proposed indicators.**

The indicators defined in this article intend to evaluate the quality and effectiveness of the decisions made in the solution of a particular problem with well-defined decision options and expected values, also defined. These indicators work well to establish the capacity of an organizational information system to support the decision making of a group of users, for whom the answers and alternatives provided by the system have been previously evaluated by an expert with knowledge of the organization.

They cannot be used in the general organizational environment with varied information systems, in which, in most cases, the quality values of the alternatives and the implication of the decision made are not known. In addition, it is suggested not to use them to foresee future results, since they can evaluate the final decisions made from the collection of historical data.

The number of variables involved in decision-making is very large and can be as specific as the same number of existing organizations; therefore, evaluation of decision-making is still a very broad field of study, in which we would have to go much deeper to make a more specific treatment of indicators in this regard.

Based on these indicators proposed in the object of study, an approach is made to the evaluation of decision-making based on minimum specific conditions of the information system that supports said decision-making.

c) Sample and variables: The sample and the variables are the same defined for the experiment of validation tests of the answers obtained, taking as a basis the case study of the "Presentation and defense of the Doctoral Thesis at UC3M" procedure with the 20 PhD students, as homogeneous as possible and variables B1, B2, B3 and B4, which represent the different ways of searching for the answers of the ontology developed with MONPRO.

d) Hypothesis formulation:

- **The research hypothesis**: The MONPRO methodology supports decision-making through the search for information, using natural language approximation.
- **The alternative hypothesis:** The MONPRO methodology does not support decision making through the search for information, using natural language approximation.

2. EXPERIMENT DESIGN

The design of the experiment, as with the sample and the variables, is the same as the experiment performed in the validation tests of the answers obtained, taking four user groups G1, G2, G3 and G4 as references for the comparisons, taking into account each of the validations performed in the aforementioned experiment.

3. VALIDATION OF SUPPORT FOR DECISION-MAKING THROUGH CONSULTING THE ONTOLOGY USING HIPROOR

The data collection was done from the filling of a form that was given to each of the students participating in the test.

TABLE XIV presents the final results applied to the three experimental groups. It should be noted that the number of questions refers to the number of questions that were necessary to find the correct answer to the selected question.

TABLE XIV
RESULTS OF THE APPLICATION OF THE INDICATORS PROPOSED TO SUPPORT DECISION-MAKING

HIPROOR indicator Decision-making measure	Value with G1	Value with G2	Value with G3	Value with G4
Quality of the Decision Made (QDMM)	95%	95%	85%	50%
Efficacy (EfDM)	90%	90%	80%	50%
Efficiency (TEfDM)	3,61	3,73	3,94	1,47
Effectivness (EDM)	95%	95%	90%	75%

Fig. 20 presents the graph resulting from the quality of the decision made, efficacy of the decision made and effectiveness of the decision made in groups G1, G2, G3 and G4.

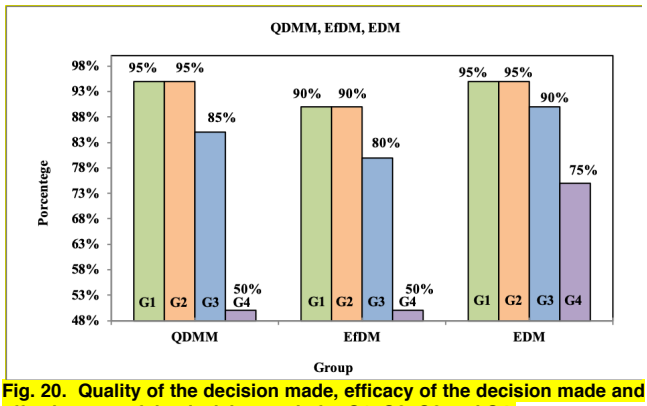

Fig. 20. Quality of the decision made, efficacy of the decision made and effectiveness of the decision made for G1, G2, G3 and G4.

Fig. 21, presents the graph resulting from the efficiency of the decision taken in the groups G1, G2, G3 and G4.

