Mechanisms to Support Requirements Prioritization: A Systematic Mapping Review

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Abstract. Requirements prioritization is applied to identify which artifacts must be implemented first, in order to create a product that best satisfies the customer's need by using the smallest number of resources. However, the task of prioritizing requirements is challenging and complex, and there is no well-defined set of mechanisms that help this activity. This article aims at identifying and analyzing the mechanisms to support the requirements prioritization. So, a systematic mapping review was conducted. The result is a report that presents the different types of publications (journals, conference papers, thesis, book chapters), the published year, the supporting mechanisms, the phases of the requirements engineering process, and the prioritization techniques and tools used. It was observed that the prioritization requirements field is quite needy of mechanisms and tools that support this activity, mainly that ones that provide visual resources.

Keywords: requirements engineering, requirements prioritization, supporting mechanisms, systematic mapping review.

1 Introduction

The prioritization of software requirements consists of identifying the most important requirements for the software being developed and for its stakeholders, as well as optimizing the delivery planning of its releases. Requirements prioritization can be defined as an activity within requirements engineering (RE), which aims at supporting several tasks, such as, guiding the planning releases, helping with stakeholder negotiation and pondering among benefits for the business and project constraints [1].

In order to prioritize requirements efficiently, it is necessary to establish the objective(s) for which to prioritize, such as: the choice of the prioritization criterion, the importance of requirements, involved risks, costs, development time, and volatility of requirements. Generally, software developed using requirements prioritization have a high degree of acceptance by customers and clients [2]. But, the prioritization of requirements is usually a costly activity in the process of RE, since it requires time for its application, availability of the involved stakeholders, analysis of the dependency between requirements, etc. In addition, there is a lack of methods, processes, models and frameworks that help the requirements engineer to plan, organize, structure and represent the information that involves the prioritization of requirements.

There are several specific modelling languages for RE, like: KAOS [10], iStar [11], AGORA (Attributed Goal Oriented Requirements Analysis Method) [12] ereqT [13]. However, they do not represent concepts intrinsic to the planning and execution of prioritization, such as the applied prioritization technique, criteria used, stakeholders, and stakeholder weight. As a result, several aspects of requirements prioritization become neglected.

On the other hand, various studies, such as Gotel et al. [7], Savio and Poothiyot [8] and Carod & Cechich [9], highlight the relevance of RE artefacts to have visual representations, in addition to textual ones. In Carod &Cechich [9], the authors explored the relationship between prioritization of requirements, adherence to the cognitive skills of each participant. The results indicate that both visually impaired individuals and persons with non-visual personality present a high degree of satisfaction in performing the prioritization of requirements with visual requirements artefacts. One hypothesis is that the use of visual representations helps in the reasoning of planning, organization and execution of requirements prioritization. This hypothesis serves as a starting point and foundation for research.

In this context, we recognize the importance and motivation to execute of a systematic mapping review (SMR), in order to identify, establish and analyse how requirements engineering is being realized.

Despite the existence of some systematic and mapping literature reviews in the context of requirements prioritization, like [2], [6], [8], and [9], none of them focus on the identification of mechanisms used and existing visual representations, in the context of requirements prioritization. In [2] the authors focus in identifying limitations, taxonomies, and processes of existing prioritization techniques; they consider papers up to December 2013. In [6] focus in investigating search-based software engineering (SBSE) approaches for addressing requirement selection and prioritization problems. In [8] the authors present a collection of prioritization criteria structured in six major categories and 31 subcategories; they analysed relevant studies up to 2014. In [9] the authors present a systematic mapping study that aims at understanding requirement prioritization artefacts; it considers relevant studies up to December 2015. Mainly, the gap of this is studies can be observed as they not consider visualization resources.

This article is organized as follows. Section 2 describes the research protocol used, including the search process, selection of studies, data extraction, limitations and threats to validity. Section 3 introduces an overview of the results and answers to the research questions. Finally, section 4 presents the conclusions and directions for future work.

2 Research Protocol

The SMR counted on the participation of three postgraduate students, in a master's degree level, responsible for carrying out the systematic review, two professors who supervised the implementation of the review, and three experts (Dr.Björn Regnell - Lund University, Sweden; Dr. Marjan Mernik - University of Maribor; and Dr.

