# Application and Evaluation of a Taxonomy in the Context of Software Requirements Management

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**Abstract.** The requirements of a software are the characteristics of the system, being identified based on information provided by the users or by experts in the business; and the effective management of this information is essential to ensure that the system meets the needs of those who will use it. According to research, one of the problems that negatively impacts the software development process is related to the conduction of the project requirements management activity. And in order to alleviate this problem, we carried out a research to verify if taxonomies, as tools used by the area of information management, can be applied in the context of requirements management. For this, we developed a taxonomy to meet a real software project and the results were evaluated in relation to its complexity, satisfaction, resources involved and adaptability. The present research is characterized in terms of nature as an applied research, aiming at solving real-world problems; as for the objectives, as exploratory and descriptive; and as for the approach, mixed methods are used, since it combines qualitative and quantitative forms of research in the same study. As for the methodological procedures, the bibliographic research was chosen to understand the concepts related to information management, taxonomies and requirements management. The evaluation results showed that taxonomies can contribute to the activities of the requirements management process and consequently increase the chances of project success.

**Keywords:** Requirements engineering · Software · Information management · Requirements management · Taxonomy

## 1 Introduction

The initial specification activity, in which the software functionalities and restrictions to its operation are defined, counts on the Requirements Engineering area to support the discovery, analysis, documentation, validation and management of system requirements


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[1]. Requirements are conditions or capabilities that a software needs to have in order to meet the needs of its users, being considered a critical factor in projects, because, if not well defined and managed, they directly impact the success of the product that will be delivered.

It is possible to observe in the literature different proposals regarding how Requirements Engineering activities should be carried out, and this definition should consider factors such as the type of software that will be developed, the organizational culture or the resources involved [2]. Authors such as [3–6] propose that one of the activities of Requirements Engineering is related to requirements management, and this activity should manage the identified requirements, defining their relationships, allowing their traceability and facilitating changes when necessary.

Requirements management involves generating and managing considerable amounts of information about system requirements and, like other requirements engineering activities, it demands techniques and tools to assist in their realization. Despite the efforts of Requirements Engineering to propose solutions that help the execution of its activities, it is still possible to observe the need for proposals contemplating new approaches to improve requirements management, an activity considered transversal and in support of the others [5].

Software requirements are based on and also generate information [7, 8]. And it was taking into account that the main object of Requirements Engineering is information, whether as a subsidy for the definition of software requirements or being contained in the different documents generated throughout the process, that it was considered pertinent to investigate how the tools used by the information management area could contribute to the requirements management activity.

This investigation resulted in the proposition of a framework, called FIRMa – Framework based on Information Management to Requirements Engineering, composed of tools used by information management to be applied in the requirements management process with the objective of helping the development of the activities of (i) organization of requirements; (ii) control of the changes suffered by them; (iii) maintenance of traceability between them; and (iv) management of artifacts containing project requirements [9].

Therefore, this article focuses on presenting the application of taxonomies, one of the information management tools contemplated by FIRMa, as well as the results of the evaluation of its application in a real software development process that considered four aspects: complexity in its utilization, satisfaction with results, utilization of resources and adaptability.

The research that resulted in the elaboration of this article is characterized in terms of nature as applied research, aiming at solving real-world problems; as for the objectives as exploratory and descriptive; and as for the approach, mixed methods were used, since it associates forms of qualitative and quantitative research in the same study.

As for the structure of this article, Sect. 2 presents: concepts related to Requirements Engineering, focusing on requirements management activity; taxonomies as a tool used by the information management area to organize and categorize information and; some research has already been developed proposing the application of taxonomies to assist in the requirements management process.

Section 3 presents an analysis of the taxonomies' objectives in relation to the objectives of each of the four requirements management activities, namely: requirements organization; control of the changes suffered by them; maintenance of traceability between them; and management of artifacts containing the requirements. This analysis allowed us to verify that taxonomies can be considered to help all four activities.

Section 4 presents the stages and activities carried out during each one of them for the development of this research.

