DOI: 10.15514/ISPRAS-2023-35(1)-10

A Systematic Mapping Study on Process Improvement in Software Requirements Engineering

S. Almeyda, ORCID: 0000-0002-4943-0904 <silvana.almeyda@pucp.edu.pe>
A. Dávila, ORCID: 0000-0003-2455-9768 <abraham.davila@pucp.edu.pe>

Pontificia Universidad Católica del Perú,
Lima, Perú, 15088

Abstract. Software analysis is the process carried out to obtain requirements that reflects the needs of a client's stakeholders and that allows the construction of a software product that meets their expectations. However, it is also known as a process where many defects are injected. In this context, although process improvement has contributed to the software industry, in the case of software requirements it needs to be studied to determine the improvements obtained and established models. In the literature reviewed, a similar mapping study with 4 research question was identified and used as a reference. The objective of this work is to structure the available literature on process improvement in the software requirements engineering (SRE) domain to identify the improvement phases, paradigms, principles, and established models. For this purpose, a systematic mapping study (SMS) was carried out in the most recognized digital databases. The mapping carried out recovered a total of 1,495 studies, and after the process, 86 primary studies were obtained. In this SMS had established and answered 13 research questions. The different models that are applied throughout the software requirements engineering process were identified, and accepted studies were classified and findings on SRE process improvement were collected. The most used models are CMMI, Requirements Engineering Good Practice Guide (REGPG), and ISO/IEC 15504. Also, 62% of accepted studies are of the proposal and evaluation type; that is, they propose a framework and study the implementation of a proposal in one or more case studies respectively. On the other hand, it was found that most of the studies focused on the process improvement analysis phase. Likewise, in contrast with a previous study, proposal and validation type of studies increased in 9 papers each one from 2014 to date. This shows the interest of the scientific community in this domain.

Keywords: software analysis; software requirements engineering; systematic mapping study; software process improvement

For citation: Almeyda S., Dávila A. A Systematic Mapping Study on Process Improvement in Software Requirements Engineering. Trudy ISP RAN/Proc. ISP RAS, vol. 35, issue 1, 2023. pp. 141-162. DOI: 10.15514/ISPRAS-2023-35(1)-10

Acknowledgments. The authors acknowledge Dr. Daniel Méndez for the information shared from his SMS. Authors recognize reviews from members of Grupo de Investigación y Desarrollo en Ingeniería de Software-Pontificia Universidad Católica del Perú (GIDIS-PUCP).

Систематический обзор литературы по совершенствованию процессов разработки требований к программному обеспечению

С. Алмейда, ORCID: 0000-0002-4943-0904 <silvana.almeyda@pucp.edu.pe>
А. Давила, ORCID: 0000-0003-2455-9768 <abraham.davila@pucp.edu.pe>
Папский католический университет Перу,
Перу, 15088, Лима

Аннотация. Анализ программного обеспечения – это процесс, выполняемый для получения требований, которые отражают потребности заказчиков, и позволяющий создать программный продукт, отвечающий их ожиданиям. Однако хорошо известно, что в этом процессе порождается множество дефектов. Хотя усовершенствование процессов разработки внесло свой вклад в индустрию программного обеспечения, процесс разработки требований к программному обеспечению нуждается в дополнительных исследованиях для определения достигнутых улучшений и используемых моделей. В рассмотренных литературных источниках было выявлено и использовано в качестве эталона аналогичное систематическое исследование с четырьмя исследовательскими вопросами. Целью данной работы является структурирование доступной литературы по улучшению процессов в области разработки требований к программному обеспечению для определения этапов совершенствования, парадигм, принципов и моделей. Было проведено систематическое исследование с использованием наиболее признанных баз данных цитирования. В общей сложности было выявлено 1495 исследований, после анализа которых было отобрано 86 основных исследований. Использовались 13 исследовательских вопросов. Были определены различные модели, которые применяются в процессе разработки требований к программному обеспечению, классифицированы выполненные исследования и собраны результаты по улучшению процесса разработки требований. Наиболее часто используемыми моделями являются CMMI, Requirements Engineering Good Practice Guide (REGPG) и ISO/IEC 15504. 62% отобранных исследований относятся к типу предложений и оценок; то есть в них предлагается некоторый фреймворк и изучается возможная реализация предложения в одном или нескольких частных случаях. Было обнаружено, что большинство исследований сосредотачивалось на этапе анализа способов совершенствования процесса. Аналогичным образом, в отличие от предыдущего исследования, с 2014 года по настоящее время количество публикаций типа предложений и валидации увеличилось на 9 статей. Это свидетельствует об интересе научного сообщества к этой области.

Ключевые слова: анализ программного обеспечения; разработка требований к программному обеспечению; систематический структурный обзор литературы; совершенствование процесса разработки требований

Для цитирования: Алмейда С., Давила А. Систематический обзор литературы по совершенствованию процессов разработки требований к программному обеспечению. Труды ИСП РАН, том 35, вып. 1, 2023 г., стр. 141-162. DOI: 10.15514/ISPRAS-2023-35(1)-10

Благодарности. Авторы признательны д-ру Даниэлю Мендесу за информацию, почерпнутую из его обзора. Благодарим за отзывы членов Группы исследований и разработок в области программной инженерии Папского католического университета Перу.

1. Introduction

The software industry continues to evolve, and new techniques, tools, and good practices are increasingly being applied to improve the software life cycle. Likewise, software continues to revolutionize the world and people's lives, causing a favorable impact on organizations [1]. However, in the software industry, there are many reports of software anomaly related to software requirements [2].

In the software development, there is software requirements engineering process, which is a key stage during the entire software life cycle, since the requirements that reflect the user's needs are obtained [3]. The main measure of the success of a software system is the degree to which it fulfills the purpose for which it was designed [3]. In this context, Software Requirements Engineering (SRE) is the process of discovering that purpose, by identifying the interested parties and their needs, documenting them in a way that is susceptible to analysis, communication, and subsequent implementation [4]. However, in the industry [5], a few people have had significant experience in requirements management, and many people do not properly distinguish between user requirements and system requirements [5].

According to ISO/IEC/IEEE 29148:2018, requirements engineering is concerned with discovering, eliciting, developing, analyzing, verifying, validating, communicating, documenting and managing requirements [6]. Likewise, it is indicated that the system requirements specification is a structured collection of requirements, that is, it involves functions, performance, design constraints and other attributes for the system and its operational environments and external interfaces [6]. On the other hand, the software requirements specification is also a structured collection of essential requirements that, in this case, involves functions, performance, design constraints, and attributes of the software and its external interfaces [6].

On the other side, Software Process Improvement (SPI) is used in the software industry as a way to move from current inefficient software processes towards processes that achieve the established objectives in terms of quality, time, and productivity [7]. In addition, SPI methodology is defined as a sequence of tasks, tools, and techniques that are performed to plan and implement improvement activities [8].

Software requirements engineering and process improvement have been identified as key processes to improve software quality [7]. In this sense, Méndez's work represents an initial work of the present study [9]. Mendez's study raises 4 research questions about REPI (requirements engineering process improvement): (i) Of what type is the research?, (ii) Which process improvement phases are considered?, (iii) What paradigms do the publications focus on? and (iv) Are the underlying principles of normative or of problem-driven nature? [9].