Norman Riegel - director of OSSENO Software GmbH, Germany) who provided advice by indicating primary studies. This SMR followed the process pointed out by [3].

2.1 Research Questions

The purpose of this SMR is to identify and analyze the mechanisms to support the requirements prioritization within RE. The goal is to answer the main question of the research: "How are the support mechanisms for requirements prioritization supported in the requirements engineering process?". Based on this question, other five were defined and are detailed in Table 1.

Table 1. Research Questions, Description and Motivation

Secondary Research Questions	Description and Question Motivation
RQ1 - What are the mechanisms used to support the prioritization of requirements?	Identify which existing mechanisms in the literature support the requirements prioritization, such as: model, method, frame work, textual language, modeling language, algorithm, DSL, DSML, among others.
RQ2 - Do the mechanisms include visual elements to represent aspects of requirements prioritization?	For the visual elements, the search includes: visual representation of prioritization techniques, criteria, requirements, and involved stakeholders
RQ3 - What are the phases of the requirements engineering process that support the prioritization supporting mechanisms?	Identify the stages of the requirements engineering process that support supporting mechanisms for requirements prioritization. It was considered the stages established by [4]: elicitation, analysis and negotiation, specification, validation and management.
RQ4 - What are the prioritization techniques used by the supporting mechanisms for requirements prioritization?	Identify which requirements prioritization techniques (such as: AHP, MoScoW, Hundred Dollar, Wiegers matrix, among others) might be used together with the prioritization supporting mechanisms.
RQ5 - What are the tools used by the prioritization supporting mechanisms?	Identify which tools support the prioritization supporting mechanisms.

In this SMR, we considered the term "mechanisms to support the requirements prioritization" (MSRP) any structure that influences directly the final result of the requirements prioritization process. Because of this, mechanisms that have as diverse characteristics, as for example, model and algorithm were identified.

Also, for this SMR, it was considered literature from different types of publication, such as: journal, conference and workshop articles, book chapters, and doctoral and master's thesis.

2.2 Search Process

The rigor of the search process is the factor that distinguishes systematic reviews from other types of reviews [3]. In this SMR, the search process, selection and analysis of studies counted on four different phases:

- Phase 1 (Preliminary selection): Choice of research sources, specialists, execution of search strings in automatic and manual sources;
- Phase 2 (First selection): Reading of titles, keywords and abstract. Works that are not in the context of this SMR were deleted;
- Phase 3 (Second selection): Reading of title and conclusion, considering inclusion and exclusion criteria;
- Phase 4 (Final selection): Reading of the potentially relevant studies, considering the quality criteria. Afterwards, the included studies were documented through forms for data extraction.

The preliminary selection phase was based on the choice of research sources and search execution through the defined string. For this research, seven search sources were used, being four of them automatic search engines: IEEE[1], SCIENCE DIRECT[2], ACM[3] and SPRINGER LINK[4] (for which some minor manipulations have to be done in the search string, due to dependencies to the libraries); two manual search engines: REFSQ[5] (International Working Conference Requirements Engineering: Foundation for Software Quality) e RePriCo[6] (Workshop on Requirements Prioritization and Communication); besides the participation of some experts from the area. Both the search engines and the chosen specialists are justified by their relevant role in Software Engineering, especially in the field of Requirements Engineering.

The search string has been developed for the purpose of comprising the maximum of synonyms and variations related to the expressions “support mechanism” and “requirements prioritization”. We sought for synonyms of this expressions in: articles, reviews, systematic mappings and dictionaries. The string is presented in Table 2.

Table 2. Search string applied in SMR.

Search String
(language OR expression OR “modeling language” OR representation OR “domain specific language” OR “domain specific modeling language” OR DSL OR DSML OR notation OR specification) AND (“requirements” OR “requirement”) AND (“prioritizing” OR “prioritization”)

The words “prioritisation” and “prioritising” were inserted in the search string, but from the results, it turned out that the number of articles was the same with or without those words.