Section 5 presents the process we used to apply and evaluate taxonomies in a real software project. The criteria defined for the evaluation of taxonomies are exposed in relation to their applicability in the requirements management process and the results obtained with the application and evaluation of the tool are shown. The results showed that taxonomies: present low complexity in terms of understanding, applicability and use; are considered highly satisfactory about their possibility of contributing to requirements management; they do not require large resources and investments for their application and; have a high degree of adaptability, as they can be designed to meet any type of software project.

Finally, Sect. 6 presents the conclusions for this research and proposals for future work.

## 2 Background

### 2.1 Requirements Engineering and the Activity of Software Requirements Management

Requirements Engineering is considered a subarea of Software Engineering and belongs to the specification stage in the development process, in which the person responsible for the project's requirements seeks to understand what the real needs of users are with regard to solving the problem that arises.

Regarding the understanding of users' needs, requirements are considered a critical factor in software projects, because, if not well defined, they directly impact the success of the project. In addition, requirements are used to measure the size, complexity and, consequently, the cost of the software. Furthermore, when problems with the identification of requirements are detected late, there is a high cost to correct them.

From the perspective of [10], a software requirement is a condition or a capability that a software needs to have in order to meet the needs of its users. The requirements of a system are the descriptions of what the system must do, the services it offers and the restrictions on its operation and it can be classified as functional and non-functional. Functional requirements are statements of services that the system must provide, of how the system must react to specific inputs, and of how the system must behave in certain situations; and non-functional requirements, unlike functional requirements, do not express any function to be performed by the software, but rather behaviors and constraints that the software must satisfy [1].

According [6], Requirements Engineering involves the process of determining requirements, analyzing them, validating them and managing them throughout the project lifecycle. The requirements management activity can be defined as a systematic

approach to managing the requirements of the system, in the same way that it establishes and maintains an agreement between the client and the technical project team about the changes suffered by the requirements [11].

The requirements management process must provide a means for the requirements, which were previously identified, documented and validated, to be carefully controlled, in order to establish a baseline for project management. The artifacts containing the specifications of the software requirements are treated as the central document, being an element that has important relationships with other elements of the project. Problems caused by failures during the requirements management process in the software project are widely recognized and studies show that this is one of the areas with the highest incidence of failure in this type of project [12].

It is possible to find in the literature different proposals on which activities should be performed during the requirements management process. This article considers the activities recommended by [3–6], which suggest the following: (i) organizing the identified requirements; (ii) control the changes suffered by the requirements throughout the project; (iii) maintain traceability between requirements; and (iv) manage artifacts containing information about requirements.

### 2.2 Taxonomies in the Context of Information Management

The information management comprises a variety of activities and disciplinary areas, each focused on different types of information and management [13, 26]. Information management is composed of elements of a polysemic nature and, as such, is addressed in several areas of knowledge. At the same time that it presents influences from the areas of Administration, Document Management, Librarianship, Computing and Information Science, information management practices can also be applied in different sectors of society.

For [14], information management is an area of interest in Computing with regard to the development of support tools for information management in organizations. Such tools constitute a valuable resource in practically all organizational processes, supporting the identification of information needs, guiding the search and acquisition of information, and constituting the basis of the organization and storage of information, in addition to enabling the elaboration of and the distribution of information products and services.

Among the activities of the information management process are the organization and representation of information and one of the tools used to carry out this activity are taxonomies. A taxonomy can be defined as a classification system that supports access to information, allowing it to classify, allocate, retrieve and communicate information in a logical way. According to [15], a taxonomy organizes information from the most generic to the most specific, using the hierarchical relationship or the gender-species relationship between the terms.

In this context, [16] present four methodological steps to be carried out in the elaboration of a taxonomy: the first consists of surveying the areas of knowledge and the hierarchical relationships of the terms that will compose the first version of the taxonomy; the second is about to analyze the documents and information that will be added to the taxonomy in order to adapt the existing information in the collections to the terminology presented; the third refers to the elaboration of the preliminary version of the

taxonomy, including the specification of sub-terms in levels, as necessary; and the fourth concerns the validation of the preliminary version of the taxonomy with the professionals involved.