The objective of this study is to structure the available literature on process improvement in the software requirements engineering (SRE) domain to identify the improvement phases, paradigms, principles, and established models through an SMS in the relevant digital databases such as Scopus, IEEE Xplore, Web of Science, ACM Digital Library, Science Direct, Wiley Online Library, ProQuest, Ebsco, and SpringerLink. It seeks to classify the studies found based on the type of research, process improvement phases, paradigms, principles, and established models of process improvement in SRE. In our study, we have extended and contrasted the study prepared by Méndez et al. [9]. In addition, the problems, factors and metrics that were reported in the SPI implementations in SRE were identified.

The article is organized as follows: in Section 2, the fundamental concepts and related works are presented; in Section 3, the methodology applied to SMS is described; in Section 4, the results found are presented and discussed; in Section 5, the conclusions and future work are established.

2. Background and Related Work

In this section, the concepts of software requirements engineering and software process improvement are presented, and four related studies are presented.

2.1 Software Requirements Engineering

Software requirements engineering (SRE) is the science and discipline related to requirements analysis and management [10], which is an integral part of the software life cycle process connected to other parts through continuous feedback loops [11].

The SRE deals with discovering, developing, tracking, analyzing, qualifying, communicating, and managing requirements that define the system [5], its main objective being to discover the quality requirements that can be implemented in software development [12]. This should make it possible to obtain products that meet customer expectations in terms of functionality and quality [13].

The release of ISO/IEC/IEEE 29148:2011 and its update in 2018 (referred as ISO 29148), represents an important reference since it is articulated to the standards of the system life cycle processes ISO/IEC/IEEE 15288 (referred as ISO 15288) and software life cycle processes ISO/IEC/IEEE 12207 (referred as ISO 12207), and specifies the processes required in engineering activities that result in requirements for systems and software products (including services) throughout the life cycle [6]. These identified requirements must be clear, consistent, modifiable, and traceable to produce a quality product.

2.2 Software Process Improvement

The software process improvement (SPI) is a systematic approach to increase the effectiveness and efficiency of a software development organization and to improve software products [14, 15]. The most used models in the software industry [16] are CMMI, which includes the CMM-Sw and the set of ISO/IEC 15504 with ISO 12207. Also, for the context of small organizations or VSEs (very small entities), the ISO/IEC 29110 family of standards has been published since 2011 [17]. In all cases, it can be observed that they are models that continue to adapt to new contexts, based on previous experiences in the industry of their previous versions.

2.3 Related Works

The works identified as relevant are:

- The Méndez study [9], on software requirements engineering, is an SMS that seeks empirical evidence on existing solutions, their underlying principles, and their research facets, of what he calls REPI (requirements engineering process improvement). One of the results of [9], identifies a research bias on existing proposals instead of SRE improvements according to the individual objectives of the companies. Our study ends up being, in practical terms, an update and extension of the study by [9], as it includes 9 questions and 5 additional databases.
- The study by Kabaale and Kituyi [7], on the design and empirical validation of a theoretical framework to help improve SRE processes in small or medium-sized companies, the key requirements for process improvement being: participation the use of an evolutionary requirements engineering process improvement strategy, change management, training and education, and management engagement.
- The study by Hannola et al. [18] is about the evaluation and improvement of the practices, tools, and techniques used in SRE activities and their problems and needs, carried out through a case study. The authors [18] determine that there is a broad need to improve SRE practices (preparation, analysis, documentation, validation, and management) in the case studied.

3. Systematic Mapping Study

To achieve the objective of the research, a Systematic Mapping Study (SMS) was carried out based on [19], see Fig. 1. The SMS, according to [19, 20], allows defining the general vision for a research area, identifying the amount and type of contribution, as well as the available results.

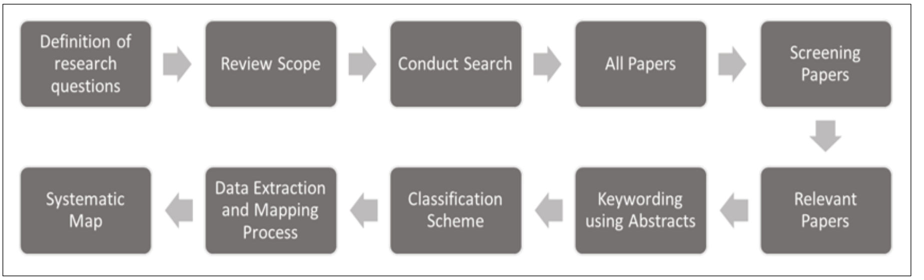

Fig. 1. Systematic mapping process adapted from [19]

3.1 Identification and Scope of the Need

In this study, an SMS is proposed to select and classify the primary studies based on the process improvement phases, paradigms, principles, problems, factors, and metrics that are reported in a requirement engineering process improvement. Likewise, in this study, findings are collected to date and identify the new models that have been developed in software requirements engineering, considering that there is a previous SMS, carried out by [9]. The differences between our work and that of Méndez are: (i) 13 research questions have been established, of which 4 are those of Méndez's previous work; and (ii) the 9 databases (ACM, Scopus, IEEE, Web of Science, Science Direct, Wiley, ProQuest, Ebsco, and SpringerLink) were considered instead of the 5 of Méndez (ACM, SpringerLink, ScienceDirect, Google Scholar, and IEEE Xplore). In addition, the results of Mendéz [9] were taken as a data source.

Table 1. Research question, answer classifier and rationales

Question	Sorter/Rationale
RQ-1. What are the types of study research found?	The classifier proposed by [21] is used, which includes: {Proposal, Evaluation, Validation, Experience, Opinion, Philosophical} and "Exploratory" is added according to [9], which is characterized by studying a problem that is not clearly defined. Identify the type of recurring research has performed in this domain. This RQ is the same to the previous study [9].
RQ-2. What phases of process improvement are considered?	The classifier used in the SMS of [9]: {analysis, construction, validation and SRE process improvement life cycle}. Identify the phase of SPI more studied in this domain. This RQ is the same to the previous study [9].
RQ-3. What paradigms do the studies focus on?	The considered paradigms are taken from [9] and are classified into activities and artifacts. Identify the most studied paradigms in this domain. This RQ is the same as the previous study [9].
RQ-4. Are the principles normative or problem-driven?	The principles considered are taken from [9] and are classified as normative and problem-driven. This RQ is the same as the previous study [9].
RQ-5. What models were used in process improvement?	Identify the most used models in recent years.
RQ-6. What problems have been reported in process improvement projects?	Identify the most recurring problems involved in performing a process improvement in software requirements engineering.
RQ-7. What factors have been reported in SPI implementations in RE?	Identify the reported factors (cultural, organizational, environment, technology, senior management).
RQ-8. What size of the organization is reported in the SPI implementation investigations?	Identify the size of the organizations that carry out improvement implementations
RQ-9. How do you measure the benefit obtained from process improvement?	Identify process improvement metrics in RE.

RQ-10. In which journals or conferences have the publications been made?	The Conference, Journal and Book Chapter classifiers are used. Identify where the authors publish more investigation on the topic.
RQ-11. How has the number of publications on this topic evolved?	Years of publications.
RQ-12. What are the means of publication of the research?	Publication media that concentrate the largest number of studies on this topic.
RQ-13. What are the countries with the greatest contribution from this type of research?	Countries that concentrate the largest number of studies on this topic.