1 http://ieeexplore.ieee.org/Xplore/home.jsp
2 http://www.sciencedirect.com/
3 http://dl.acm.org/
4 http://link.springer.com
5 https://refsq.org
6 http://www.icb.uni-due.de/researchreports/reportliste/

2.3 Quality Criteria

In the preliminary selection, the potentially relevant primary studies were obtained and secondly, they were analyzed. For this purpose, it was necessary to indicate some inclusion, exclusion and quality criteria. We decided not to accomplish many restrictions regarding the use of research filters. So, the results returned by the automatic search engines had only the "publication date" filter, with a 10 years period, which corresponds to the period of 2006 to 2016. The same filter was used for manual searches. The description of the inclusion and exclusion criteria are presented in Table 3. Altogether, six quality criteria were defined based on [5], [6] e [2]. All the questions of the criteria have possible answers that vary among the values N=0, P=0.5 and Y=1, in which 0 corresponds to the minimum score, 0.5 to the medium score and 1 to the maximum score. It was established that the studies that scored below 3.0 would be discarded. Table 4 shows the quality criteria and their respective possible answers.

Table 3. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
- Studies in English language	- Studies in different languages than English
- Studies that respond to one, or more than one, of the questions defined in this review	- Studies that does not show bibliographic, information, year of publication and references
- Studies that include support mechanisms to requirements prioritization techniques	- Studies that are not related to the systematic review focus
- Studies that include support mechanisms requirement prioritization process	- Studies whose abstract and keywords show that they are not related to the systematic review
- Studies during the period of 2006 to 2016	- Studies conducted prior to 2006

Table 4. Quality criteria.

Questions of Quality Criteria
QC1 - Are the research goals clear?
QC2 - Are the results of the research clearly described?
QC3 - Is there a precise description of the context (industry, academy, among others) in which the validation of the research was made?
QC4 - Is the study based on any research? (or has it simply used "learned lesson" based on experience and expert opinion)?
QC5 - Did the research use or developed any tool?
QC6 -Is there any limitation, restriction or threat to the validity in the results?

2.4 Data Extraction

The data extraction was performed through the use of a spreadsheet divided into several tabs corresponding to each source used. Each tab of the spreadsheet comprised the following fields: Identifier; Title; Year; List of authors; type of study, Keywords;

Prioritization technique; Tools; Requirements Engineering Process; Support Mechanisms for the Prioritization and subjective extraction of results.

The extraction of the prioritization support mechanisms was performed by the description of the features that the studies showed regarding the use of requirements prioritization in the requirements engineering process.

2.5 Threats to Validity

The review protocol followed some steps pointed out by [3], in order to ensure that the research is as clear and direct as possible. However, some possible limitations were identified, and no specific action was done to avoid them. The first limitation refers to the inclusion of studies only in English; the restriction on studies in only one language may have failed to potentially find relevant studies. The second limitation refers to the returned studies, the search string used may not encompass all the existing synonyms for the terms "Prioritization support mechanisms", and, consequently, have been insufficient to capture all the relevant studies of the area.

3 Presentation of the Results

The SMR counted on the participation of 8 persons: 3 postgraduate students responsible for carrying out the main process of the systematic mapping, 2 professors who supervised the implementation of the review, and 3 experts who indicated primary studies. This SMR followed the process pointed out by [3].

3.1 Selection and Data Extraction Process

The selection of works was done in 4 phases: preliminary selection, first selection, second selection, and final selection; each one is detailed next, with the respective results.

For preliminary selection we considered: the research sources, experts, and search string execution (in manual and automatic sources). The results included a total of 878 studies returned. None of the automatic databases presented access problem. Table 5 describe the amount of returned studies according to each research source.

Table 5. Preliminary selection of studies

Preliminary Selection (Automatic Search/Manual Search)	
Sources	**Returned Studies**
IEEE XPLORE	116
SCIENCE DIRECT	26
ACM	233
SPRING LINK	217
REFSQ	246
RePriCo	27
EXPERTS INQUIRY	13
TOTAL	878

After, the first selection phase comprised: reading the titles, abstracts and keywords of the returned studies from the previous step. By the end of this selection, 596 studies were excluded, and 282 studies were selected to the second selection. The details of this phase can be viewed in Table 6.

The second selection phase included the reading of the introduction and conclusion of each study, in order to verify if they were compatible with the criteria of inclusion and exclusion. The excluded studies were divided into 3 categories: irrelevant according to the focus of this SMR, duplicated, and does not meet the inclusion and exclusion criteria. By the end of this phase, we obtained: 77 relevant studies that proved to be compatible with the focus of this SMR; and 194 irrelevant studies, 8 duplicated. and 3 does not meet the inclusion and exclusion criteria, totalizing 205 excluded studies. Table 7 summarizes this step.