### 2.3 Related Works

In order to identify studies already carried out on the use of taxonomies in requirements management, we we realized a systematic literature reviews [25] using the string ("taxonomies" OR "taxonomy") AND ("requirements management" AND "software") in the following databases: Web of Science, Scopus, IEEE Xplore Digital Library (IEEE) and Library, Information Science & Technology Abstracts (LISTA). And we defined as inclusion criteria within the tools of each of the databases studies published between 2000 and 2020; studies that were publications in journals or publications in conference proceedings; studies that went through the peer review process; and studies in Portuguese, English and Spanish.

The results were analyzed and after that, we selected those published in journals and/or events recognized as of quality by the scientific community and those in which it was possible to identify in which or in which requirements management activities the proposed taxonomy was applied. Other factors that were considered in the selection of the study were whether it presented the taxonomy application process, as well as the results obtained with its application. Studies identified according to the defined criteria are presented below.

The paper presented by [17] defines a taxonomy to be used in different software projects in order to help control changes in requirements based on documentation, more specifically in cases containing the requirements. Another study with a similar purpose is presented by [18], in which the proposed taxonomy, based on the types of changes that occur in UML models, is used to identify changes between two different versions of the models, helping the identification of the impact of the changes.

In [19] is propose a taxonomy based on characterizing the factors that influence changes, but focusing on technical aspects (how, when, what, and where), rather than the purpose of the change (why) or the stakeholders interested in it (who). And in [20] pro-pose a taxonomy that considers the source (who) that requested the change, allowing distinctions between the factors that contribute to the uncertainty of the requirements.

Table 1 presents a comparison between the identified works and the study presented in this article. It is presented which requisition management activities are involved in the application of the taxonomy.

As can be seen, we identified that taxonomies have been used to assist the requirements management process, especially in what involves the activities of controlling changes to requirements and managing artifacts. What differentiates this study from those that have already been developed is that it is being proposed that taxonomies be used in the four activities of the requirements management process: organizing the requirements; control changes to requirements; maintain traceability between requirements; and manage artifacts containing information about requirements; and not only in a specific activity of this process.

**Table 1.** Works identified in the literature X objectives of this article.

| Publication | Requirements management activity |
|---|---|
| [18] | Artifacts management |
| [19] | Change control |
| [20] | Change control |
| [17] | Change control |
| This work | Organization of requirements; change control; maintenance of traceability, and management of artifacts |

## 3 Research Stages

For the development of this research, the steps presented in Table 2 were followed:

**Table 2.** Research stages.

| Stages | Description |
|---|---|
| 1. Identification of the problem to be solved | Based on the literature, we identified that one of the main factors of failure in software projects is related to the Requirements Engineering process [12]. And considering that requirements are information, we look for an area called information management tools used to assist this process, identifying taxonomies as one of the possible tools to be used in this context |
| 2. Analysis of taxonomies' goals in relation to requirements management goals | In order to verify if the taxonomies were indeed capable of being applied in Software Requirement Engineering, we carried out an analysis of their objectives in relation to the objectives of each of the activities of the requirements management process, and after this analysis we found that the taxonomies could help the activities of: requirements organization; control your changes; maintenance of traceability between them and management of artifacts containing the project requirements |
| 3. Definition of the process for applying taxonomies and criteria for evaluating the results | During this stage, we defined the project in which the taxonomy would be applied. We developed guidelines for applying the taxonomy in the context of requirements management, and defined the criteria for evaluating the results of applying the taxonomy |
| 4. Construction of a taxonomy to meet the requirements management of a project and evaluation of the results obtained | We built a taxonomy to help the requirements management process of a real software, and after its application, it was evaluated and classified considering four aspects of applicability: complexity of use in the context of software development, satisfaction with the results, use of resources and adaptability |

## 4 Analysis of Taxonomies' Objectives in Relation to the Objectives of Requirements Management Activities

To verify if in fact the taxonomies would be candidates to be used in the context of requirements management, we carried out an analysis to identify in which or which of the activities of the requirements management process they could add value to. The analysis was carried out based on the objectives of the taxonomies and the objectives of the requirements organization activities; control your changes; maintenance of traceability between them and management of artifacts containing the project requirements.

According to [15], a taxonomy is defined as a classification system that supports access to information, allowing to classify, allocate, retrieve and communicate information in a logical way, and can be used both for the organization of documents and for the organization of information related to a given context.