The established research questions and the classifier to be applied to the answers are presented in Table 1.

3.2 Research Strategy

According to [19], this research used the search in relevant digital databases; we worked with PI (Population and Intervention) to build the search chain. The "Population" considered is "Software Process Improvement" and the "Intervention" is "Requirements Engineering" with the aim of covering a greater number of studies related to the research topic, which after finding equivalent terms, remains as presented in Table 2. Before SMS planning, 7 studies of interest from the Scopus database had been identified, which served as a verification mechanism that the search chain can find them and verify if the research questions make sense for those 7 studies.

Table 2. Search string elements

Concept	Terms
Population	"software process improvement" OR SPI
Intervention	"requirements engineering" OR RE OR "software requirement" OR "requirements analysis"
P and I	("software process improvement" OR SPI) AND ("requirements engineering" OR RE OR "software requirement" OR "requirements analysis")

The inclusion (IC) and exclusion (EC) criteria are presented in Table 3. These criteria are applied in the selection process, which is presented in Table 4. It should be noted that, to classify the primary studies by Méndez et al. [9] in the present study, only IC.4 (full-text availability) was applied, so our study includes, as much as possible, Méndez's SMS.

Table 3. Inclusion and exclusion criteria

Id	Criteria
IC.1	They belong to indexed databases.
IC.2	Written in Spanish, English, or Portuguese.
IC.3	Published as Journal Article, Book Chapter, Conference Article.
IC.4	Availability of the full text of the publication.
EC.1	Duplicates or extensions of a study. The less complete version is excluded.
EC.2	Not related to the process improvement field.
EC.3	Not related to the requirements engineering field.

Table 4. Stages and inclusion and exclusion criteria

Stages of the selection process	Criteria
1st. Stage. Extraction of metadata from the considered databases	IC.1, EC.1
2nd. Stage. Title review.	IC.2, IC.3, EC.2, EC.3
3rd. Stage. Review of abstracts	EC.2, EC.3
4th. Stage. Content review.	IC.4, EC.2, EC.3

3.3 Classifiers of Primary Studies

According to what is indicated in the Petersen guide [19], a set of independent indicators of the topic was established. The established classifiers are (i) type of article; (ii) study focus, such as academic, industrial, governmental, project, and organizational; (iii) type of contribution, such as process, method, model, tool, or metric; and (iv) research method, such as case studies, experiment, survey, expert opinion.

In the case of the classifiers of the topic, what is described in [21] and others will be taken into account: (i) solution proposals (ii) solution validation (iii) solution evaluation, (iv) philosophical, (v) experience, and (vi) opinion.

4. Results and Discussion

As defined in the selection and classification process, the search strings were executed in the selected databases, between May and June 2021.

In Fig. 2, the partial results of the selection process are presented. The search was carried out by the first author and the review was carried out by the second author. In addition, of the defined criteria, a general criterion of rejecting only those in which it was very sure to reject was applied, and provisionally accepting, to be resolved in the next stage, any other case. This implied a greater workload in the process, but increased the confidence of not eliminating, in the early stages, some potential primary study. As can be seen in Fig. 2, 1,495 studies were initially obtained, the 58 primary studies from [9] were added and after the process, 86 primary studies were obtained, which are listed in Appendix A. The answers and discussions of the research questions are presented below.

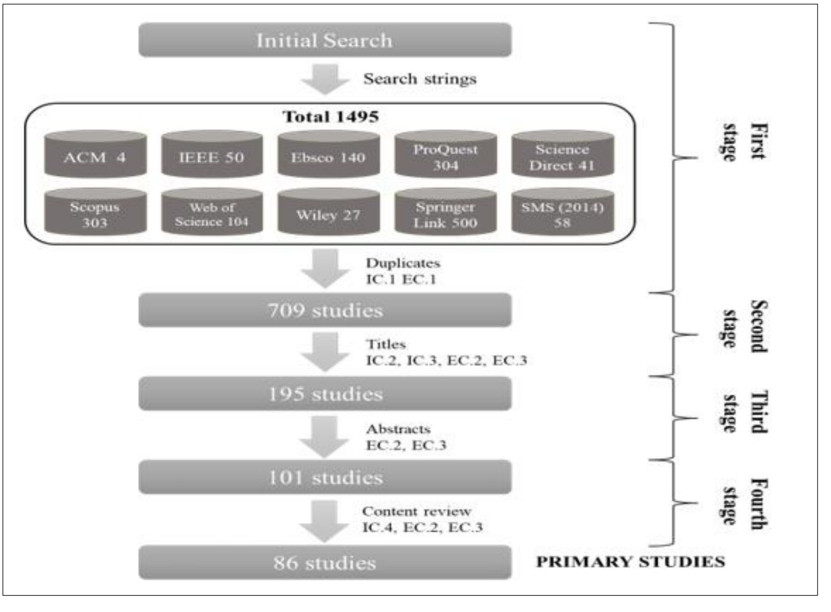

Fig. 2. Study selection results

4.1 RQ-01 What are the types of study research found?

In Table 5, considering the classifiers in Table 1, shows the type of research, the categorized studies and the number of studies, and the percentage (“%”) concerning the total (86 studies). The most studied articles are of the proposed type (38,4%) and evaluation (23,3%).

Table 5. Types of research

Types of research	Studies	Quantity	%
Proposal	S01, S02, S06, S07, S08, S15, S16, S26, S28, S30, S32, S35, S39, S46, S48, S49, S50, S52, S55, S56, S59, S61, S66, S69, S76, S78, S79, S80, S81, S82, S83, S84, S85	33	38,4
Evaluation	S04, S05, S22, S23, S27, S34, S37, S38, S40, S44, S45, S47, S51, S53, S54, S64, S67, S68, S71, S72	20	23,3
Validation	S03, S10, S11, S13, S14, S17, S31, S42, S43, S74, S77	11	12,8
Experience	S12, S25, S29, S36, S58, S62, S63, S70, S73, S75	10	11,6
Exploratory	S09, S19, S20, S33, S41, S60, S65, S86	8	9,3
Opinion	S18, S21, S24	3	3,5
Philosophical	S02, S57	2	2,3

The articles of the proposed type, propose frameworks to improve the processes in the software requirements engineering through activities or artifacts. The evaluation-type articles study the implementation of a proposal in one or more case studies to obtain metrics and indicators of the process improvement carried out. Among the least studied are those of opinion (3,5%) and philosophical (2,3%), also considering that the S02 study was classified into two types of research: philosophical and proposed. In addition, in the exploratory type, introduced by [9], 8 studies were found (9,3%).

In Fig. 3, the comparison of the results obtained in the SMS of Méndez [9] and the present study is shown, considering that both take the same classifier (See Table 1). It is observed that the results of each type of research maintain the trend reported in SMS of 2014. Regarding the exploratory type, it is observed that few studies have been published over the years, in the same way as that stated by Méndez [9], this implies that there is little evidence about the problems that organizations face.