Table6. First selection of studies

1st Selection (Title, Keyword and Abstract)		
Sources	**Excluded**	**Relevant Studies**
IEEE XPLORE	45	71
SCIENCE DIRECT	24	02
ACM	185	48
SPRINGER LINK	132	85
REFSQ	192	54
RePriCo	18	09
EXPERTS INQUIRY	-	13
TOTAL	**596**	**282**

Table 7. Summary of the second selection of studies

2nd Selection (Introduction and Conclusion)				
Sources	**Irrelevant**	**Duplicated**	**Does not meet the inclusion and Exclusion Criteria**	**Included Studies**
IEEE XPLORE	48	01	-	22
SCIENCE DIRECT	01	-	-	01
ACM	36	-	-	12
SPRINGER LINK	66	01	-	18
REFSQ	43	-	-	11
RePriCo	-	09	-	09
EXPERT INQUIRY	-	06	03	04
TOTAL	194	**17**	**03**	**77**

At the final selection phase, the integral reading of the studies was performed, and the adherence, of works with the quality criteria, was analyzed. At this phase, 24 studies were excluded because they did not meet the specified quality criteria. With the goal of bringing more complete information, it was also decided to make an analysis of the references used in the studies; this resulted in the inclusion of two more studies.

After a meticulous evaluation and exchange of information among the SMR participants, the result was: 55 selected studies and 825 excluded. Table 8 shows the amount of included and excluded studies according to each resource source. A complete list of all selected papers with their respective quality indexes are available at the address: http://robertafagundes.wixsite.com/raaf/wer2018.

Table 8. Final selection of studies

Final Selection (Potentially Relevant Studies)		
Sources	**Does not meet the quality criteria**	**Included studies**
IEEE XPLORE	08	14
SCIENCE DIRECT	-	01
ACM	-	12
SPRINGER LINK	05	13
REFSQ	06	05
RePriCo	05	04
EXPERTS INQUIRY	-	04
REFERENCEANALYSIS	-	02
TOTAL	**24**	**55**

3.2 Overview of the Results

The information presented in Figure 1 shows the selected studies published between 2006 and 2009. The years of 2006 and 2009 show the worst results (1,8%), with none published study in 2006, and only 1 in 2009. During the years of 2007 and 2008 there was an increase in the number of publications with 8 studies (14,5%), and between 2010 and 2015 there was also a considerable increase (80%) being 2010 the biggest highlight with 10 studies (18%). Until the first half of 2016 year, only 2 studies had been published (3,6%).

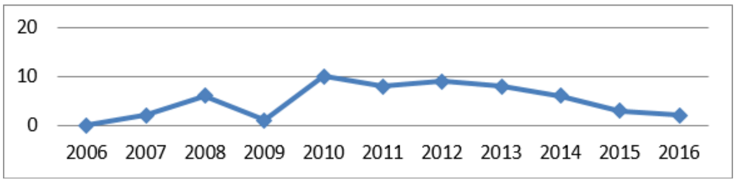

Fig. 1. Number of papers per year of publication

Despite the obtained results in 2009, it is possible to notice an increase in the number of publications in the analyzed period, suggesting a growing interest in the requirements prioritization field, including the prioritization support mechanisms.

Figure 2 shows the number of selected studies by means of publication. Most of the studies had their origin from journals s (32 articles, 56%), followed by workshops (11 articles, 21%), book chapters (5 articles, 9%), conferences (5 articles, 9%) and thesis (2 articles, 5%). According to the results, it is possible to deduce that the increase in the interest in the requirements prioritization field in the past years, stimulated an increase in the number of publications, mainly in journals and magazines, due to the fact that they commonly reach easily the target audience.

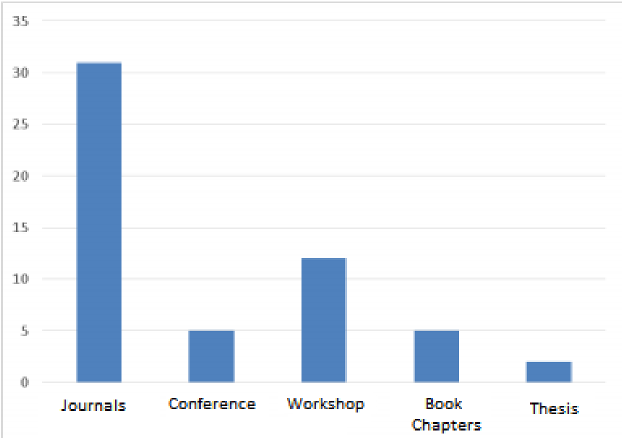

Fig. 2. Number of studies per year type of publication

3.3 Research Questions

Concerning the first research question:

"RQ1: What are the mechanisms used to support the prioritization of requirements? Do they include visual elements to represent aspects of requirements prioritization?"