Despite having been identified in the literature proposals for the use of taxonomies to support the activities of control of the changes suffered by the requirements, and of management of the artifacts containing the information about the project requirements – as presented above; based on the objectives of this tool, we found that, in addition to assisting in the aforementioned activities, taxonomies can be used in requirements organization activities and also in maintaining traceability between them, through the classification of requirements and also of the documents generated.

## 5 Application and Assessment of Taxonomies in the Context of Software Requirements Management

To demonstrate that taxonomies can be used in the context of requirements management and meet the four activities of this process, they were applied in a project of a system to meet a need of the Personnel Management Department of a company in southern Brazil called Special License System, whose objective is to automate the process of requesting and authorizing the company's employees to enjoy a special leave, and after its application, the taxonomy created was evaluated in relation to its complexity, satisfaction, resources involved and adaptability.

### 5.1 Taxonomy Application

The taxonomy application process began at a meeting with those responsible for the Special License System requirements, where we presented the planned steps for the application and evaluation of the tool. Soon after, those responsible for the requirements made available the documentation containing the requirements and other artifacts already prepared. For the Special License System design, the team used the Enterprise Architect tool to document the functional requirements (FR), non-functional requirements (NFR) and business rules (BR); develop use case diagrams; and store images of screen prototypes to meet some of the requirements. And, to represent the most critical functional requirements, the Business Process Model and Notation (BPMN) and the Bizagi Modeler tool were used.

After analyzing the artifacts, we started the construction of the taxonomy based on the identified requirements and their documentation, which followed the four steps suggested in [16]: (i) capture of knowledge related to the taxonomy to be developed; (ii) analysis of the information that will compose the taxonomy; (iii) elaboration of the taxonomic structure; and (iv) validation of the taxonomy created.

To capture knowledge related to the taxonomy, we used all artifacts containing functional requirements, non-functional requirements, business rules, use case diagrams, prototypes and BPNM models prepared by the Special License System project team. It is important to emphasize that, in general, taxonomies are organized based on hierarchical categories, but for [21] this is not the most suitable option for those that aim to meet demands in corporate environments, since, for this purpose, they need to be flexible, pragmatic and coherent. Considering that a taxonomy, to meet the context of software development, has such characteristics, we chose not to use hierarchical categorization, but rather the associative classification, which is more recommended in these cases.

After the first step, we started the process of analyzing the information to compose the taxonomy, giving rise to four main classes: artifacts, business rules, functional requirements and non-functional requirements. Using associative classification, each class was subdivided, generating a structure to assist the requirements management process in its four activities: organizing the requirements, controlling the changes suffered by them, maintaining their traceability and organizing the documents containing the requirements. We classify the functional requirements and business rules according to the modules to which they belong in the Special License System, we classify the non-functional requirements according to the classification suggested by [22] – reliability, usability, performance and supportability – and we classify the artifacts according to the information contained in each of them. Figure 1 presents a part of the elaborated taxonomy.

In addition to the organization of requirements and artifacts, this classification structure enabled the establishment of requirements-requirements, requirements-business rules and requirements-artifacts relationships, allowing better traceability and, consequently, better control of its changes. We used the TemaTres[1] tool to build the taxonomy and the taxonomy created to meet the requirements management process of the Special License System is available in full at https://pbfagundes.com/firma.

[1] TemaTres is an open source tool for managing formal representations of knowledge, including thesauri, taxonomies, ontologies and glossaries. It is available for download at: https://www.vocabularyserver.com/.


**Fig. 1.** Part of the taxonomy elaborated for the Special License System.

### 5.2 Taxonomy Assessment

After preparing the taxonomy, we started its evaluation and, for that, we defined that the process would be composed of two steps: verifying if in fact the taxonomy meets the objectives of the requirements management activities to which it was related in the analysis carried out and presented in the Sect. 4; and classify the taxonomy in terms of its applicability in the requirements management process.

To classify the taxonomy in relation to its applicability, aspects of complexity, satisfaction, resources and adaptability were considered. These aspects were defined with reference to other research already carried out that addressed evaluation methods in models for Software Engineering and Requirements Engineering, such as those presented in [23–25], who suggest that techniques, tools, instruments, models or processes should be easy to use and understand, adaptable to different application contexts, and its results must satisfy the needs of the interested parties.