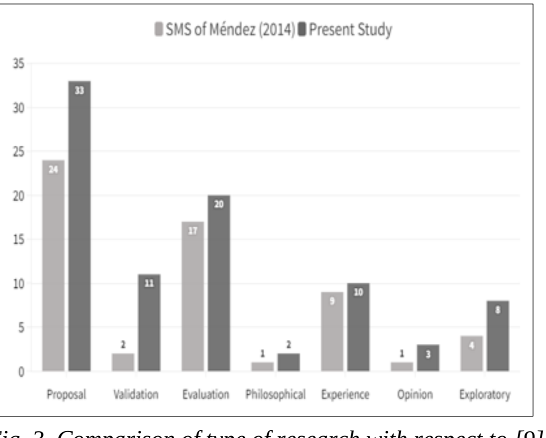

Fig. 3. Comparison of type of research with respect to [9]

4.2 RQ-2 What phases of process improvement are considered?

In Fig 4, the classification of the 86 primary studies distributed in 4 phases is presented. Most focused on the SRE process improvement life cycle and analysis phases with 59 and 23 from primary studies respectively. Based on this, it can be determined that 82 of the primary studies cover the analysis of what happens in the process (or model) of software requirements engineering. Of these, 23 studies are carried out as part of an SRE process improvement life cycle study in a holistic way, which includes all phases, metrics, and general measurements. In addition, it can be observed that there is a second interest, aimed at knowing what happens in a real or realistic context (34%) such as validation (12,8%), experience (11,6%), and exploratory (9,3%). Finally, there are a few studies from the most reflective perspective (5,8%): opinion (3,5%) and philosophical (2,3%).

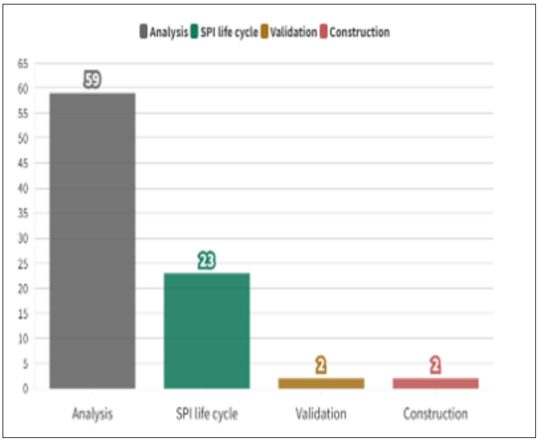

Fig. 4. Process improvement phases

Analogously to the previous question, Table 6 shows the comparison between the SMS of Méndez [9] and the present study. There is an increase in the analysis phases and life cycle of SPI of 21 and 7 studies respectively; while, in the construction and validation phases, the number of studies is maintained. However, from a higher-level perspective, it can be seen that the overall behavior has varied little since the percentage variations are smaller in each phase.

Table 6. Comparison of results on Improvement Phases

Improvement phases	SMS of Méndez (2014)		Present Study (2021)	
	Quantity	%	Quantity	%
Analysis	38	65,6	59	68,6
Construction	2	3,4	2	2,3
Validation	2	3,4	2	2,3
SPI life cycle	16	27,6	23	26,7
Total	58	100,0	86	100,0

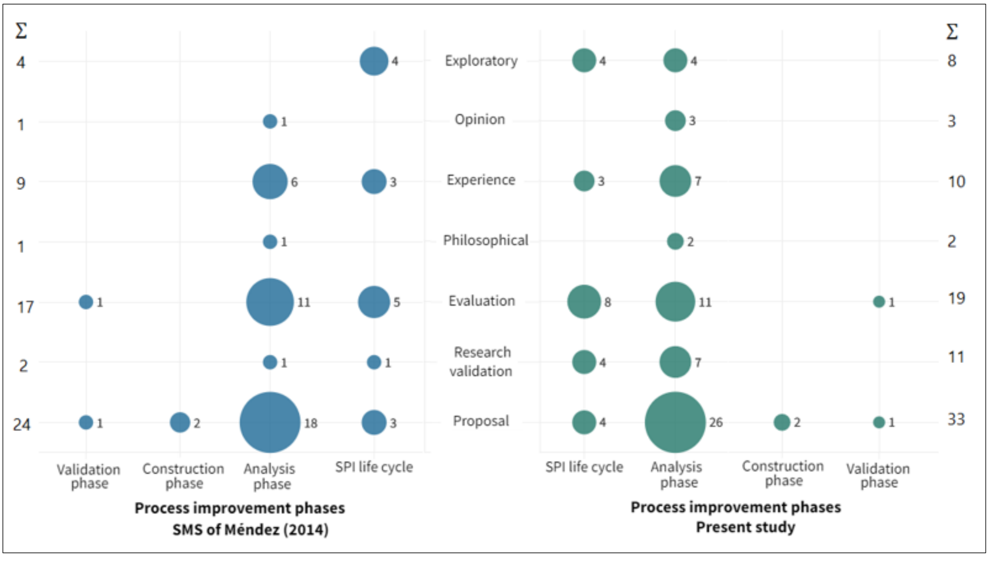

Fig. 5. Process improvement phases vs types of research

In Fig. 5, a diagram of the classification of the process improvement phases and the types of research of the SMS of Méndez [9], left side and the present study (right side) is presented. An increase in studies is observed in the analysis phase of the proposal type (from 18 to 26 studies) and in the research validation (from 1 to 7 studies), which shows the interest of the authors in these aspects. On the other hand, in the construction and validation phases, there is no increase to date.

4.3 RQ-3 What paradigms do the studies focus on?

Paradigms are classified into activities and artifacts, that is, they focus on improving the activities that are part of the SRE process or improving SRE artifacts. In Table 7, the results of the distribution of the primary studies by type of paradigm of the SMS de Méndez of 2014 and the present study (2021) are shown comparatively. It is observed that 81,4% focus on an activity-oriented paradigm, while 10,5% focus on artifacts. Most of the contributions are focused on improvements through models, practices, or strategies focused on SRE activities. Furthermore, in 7 studies not enough information could be found to indicate the paradigm adopted. Furthermore, in contrast, studies, it is observed that, in the intervening 7 years, 22 activity-oriented studies increased, while only 6 oriented artifacts.

Table 7. Comparison of results on activity or artifact-oriented paradigms

Paradigm	**SMS of Méndez (2014)**		**Present Study (2021)**	
	Quantity	**%**	**Quantity**	**%**
Activity Orientation	48	82,7	70	81,4
Artefact Orientation	3	5,2	9	10,5
N/A	7	12,1	7	8,1
Total	58	100,0	86	100,0

4.4 RQ-4 Are the principles normative or problem-driven?

The principles were classified, according to [9], as normative or problem-driven (as indicated in Table 1). It is classified as normative when an activity-oriented improvement or SRE artifact is evaluated against an external standard. It is classified as problem-driven when improvement is made against the objectives and problems of an organization. Table 8 shows the distribution of the primary studies according to the principles in a comparative way between the 2014 study by Méndez and the present study (2021). By 2021, it can be seen that 83,7% belong to a normative principle, while 16,3% are driven by problems. Most of the contributions focus on evaluating the activity-oriented or artifact-oriented paradigm against an SRE improvement proposal. In contrast, it can be seen that studies of the type of normative principles have increased by 23 compared to those driven by problems in 5.

Table 8. Comparison of results on normative or problem-driven principles

Principle	**SMS de Méndez (2014)**		**Present Study (2021)**	
	Quantity	**%**	**Quantity**	**%**
Normative	49	84,5	72	83,7
Problem-Driven	9	15,5	14	16,3
Total	58	100	86	100

In Fig. 6, the classification of the principles and paradigms is shown. According to the findings, where it is evidenced that, of the activity-oriented studies, 61 are normative and 9 are problem-driven. On the other hand, of those oriented to artifacts, 5 are normative and 4 are problem-driven.