It is possible to observe, see Figure 3, that in the published papers, the most prominent approach is the Model, with a total of 13 (23,6%), followed by the Framework with 9 (16,3%) papers. Right after are Methods and Algorithms, each one with 8 (14,5%); then comes Matrix and Domain Specific Language (DSL), each one with 4 (7,2%); Process with 3 (5,4%), Simulation and Heuristic Recommendation Group each one with 2 (3,6%). The ones with less representativity are Textual Linguistics and Language of Patterns, each one with 1 (1,8%). The results are important for identifying how requirements prioritization have been realized.

Concerning the second research question:

"RQ2: Do the mechanisms include visual elements to represent aspects of requirements prioritization?"

For this question, it was noticed that only 8 (14,06%) of the MSRP have visual elements that represented aspects (elements/particularities) present in requirements prioritization, such as: stakeholders, requirements, criteria and prioritization techniques. Some of the works include [13, 14, 15, 19, 20, 21]. Of these, none had more than three elements that represented essential components of the prioritization requirements. So, it was identified a lack of a single mechanism that concentrates and visually represents the main components that integrates the requirements prioritization process. More details about the visualization elements and corresponding works are detailed in [18].

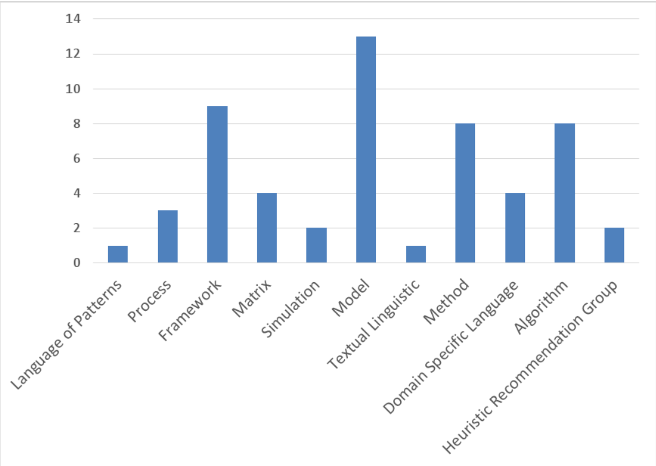

Fig. 3. Number of studies that indicates the types of MSRPs

Regarding the third research question:

RQ3: What are the phases of the requirements engineering process that support the prioritization supporting mechanisms?

It is possible to consider that, according to Figure 4, the Analysis and Negotiation phase obtained more representations, with 18 (32,7%) studies, followed by Elicitation with 12 (23,6%). Management phase with 8 (14,5%), Specification phase with 5 (9%), and finally, Validation with 1 (1,8%).

There were works that did not indicate the stage of the requirements engineering process that support the MSRP; they correspond to 10 (18,1%) of all analyzed papers. On the other hand, it is important to point out that only two studies presented more than one stage. The phases of the RE process considered here were based on [4].

The results from this research question present greater prominence of the Analysis and Negotiation and Elicitation phases, due to the fact that they are stages in which there is interaction with the user, stakeholders conflict resolution, clarification of ambiguous requirements and trade-offs.

Klaus Pohl in [7] says that requirements prioritization is an activity that is in every requirements engineering process, acting in a different way according to the nature of each stage of the process. The obtained results show that the same occurs to the mechanisms that support the requirements prioritization.