A set of questions was defined to evaluate each of the mentioned aspects, which composed an evaluation form where we used dichotomous questions (yes or no) and using a Likert scale from 1 to 4: 1. I totally disagree; 2. Disagree; 3. Agree; and 4. I fully agree.

The taxonomy elaborated was evaluated with the contribution of the professionals involved in the Special License System project. For each question, only one value was assigned, which, depending on the case, was a consensus among all. To arrive at the final classification of each of the aspects evaluated, the same value of the evaluation scale was considered – 1. I totally disagree; 2. Disagree; 3. Agree; and 4. I fully agree – for each of the questions answered, and the arithmetic average calculated, according to the formula presented in Fig. 2.

$$\frac{QV1 + QV2 + \ldots + QVn}{TI} = FAV$$

QV = question value;
TI = total aspect issues; and
FAV = final aspect value.

**Fig. 2.** Formula for calculating the final aspect value (FAV)

After calculating the final value of each aspect, which could vary from 1 to 4 in decimal values, it was necessary to define a rounding criterion to transform it into an integer value, which would be assigned to the final classification of the aspect (FCA), presented in Table 3. The description of each FCA for each of the aspects is presented in Table 4.

**Table 3.** Criteria for the final appearance classification (FAC).

| FAV | FAC |
|---|---|
| If FAV = 4 | 4 |
| If FAV < 4 e > =3 | 3 |
| If FAV < 3 e > =2 | 2 |
| If FAV < 2 | 1 |

Table 5 presents the form with the results of the assessment made for the taxonomy designed to help manage the requirements of the Special License System project.

**Table 4.** Description of the final aspect classification (FAC).

| Aspect | Description of Each Final Aspect Classification |
|---|---|
| Complexity | If FAC = 4 - No complexity<br>If FAC = 3 - Low complexity<br>If FAC = 2 - Medium complexity<br>If FAC = 1 - High complexity |
| Satisfaction | If FAC = 4 - Highly satisfactory<br>If FAC = 3 - Satisfactory<br>If FAC = 2 - Moderately satisfactory<br>If FAC = 1 - Unsatisfactory |
| Resources | If FAC = 4 - No need to use specific resources or investments<br>If FAC = 3 - Low need to use specific resources or investments<br>If FAC = 2 - Medium need to use specific resources or investments<br>If FAC = 1 - High need to use specific resources or investments |
| Adaptability | If FAC = 4 - High degree of adaptability<br>If FAC = 3 - Medium degree of adaptability<br>If FAC = 2 - Low degree of adaptability<br>If FAC = 1 - No adaptability |

**Table 5.** Taxonomy evaluation result.

| | |
|---|---|
| 1. Do you consider that the results obtained with the elaboration of the taxonomy helped the requirements organizationactivity? | (X) yes<br>( ) no |
| 2. Do you consider that the results obtained with the elaboration of the taxonomy helped the control activity in the alterations of the requirements? | (X) yes<br>( ) no |
| 3. Do you consider that the results obtained with theelaboration of the taxonomy helped the traceability activity among the requirements? | (X) yes<br>( ) no |
| 4. Do you consider that the results obtained with the elaboration of the taxonomy helped the activity of managing the artifacts? | (X) yes<br>( ) no |

| **Complexity Aspect** | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| 1. Guidelines for applying taxonomies are easy to understand. | | | X | |
| 2. No experience is required for its application in the requirements management process. | | | | X |
| 3. The taxonomy was easy to apply in the context of softwaredevelopment. | | | | X |

(*continued*)