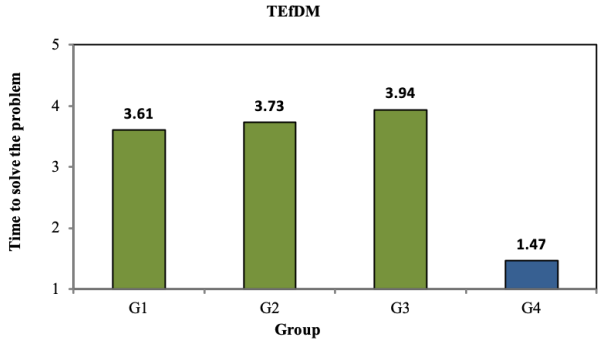

Fig. 21. Efficiency of the decision taken for G1, G2, G3 and G4.

4. ANALYSIS AND INTERPRETATION OF THE RESULTS

From the results, it can be established that the application of the proposed indicators to measure support for decision-making is possible in a controlled environment of options and expected values, as would be the consulting of organizational procedures to answer specific questions related to them and solve any problem related to the need for information. The following is concluded:

- It can be seen that both the quality, efficacy and effectiveness of the decisions made to solve the problems of the experimental groups G1, G2 and G3 are good, since they reach QDMM values of 95% (excellent), EfDM of 90% (excellent), TEfDM of 100% (very efficient), which indicates that the effectiveness of the environment in the decision making is very good (EDM = 95%), according to the results of this test and the proposed indicators for analyzing decision making.
- It can also be observed that, in terms of the degree of making good decisions, the number of solved problems with the best alternative and the time the user took to make the decision are much higher in experimental groups G1, G2 and G3 in contrast to the control group G4, which tended to make poor decisions, using more time in accessing directly the page of UC3M, which is the current means of consultation.
- Applying that defined in TABLE XIII, where the TEfDM is calculated, all of them are above 1 which indicates an efficacy of 100%, taking into account the reference times in this experiment were broad; however, it can be seen that the values are much higher in groups G1, G2 and G3 compared with those in control group G4, making decision making more efficient when using the ontology search made with MONPRO.

V. CONCLUSION

This article presents a new methodology - MONPRO - for developing ontologies of organizational procedures. MONPRO, seeks to manage such procedures through the development of a specific ontology. This allows it to become a source of consultation by organizational actors who need information. This then allows them to support their operational decisions about how to fulfill the requirements of the procedures for which they are responsible or perhaps at some point are users themselves. The aforementioned can have an impact on cost reduction by not requiring the hiring of experts to develop procedure ontologies, to reduce consultation time on procedures that on average took 4,029 between G1, G2 and G3, compared to 9,198 the G4 took, reaching a reduction of 43.8%.

Each of the concepts, phases, activities and formats defined in the MONPRO methodology can be carried out by a person who is not an expert in ontologies, but who has a background in computer engineering, which corroborates that the methodology can be used by any organization without the need to incur more costs in hiring and/or consultancy, to develop its procedures.

The case study implemented, "Presentation and Defense of the Doctoral Thesis at UC3M", made it possible to first demonstrate the possibility of using the MONPRO methodology to create ontologies of organizational procedures and as a second contribution, save time and effort finding relevant information on activities, formats and other actions to be carried out in this procedure. Moreover, its users (students and executives) can interact intuitively through the Web tool the interface in natural language makes and consult the built ontology, providing relevant answers to their searches.

In general, it may be concluded that the MONPRO methodology is able to support the development of organizational procedures through ontologies that contain organizational jargon. However, it is necessary to validate it with more procedures in different domains, to demonstrate better its effectiveness and to improve it.

As an additional contribution, some indicators were defined that can evaluate decision-making in a well-controlled environment supported by a computer tool such as HIPROOR, responding to concerns about how good or not was the decision made in relation to a problem raised about

the search of organizational procedures using the ontology and HIPROOR.

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