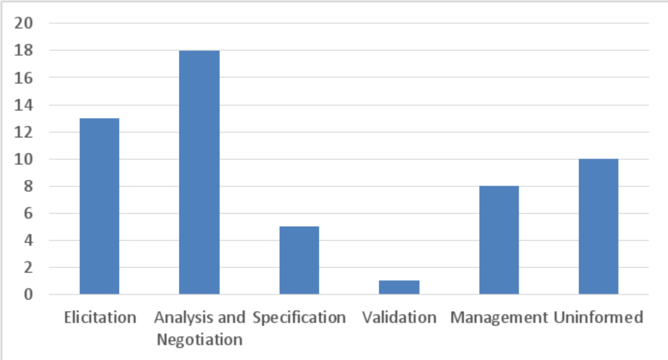

Fig. 4. Number of studies mentioning MSRP according to the phases of RE

Regarding the fourth research question:

"RQ4. What are the prioritization techniques used by the supporting mechanisms for requirements prioritization?"

It is possible to verify, see Figure 5, that the prioritization technique that is most evident is the Analytic Hierarchy Process (AHP), with a total of 12 (21,8%) published studies. Right after comes Hundred Dollar ($100) or Cumulative Voting (CV), with 7 (12,7%) studies, following are MoSCoW and Ranking techniques, each one with 5 (9%) studies.

The techniques, Quality Function Deployment (QFD), Planning Game (PG) and they all had 3 (5,4%) studies with, following the techniques, Technique of Ordered Preference (TOPSIS), Wiegers Matrix, Numerical Assignment Technique (NAT) and Binary Search Trees (BST (B-Tree) with 2 (3,6%) each and finally the techniques of lesser representativity, Binary Priority List (BPL), Value Oriented Prioritization (VOP), Fuzzy AHP, Kano Model, Analytic Network Process (ANP), Cost-value, Value Charts and Multiple-Criteria Decision-Making (MCDM) with 1 (1,8%).

Philip Achimugu et al. in [2] evidences the AHP as the most cited prioritization technique. The obtained results show that the same occurs to the mechanisms that support the requirements prioritization.

Most of the published papers do not mention the prioritization techniques used by MSRP, these studies correspond to 25 (45,4%) of all analyzed works. These demonstrates that the prioritization technique is still done, in many situations, in ad-hoc way, without formalism and using as main prioritization criterion the feeling of the process participants [8].

On the other hand, it is important to point out, that 5 (9%) studies show the use of more than one prioritization technique. Some of the prioritization techniques that are used together include: AHP with $100, AHP with ranking, MoSCoW with PG and MCDM with Value Charts. These results confirm that the association of different prioritization techniques is valuable, as they tend to complement each other. However, before using more than one prioritization technique the context where the technique will be applied must always be analyzed [8].