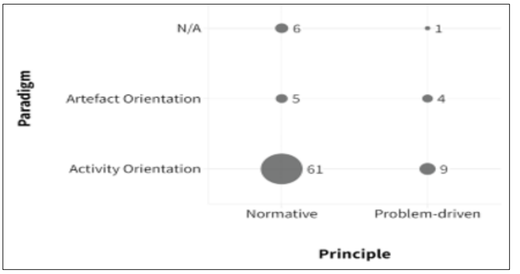

Fig. 6. Principle vs Paradigm

Table 9. Process improvement models in RE

Models	Studies	Quantity
Ad-Hoc	S08, S11, S14, S16, S19, S22, S26, S27, S35, S38, S40, S43, S44, S46, S47, S48, S50, S51, S53, S55, S61, S63, S67, S79, S80, S85	26
CMMI	S01, S03, S04, S07, S32, S33, S49, S58, S66, S70	10
Requirements Engineering Good Practice Guide (REGPG)	S24, S68, S72, S76, S78, S82, S83	7
ISO 15504	S01, S05, S59, S74	4
Requirements Capability Maturity Model (R-CMM)	S30, S52, S54	3
REAIMS	S72, S82, S83	3
Requirements Abstraction Model (RAM)	S42, S45	2
ArtREPI	S10	1
ASAP RE	S71	1
Concern of Requirement Engineering" (CORE)	S64	1
Improvement Framework utilizing light weight assessment and planning (iFLAP).	S37	1
ISO 29110	S13	1
LEGO (Living EnGineering prOcess)	S15	1
Framework of dependent variables	S39	1
Market-driven requirements engineering process model (MDREPM)	S17	1
MESOPYME	S69	1
Method Delphi	S06	1
Modelo descriptivo de RPI	S23	1
NATURE	S84	1
RE maturity measurement framework (REMMF)	S31	1
REPEAT	S81	1
ReqMan	S29	1
Requirements process maturity assessment instrument (RPMAI)	S56	1
Software Requirements Specification (SRS)	S77	1
SRE-MM (software requirements engineering maturity model)	S02	1
Story card Maturity Model (SMM)	S28	1
The QuARS: Quality Analyser for Requirements Specification	S34	1
The Requirements Engineering Process Maturity Model (REPM)	S24	1
University of Hertfordshire model	S24	1

4.5 RQ-5 What models were used in process improvement?

The primary studies were reviewed and it was found that 71 of them presented one or more models of process improvement in software requirements engineering. According to Table 9, it can be observed that 25 studies are of the Ad-Hoc type, that is, they present a process improvement proposal without giving it a specific name, which suggests that many articles proposed their framework is based on software requirements engineering activities. It was also found that the CMMI and Requirements Engineering Good Practice Guide (REGPG) models are the most used with a total of 10 and 7 studies respectively. Other of the most widely found models are ISO 15504, Requirements Capability Maturity Model (R-CMM), and REAIMS with 4, 3, and 3 studies respectively.

4.6 RQ-6 What problems have been reported in process improvement projects?

Of the 86 primary studies, only 9 studies reported problems implementing process improvement in RE. Despite being few studies, these were synthesized to identify the reported problems. Table 10 shows the classified studies.

Table 10. Problems implementing process improvement in RE

Problems	Studies
Process complexity	S51, S53, S58, S73
Cultural change	S37, S72, S73
Lack of authority	S13
Staff turnover	S13
Resistance to change	S19
Informality in the process	S68

4.7 RQ-7 What factors have been reported in SPI implementations in RE?

The studies that reported at least one factor were 15, of which a total of 36 factors could be obtained. According to Table 11, it is observed that the most studied factors in the implementations of SPI in SRE are organizational culture, economic, senior management, and time. Organizational culture involves the way of working of an entire organization, from the defined processes to the principles and values of the workers. The economic factor covers the budgetary part of an organization when making a process improvement. The "top management" factor refers to the commitment of top management when implementing the improvement. On the other hand, 5 studies indicate that, when carrying out a process improvement, time should be considered as a key factor, since there may be cases of delay in improvement activities that could cause the implementation of the activity to take longer than established. Likewise, the column "K&K" was incorporated, which shows the factors categorized and reported by [7], which coincide with the most reported in our study.

Table 11. SPI factors in RE

Factor	Studies	Quantity	K&K
Organizational culture	S10, S12, S13, S60, S72, S73	6	X
Economic	S19, S51, S53, S60, S68	5	X
High direction	S04, S10, S12, S13, S60	5	X
Time	S19, S42, S45, S68, S73	5	--
Study training	S04, S10, S53, S65	4	X
Team engagement	S04, S10, S60	3	X
Organization size	S19, S42, S45	3	--
Soft factors	S10, S14	2	--
Communication	S04	1	--
Stakeholder participation	S65	1	--
Technological	S60	1	--

4.8 RQ-8 What size of the organization is reported in the SPI implementation investigations?

There are 38 primary studies of evaluation, experience, or exploratory type, of which 18 did report an organization size in SRE process improvement implementations. Table 12 shows the size of the organizations as indicated in each study where an improvement was made, from which it can be seen that most involve SMEs.

Table 12. Organization size

Size	Number of Studies	Number of Companies
Small	2	4
Medium	3	4
Large	1	1
SME	9	60
Medium and large	3	11
Not Precise	20	73

4.9 RQ-9 How do you measure the benefit obtained from process improvement?

Of the 86 primary studies, only 8 studies mention any metric used. This suggests that despite having experience and evaluation type studies, an indicator that can measure the benefit obtained after implementation of process improvement in software requirements engineering is not being taken into account. Table 13 lists the set of metrics found.

Table 13. Metrics considered for a process improvement

Metrics	Studies
Process Area Compliance Defects in Software Product Development Validation Area Compliance	S04
Functional errors detected in the product testing and certification stage	S05
Requirements with problems caused by communication problems between distributed teams. Requirements that do not meet customer needs. Non-compliance with the requirements that detail the quality audits of the process.	S36
Process Improvement	S40
Requirements disconnected with the product level. Requirements broken down to function level	S45
Requirements engineering standards used. System requirements that had to be reworked. Time elapsed between system conception and deployment. Project execution time. Effort dedicated to rework. Number of system modifications resulting from RE errors.	S51
It does not require metrics, but used the method based on present value (PV) to perform the financial analysis of this case study.	S34
You don't need metrics, but you used the method Goals-Questions-Metrics (GQM).	S72

4.10 RQ-10 In which journals or conferences have the publications been made?

In Table 14, a list of publications is presented, indicating the type of publication (Column 2 of Type, which can be C = Conference, J = Journal, B = Book Chapter) where the primary studies have been published. Only those publications in which at least two articles have been published are presented. From this Table 14, it is observed that the largest number of studies were published in (i) the

International Conference on Product Focused Software Process Improvement, (ii) International Working Conference on Requirements Engineering: Foundation for Software Quality and (iii) Software Quality Journal. These results allow us to show which conferences or journals generate the greatest interest in the authors of the present study. In addition, 20 studies were published in conferences, 22 in journal and 2 in Book chapter.