**Table 5.** (*continued*)

| | | | | |
|---|---|---|---|---|
| 4. The generated artifacts were easy to understand and use by those responsible for the project requirements. | | | | X |
| **FAC - Complexity: 3 (Low complexity)** | | | | |
| **Satisfaction Aspect** | **1** | **2** | **3** | **4** |
| 1. The resulting artifacts were found to be useful for requirements management. | | | | X |
| 2. The results achieved the objectives of the requirements management activities for which it is proposed. | | | | X |
| 3. The effort required was satisfactory in terms of its contribution to the requirements management process. | | | | X |
| **FAC - Satisfaction: 4 (Highly Satisfactory)** | | | | |
| **Resources Aspect** | **1** | **2** | **3** | **4** |
| 1. It does not require the use of specific resources for itsapplication in the context of requirements management. | | | X | |
| 2. It does not require the use of specific resources for the use of artifacts resulting from its application in the context of requirements management. | | | | X |
| 3. It does not require financial investments for its application in the context of requirements management. | | | | X |
| 4. It does not require financial investments for the use of artifacts resulting from its application in the context of requirements management. | | | | X |
| **FAC - Resources: 3 (Low need to use specific resources or investments)** | | | | |
| **Adaptability Aspect** | **1** | **2** | **3** | **4** |
| 1. Taxonomies can be applied to any type of software development process. | | | | X |
| 2. You can apply taxonomies regardless of project size. | | | | X |
| 3. You can apply taxonomies regardless of the project domain. | | | | X |
| **FAC - Adaptability: 4 (High degree of adaptability)** | | | | |

### 5.3 Analysis of Application Results and Assessment of the Taxonomy in the Context of Requirements Management

Regarding their understanding, applicability and use, taxonomies present a low degree of complexity. The evaluation showed that there is no need for previous experience with the instrument itself; however, we believe that a prior knowledge of classification processes on the part of the person responsible for requirements management can help in its elaboration.

The evaluation carried out indicated that the taxonomy elaborated was classified as "highly satisfactory" in terms of its possibility of contributing to the management of the Special License System requirements, as well as in relation to the effort required for its application, since the results obtained reached the objectives of the requirements management activities to which they were related.

Regarding the resources needed for the elaboration of the taxonomy, we found that this tool does not need specific resources or financial investments for its elaboration and use, given that it can be built and visualized from tools available for free. However, we recommend the use of software that helps in the elaboration, maintenance and use of this type of tool, such as, for example, TemaTres.

Taxonomies can be developed to meet any type of software project and do not necessarily need to cover all requirements and/or all artifacts generated for the project. If the person responsible for managing requirements identifies, for example, the need to develop a taxonomy that meets only the artifacts containing the requirements, it can be developed. The important thing to highlight in this case is that those responsible are aware of the real needs involved with the application of this instrument and that the success of its use is directly related to the purpose it seeks to meet.

## 6 Conclusions

Although there are proposals in the literature involving the use of taxonomies to meet some of the activities of the requirements management process, we found that taxonomies can contribute to the process as a whole, confirming the analysis presented in Sect. 4. Therefore, it can be said that the evaluation showed that this instrument can be considered within the scope of requirements management for:

- organize the requirements, once they have been classified and organized into classes according to specific characteristics previously defined;
- help control the changes suffered by the requirements, because from this organization and classification it was possible to establish relationships between them, so that, if a requirement is changed, it is possible to identify the other requirements related to it;
- maintain traceability between requirements (vertical traceability) and between requirements and their artifacts (horizontal traceability), because from the established relationships it was also possible to define traceability points. However, it should be noted that navigability between them is only possible through a tool that allows this action; and
- enable better management of artifacts, since the artifacts were classified according to their contents and related to the requirements contained in each of them.

We also concluded that the taxonomic structure to be used must meet the objectives defined for the taxonomy, there being no single guideline for its elaboration in the context of requirements management. The definition of the classes and subclasses that will be used in its structure must be based on the needs and objectives of its use in requirements management, and the decision must involve the person responsible for managing the requirements and the users of the taxonomy.

An important issue is the timing of taxonomy construction in the Requirements Engineering process. For the Special License System, it was elaborated after defining the general requirements of the system and after elaborating some technical artifacts; however, we believe that the taxonomy can be structured even before the requirements identification activity. As requirements are identified and artifacts are created, they are associated with classes and subclasses created.

Although we came to the conclusion that taxonomies may contribute to the requirements management process, it was not possible to establish the extent of this contribution. For this, it would be necessary to apply them in different projects and contexts and compare the results obtained. Thus, it is suggested that one of the proposals for future work is the development of studies that can continue this investigation, based on the definition of criteria for the assessment of the impacts of the application of taxonomies in the requirements management process.

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