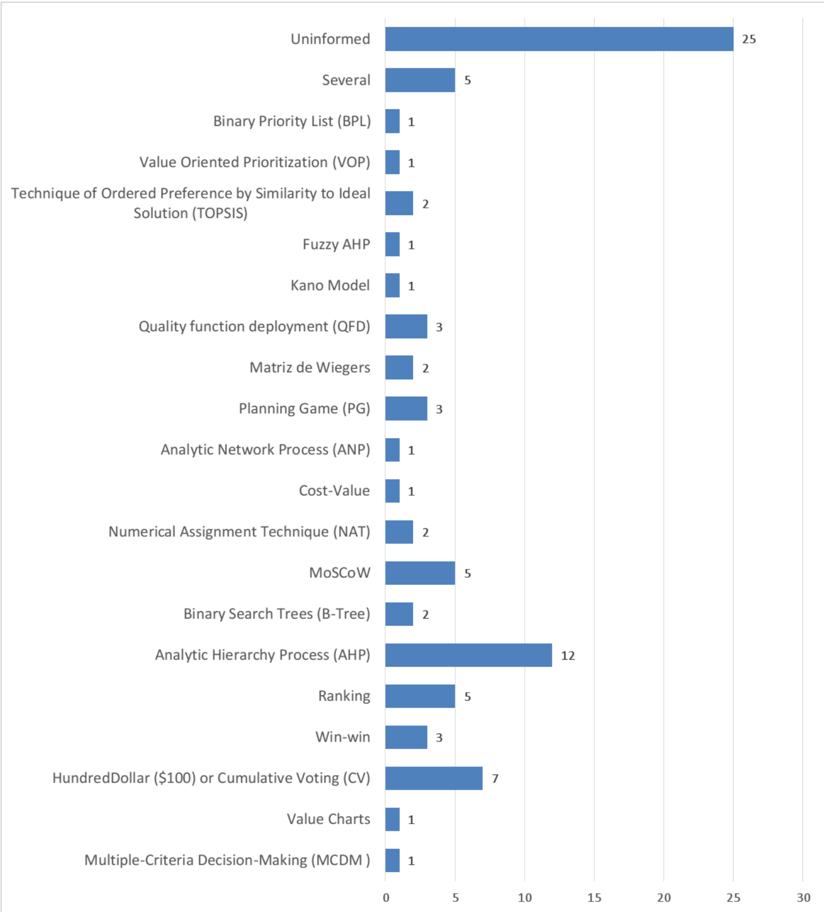

Fig. 5. Number of studies citing prioritization techniques used by MPRPs

Regarding the fifth research question:

"RQ5. What are the tools used by the prioritization supporting mechanisms?"

It is possible to verify in Figure 6 that the most evident tool is reqT, with 3 (5,4%) published papers. Right after are: PerOpteryx , IntelliReq and Winbook each one with 2 (3,6%) papers. They are followed by MS Office Excel, Organization Risk Analyzer (ORA), SimSWE, Quality Function Deployment (QFD), CARL, RE-Context, Community Z Tools, SMT solver Yices, AGORA Tool, Ar-go UML and ReqTGUI each with 1(1%) paper.

It is possible to verify that the number of papers that do not mention any prioritization tool, used by MSRP is large, correspond to 31 (56,3%) of all analyzed studies. These results demonstrate that the prioritization process has a lack of tools that support the MSRP. Nevertheless, the results also show a growing interest in changing this scenery, 4 (7,2%) of the papers present prototypes still in development.

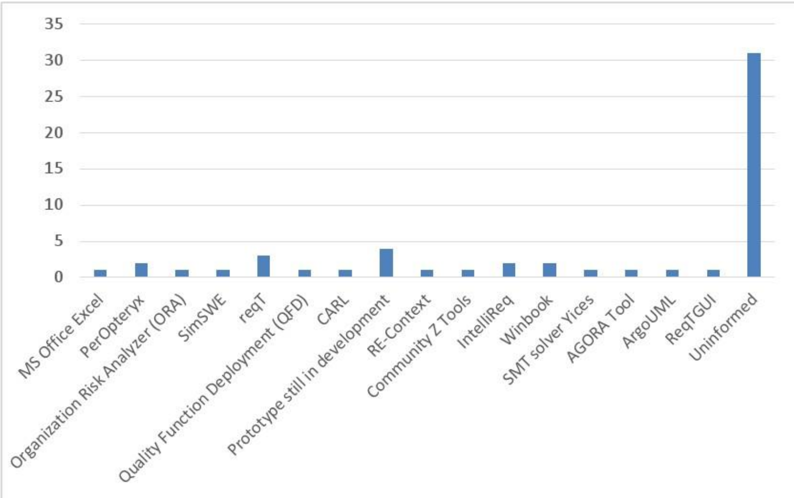

Fig. 6. Number of studies showing tools used by MSRP

4 Final Considerations and Future Work

This article presents a SMR aiming at investigating mechanisms that support the requirements prioritization. The achieved results present the types of publications, the years of publications, the mechanisms found, the stages of the requirements engineering process, and the prioritization techniques and tools applied. It was noticed that few studies report elements in the context of requirements prioritization, mainly through visual resources, representing a limited scope of prioritization's elements. So, it was identified a lack of a single mechanism that concentrates and visually represents the main components that integrate the requirements prioritization process. Besides, the obtained results also show the AHP as the most used prioritization technique, and the phases of Analysis and Negotiation and Elicitation as the most cited ones. Regarding the tools, many studies do not use this resource, but there is a growing interest in changing this scenery because some works show some prototypes still in development.

This study contributes mainly with fundamentals for the proposal of a Model for Requirements Planning and Prioritization, detailed in [18]. It also contributes to the RE community, with identification and analysis of a variety of mechanisms to support the requirements prioritization and verification of how they are supported in the requirements engineering process. For future work, we suggest considering, in the already identified mechanisms, elements that visually represent particularities of requirements prioritization, such as, stakeholders, requirements, criteria and prioritization techniques. Therefore, it is intended to provide a preliminary analysis on the overview of the requirements prioritization of a project, through the gathering of relevant and related concepts, in order to better rationalize, in a cognitive way, prioritization strategies.

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