Table 14. Publications found

Publication	Type	Studies	Quantity
International Conference on Product Focused Software Process Improvement	C	S09, S10, S11, S14, S18, S19, S23, S32, S33, S49, S56, S73	12
International Working Conference on Requirements Engineering: Foundation for Software Quality	C	S16, S22, S35, S83	4
Software Quality Journal	J	S31, S52, S69, S79	4
IEEE Software	J	S38, S62, S76	3
Requirements Engineering	J	S42, S81, S84	3
IEEE Access	J	S02, S07	2
Journal of Systems and Software	J	S37, S54	2
European Conference on Software Process Improvement	C	S08, S59	2
IEEE Transactions on Software Engineering	J	S27, S74	2
Information and Software Technology	J	S39, S60	2
International Workshop on Database and Expert Systems Applications	C	S75, S77	2
Rationale Management in Software Engineering	B	S46, S47	2
Software Process: Improvement and Practice	J	S34, S82	2
Empirical Software Engineering	J	S58, S85	2
Others (one publication in a journal / conference)	--	Rest of articles	42

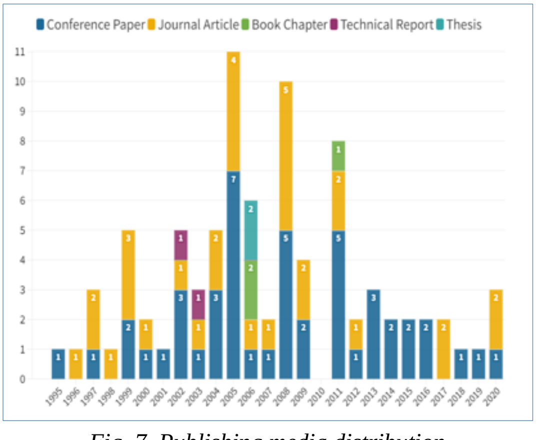

Fig. 7. Publishing media distribution

4.11 RQ-11 How has the number of publications on this topic evolved?

The evolution of the studies was reviewed over time, where publications from 1995 to 2020 were evidenced. It was found that, in 2005, 2008, and 2011, a greater number of publications were made with 11, 10, and 8 studies respectively (See Fig. 7). These years reflect the increased interest of researchers in the subject of study, however, from 2012 onwards there is a stabilization of 2 articles per year on average.

4.12 RQ-12 What are the means of publication of the research?

According to Fig. 7, the crossing of the information of the years and means of publication is presented. It can be seen that, of the 86 primary studies, the most widely used means of publication are conference articles and journal articles with 47 and 32 studies respectively. Likewise, it is observed that 2 technical reports and 2 theses were found.

4.13 RQ-13 What are the countries with the greatest contribution from this type of research?

In Fig. 8, the information crossing of the years and the distribution of the consolidated countries by continent according to the author's affiliation is presented. It should be noted that the countries are counted by author, therefore, in many cases, it is considered 2, 3, or 4 countries per study. Likewise, if there are two or more authors from the same country in a study, it is only counted as one. In total, 31 countries were consolidated and it was detected that those with the greatest contribution are the United Kingdom (18), Germany (11), Canada (8), Australia (7), and Sweden (7). In addition, it is reported that the greatest contribution to this research topic comes from Europe (52%), Asia (20%), and North America (12%).

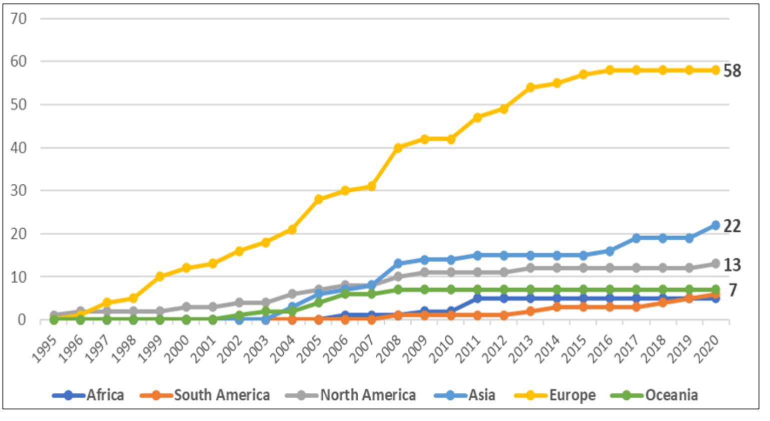

Fig. 8. Distribution of countries by continent based on authors

4.14 Threats to validity

According to Ampatzoglou [22], literature review validity threats are classified into three categories: validity of study selection, the validity of data, and the validity of the research. For the present investigation, the three categories were considered, which are detailed below:

- **Validity of the selection of studies:** The search for studies was carried out in the most relevant digital databases, the search chain was elaborated using the most representative terms of the PI strategy suggested by [19] and established the inclusion and exclusion criteria. In addition, to mitigate the threat of not finding relevant studies, with the search chain, seven studies related to the present research topic were first identified and the chain was executed in Scopus, verifying that the seven studies were in the set of results. Likewise, it was verified that they answered the proposed research questions. Also, it was established to work with the scheme that the doubt about an article was accepted to be resolved in the next stage. Although the work increases, the risk of omitting an article decreases, so a job with greater effort was chosen. However, despite this, there is a possibility that some articles from other repositories that are not being considered in this research will not be found. On the other hand, it should be noted that, in the study selection process, duplicate studies or extensions were identified and the less complete version was excluded.
- **Data validity:** To mitigate this threat, five-stage data extraction, and classification procedure

was developed to ensure the integrity of the investigation. The procedure was first reviewed by the principal investigator and subsequently validated by an experienced investigator. Furthermore, the present study is not threatened by the small sample size, since, in the initial search, 1,495 studies were obtained, leaving 86 primary studies, which were published in various conferences and important journals in the software industry.

- **Research validity:** This research is based on Petersen's methodology [19]. The study defined 10 research questions and 3 bibliometric questions that contribute to the achievement of the study objective. In the study, it was decided not to establish a date range, so findings are collected to date. Likewise, the results obtained from 4 questions were contrasted with those of the SMS of Méndez [9] being essentially similar. In addition, to generalize the results, all process improvements in software requirements engineering were examined, without focusing only on evaluation-type studies (case studies).

5. Conclusion and Future Work

This research presents a systematic mapping study of the literature on software process improvement in requirements engineering. The Petersen methodology was followed, applying a study selection and classification procedure based on inclusion and exclusion criteria. The search for studies was carried out in nine (9) relevant digital databases and; furthermore, after the selection process, the studies selected by Méndez [9] were considered as a special source. Finally, 86 primary studies were obtained. This SMS reports that the most used models are: CMMI, Requirements Engineering Good Practice Guide (REGPG), and ISO 15504. Likewise, 26 Ad-Hoc type studies were found, that is, they presented an improvement proposal based on the SRE activities without giving the framework a specific name.

Regarding the types of research, the proposals and evaluation type works were the most preferred by the authors. Regarding the process improvement phases, it was detected that the majority of studies focused on the analysis phase. On the other hand, the primary studies were classified into paradigms (activity or artifact) and principles (normative or problem-driven), the findings reported that most studies are activity-oriented and normative.

Regarding process improvement projects, it was reported that the factors of organizational culture, economics, senior management, and time are the most studied in the implementations of SPI in RE. In addition, the organizations that participated in an improvement project were classified based on size (small, medium, and large), obtaining as a result that 9 studies involve SMEs.

Since the present study considered the first 4 questions equal to Méndez's SMS [9], the findings reported in the SMS and the present investigation were compared, showing that the results of the types of investigation, paradigms, and principles follow the trend of the SMS carried out in 2014. In the process improvement phases, an increase in studies involved in the analysis phase and SPI life cycle of 21 and 7 studies respectively is reported, while, in the phases of construction and validation, no further studies have been presented since 2014. Likewise, from 2014 to date, proposal and validation type of studies increased in 9 papers each one.

From the SMS, it can be noted that: There is a great variety of models, but only 5 have more than two publications; which reveals that there is no consensus on a model for this domain. Furthermore, it is known that CMMI and ISO/IEC 15504 are not focused on SRE. Analysis is investigated as an improvement phase more than the rest. The approach followed is to implement a (normative) model that seeks a solution to a specific problem. There are few articles reporting problems, measurements and factors. Our study shows that the concern of researchers in this field remains especially from the empirical point of view (validation) and the search for solutions (proposal).

As future work, it is suggested to continue with the investigations of the proposed solution type, taking their studies to the implementation through case studies, to validate if the authors' proposals respond positively in terms of process improvement in the analysis of requirements.

References

[1] Kazman R. Pasquale L. Software Engineering in Society. IEEE Software, vol. 37, issue 1, 2020, pp. 7-9.

[2] Hastie S., Wojewoda S. Standish Group 2015 Chaos Report - Q&A with Jennifer Lynchю. 2015. Available at: https://www.infoq.com/articles/standish-chaos-2015, accessed Apr. 27, 2019.

[3] ISO/IEC/IEEE. ISO/IEC/IEEE 12207:2017 Systems and Software Engineering - Software Life Cycle Processes. 2017.

[4] Nuseibeh B., Easterbrook S. Requirements Engineering : A Roadmap. In Proc. of the Conference on The Future of Software Engineering, 2000, pp. 35-46.

[5] Dick J., Hull E., Jackson K. Requirements Engineering.4th ed. Springer, 2017, 259 p.

[6] ISO/IEC/IEEE. ISO/IEC/IEEE 29148:2018 Systems and Software Engineering - Life Cycle Processes - Requirements Engineering, 2018.

[7] Kabaale E., Kituyi G.M. A Theoretical Framework for Requirements Engineering and Process Improvement in Small and Medium Software Companies. Business Process Management Journal, vol. 21, issue 1, 2015, pp. 80-99.

[8] Aysolmaz B., Demirörs O. A Detailed Software Process Improvement Methodology: BG-SPI. in Systems, Software and Service Process Improvement. Communications in Computer and Information Science, 2011, vol. 172, Springer, pp. 97-108.

[9] Méndez D., Ognawala S. et al. Where do We Stand in Requirements Engineering Improvement Today?: First Results from a Mapping Study. In Proc. of the 8th ACM/IEEE International Symposium on Empirical Software Engineering and Measurement, 2014, article no. 58, 4 p.

[10] ISO/IEC/IEEE. ISO/IEC/IEEE 24765:2017 Systems and software engineering – Vocabulary, 2017.

[11] Macaulay L. Requirements Engineering. Springer, 2012, 220 p.

[12] Pandey D., Suman U., Ramani A.K. An Effective Requirement Engineering Process Model for Software Development and Requirements Management. In Proc. of the International Conference on Advances in Recent Technologies in Communication and Computing, 2010, pp. 287-291.

[13] Bjarnason E., Runeson P. et al. Challenges and Practices in Aligning Requirements with Verification and Validation: a Case Study of Six Companies. Empirical Software Engineering, vol. 19, issue 6, 2014, pp. 1809-1855.

[14] Unterkalmsteiner M., Gorschek T. et al. Evaluation and Measurement of Software Process Improvement-A Systematic Literature Review. IEEE Transactions on Software Engineering, vol. 38, issue 2, 2012, pp. 398-424.

[15] O'Regan G. Introduction to Software Process Improvement. Springer, 2011, 270 p.

[16] Von Wangenheim C.G.V., Hauck J.C.R. et al. Systematic Literature Review of Software Process Capability/Maturity Models. In Proc. of the International Conference on Software Process. Improvement And Capability dEtermination (SPICE), 2010, 9 p.

[17] O'Connor R.V., Laporte C.Y. The evolution of the ISO/IEC 29110 set of standards and guides. International Journal of Information Technologies and Systems Approach, vol. 10, issue 1, 2017, article no. 1, 21 p.

[18] Hannola L., Oinonen P., Nikuia U. Assessing and Improving the Front End Activities of Software Development. International Journal of Business Information Systems, vol. 7, issue 1, 2011, pp. 41-59, 2011.

[19] Petersen K., Vakkalanka S., Kuzniarz L. Guidelines for Conducting Systematic Mapping Studies in Software Engineering: An Update. Information and Software Technology, vol. 64, 2015, pp. 1-18.

[20] Kitchenham B., Charters S. Guidelines for Performing Systematic Literature Reviews in Software Engineering. Version 2.3. EBSE Technical Report EBSE-2007-012007. Keele University, University of Durham, 2007, 65 p.

[21] Wieringa R., Maiden N. et al. Requirements Engineering Paper Classification and Evaluation Criteria: A Proposal and a Discussion. Requirements Engineering, vol. 11, issue 1, 2006, pp. 102-107.

[22] Ampatzoglou A., Bibi S. et al. Identifying, Categorizing and Mitigating Threats to Validity in Software Engineering Secondary Studies. Information and Software Technology, vol. 106, 2019, pp. 201-230.

Appendix A. List of Primary Studies

Table A. Primary Studies

ID	Authors	Year	Title
S01	Gasca-Hurtado G.P., Muñoz M.	2020	A Path for the Implementation of Best Practices for Software Requirements Management Process Using a Multimodel Environment

S02	Akbar M.A., Alsanad A., Mahmood S., Alsanad A.A., Gumaei A.	2020	A Systematic Study to Improve the Requirements Engineering Process in the Domain of Global Software Development
S03	Keshta I.M., Niazi M., Alshayeb M.	2020	Towards the implementation of requirements management specific practices (SP 1.1 and SP 1.2) for small- And medium-sized software development organisations
S04	Bayona-Oré S., Chamilco J., Perez D.	2019	Software process improvement: Requirements management, verification and validation [Mejora de Procesos Software: Gestión de Requisitos, Verificación y Validación]
S05	Allasi D., Dávila A.	2018	Financial impact on the adoption of software validation tasks in the analysis phase: A business case
S06	Iqbal, J; Ahmad, R; Nasir, MHNM; Khan, M	2017	Significant Requirements Engineering Practices for Outsourced Mobile Application Development
S07	Keshta I., Niazi M., Alshayeb M.	2017	Towards Implementation of Requirements Management Specific Practices (SP1.3 and SP1.4) for Saudi Arabian Small and Medium Sized Software Development Organizations
S08	Ito M.	2016	Cardion.spec: An Approach to Improve the Requirements Specification Written in the Natural Language Through the Formal Method
S09	Femmer H., Hauptmann B., Eder,S., Moser D.	2016	Quality Assurance of Requirements Artifacts in Practice: A Case Study and a Process Proposal
S10	Méndez D., Wagner S.	2015	A case study on artefact-based re improvement in practice
S11	Reggio G., Leotta M., Ricca F.	2015	A Method for Requirements Capture and Specification Based on Disciplined Use Cases and Screen Mockups
S12	Khankaew S., Riddle S.	2014	A review of practice and problems in requirements engineering in small and medium software enterprises in Thailand
S13	Alvarez J.J., Hurtado J.A.	2014	Implementing the software requirements engineering practices of the ISO 29110-5-1-1 standard with the unified process
S14	Méndez D., Wieringa R.	2013	Improving requirements engineering by artefact orientation
S15	Buglione, L., Hauck, J. C. R., von Wangenheim, C. G., & McCaffery, F.	2013	Improving Estimates by Hybriding CMMI and Requirement Engineering Maturity Models – A LEGO Application
S16	Bennett-Therkildsen, J., Jørgensen J., Nørskov N., Rubin M.	2013	Redefinition of the Requirements Engineer Role in Mjølner's Software Development Process
S17	Gorschek, T; Gomes, A; Pettersson, A; Torkar, R	2012	Introduction of a process maturity model for market-driven product management and requirements engineering
S18	Frank Houdek	2012	Improving requirements engineering processes: Impressions during one decade of improvement at daimler
S19	Kabaale E., Nabukenya J.	2011	A systematic approach to requirements engineering process improvement in small and medium enterprises: An exploratory study
S20	Shahid M., Ibrahim S., Mahrin M.N.	2011	An evaluation of requirements management and traceability tools
S21	Kelly S., Keenan F., McCaffery F.	2011	Challenges for requirements development: An industry perspective
S22	Markov, G.A. and Hoffmann, A. and Creighton, O.	2011	Requirements engineering process improvement: an industrial case study
S23	Zawedde, A.S.A. and Klabbers, M.D.M. and Williams, D.D. and van den Brand, M.G.J.M.	2011	Understanding the Dynamics of Requirements Process Improvement: A New Approach
S24	Sawyer, P.	2011	Maturing Requirements Engineering Process Maturity Models
S25	Teufl, S. and Khalil, M. and Mou, D. and Geisberger, E.	2011	Experience with content-based requirements engineering assessments
S26	Zawedde, A.	2011	Building a Case for a Dynamic Requirements Process Improvement Model
S27	Napier, NP; Mathiassen, L; Johnson, RD	2009	Combining Perceptions and Prescriptions in Requirements Engineering Process Assessment: An Industrial Case Study
S28	Patel C., Ramachandran M.	2009	Story card Maturity Model (SMM): A process improvement framework for agile requirements engineering practices

S29	Adam, S. and Doerr, J. and Eisenbarth, M.	2009	Lessons Learned from Best Practice-Oriented Process Improvement in Requirements Engineering: A Glance into Current Industrial RE Application
S30	Solemon, B. and Shahibuddin, S. and Abd Ghani, A.A.	2009	Re-defining the Requirements Engineering Process Improvement Model
S31	Niazi, M; Cox, K; Verner, J	2008	A measurement framework for assessing the maturity of requirements engineering process
S32	Niazi M., Hickman C., Ahmad R., Ali Babar M.	2008	A model for requirements change management: Implementation of CMMI level 2 specific practice
S33	Niazi M., Ali Babar M., Ibrahim S.	2008	An empirical study identifying high perceived value practices of CMMI level 2
S34	Raffo, David and Ferguson, Robert and Setamanit, Siri-on and Sethanandha, Bhuricha	2008	Evaluating the impact of requirements analysis tools using simulation
S35	Brinkkemper S., Van De Weerd I., Saeki M., Versendaal J.	2008	Process improvement in requirements management: A method engineering approach
S36	Alves C., Valença G., Sotero T., Mendes J.	2008	Requirements engineering process improvement: A knowledge transfer experience
S37	Pettersson, F.; Ivarsson, M.; Gorschek, T.; Ã–hman, P.	2008	A practitioner’s guide to light weight software process assessment and improvement planning
S38	Dörr, J. and Adam, S. and Eisenbarth, M. and Ehresmann, M.	2008	Implementing Requirements Engineering Processes: Using Cooperative Self-Assessment and Improvement
S39	Gorschek, T. and Davis, A.M.	2008	Requirements engineering: In search of the dependent variables
S40	Tripathy S., Mishra S., Shrivastava, A.,Singh, V.K., Darbari, M.	2008	An Efficient Evaluation of Requirements Engineering Process Maturity Assessment and Improvement
S41	Lee E.-S., Bae J.-M.	2007	Design opportunity tree for requirement management and software process improvement
S42	Gorschek, T; Garre, P; Larsson, SBM; Wohlin, C	2007	Industry evaluation of the requirements abstraction model
S43	Napier N.P., Mathiassen L., Johnson R.D.	2006	Negotiating response-ability and repeat-ability in requirements engineering
S44	Palyagar, B. and Moisiadis, F.	2006	Validating Requirements Engineering Process Improvements - A Case Study
S45	Gorschek, T.	2006	Requirements Engineering Supporting Technical Product Management
S46	Hagge, L. and Houdek, F. and Lappe, K. and Paech, B.	2006	Using Patterns for Sharing Requirements Engineering Process Rationales
S47	Palyagar, B. and Richards, D.	2006	Capturing and Reusing Rationale Associated with Requirements Engineering Process Improvement: A Case Study
S48	Yamaç, P.I.	2006	Improvement proposal for a Software Requirements Management Process
S49	Cerón R., Dueñas J.C., Serrano E., Capilla R.	2005	A meta-model for requirements engineering in system family context for software process improvement using CMMI
S50	Jo J.-H., Choi H.-J.	2005	A reflective case study of software process improvement for a small-scale project
S51	Sommerville I., Ransom J.	2005	An empirical study of industrial requirements engineering process assessment and improvement
S52	Beecham S., Hall T., Rainer A.	2005	Defining a requirements process improvement model
S53	Nikula U., Sajaniemi J.	2005	Tackling the complexity of requirements engineering process improvement by partitioning the improvement task
S54	Beecham, Sarah;Hall, Tracy;Britton, Carol;Cottee, Michaela;Austen, Rainer	2005	Using an expert panel to validate a requirements process improvement model
S55	Xu, H. and Sawyer, P. and Sommerville, I.	2005	Requirement Process Establishment and Improvement: From the Viewpoint of Cybernetics
S56	Niazi, M.	2005	An instrument for measuring the maturity of requirements engineering process
S57	Ning, A. and Hou, H. and Hua, Q. and Yu, B. and Hao, K.	2005	Requirements engineering processes improvement: a systematic view

S58	Damian, D. and Chisan, J. and Vaidyanathasamy, L. and Pal, Y.	2005	Requirements Engineering and Downstream Software Development: Findings from a Case Study
S59	Rifaut, A.	2005	Goal-Driven requirements engineering for supporting the ISO 15504 assessment process
S60	Kauppinen, M; Vartiainen, M; Kontio, J; Kujala, S; Sulonen, R	2004	Implementing requirements engineering processes throughout organizations: success factors and challenges
S61	Kamal, Aatif; Ali, Arshad; Anjum, Ashiq; Nazir, Fawad; Ahmad, Hafiz Farooq; Burki, Hamid Abbas; Suguri, Hiroki; Shah, Umair Ali; Tarar, Tallat Hussain	2004	Process maturity for software project outsourcing.
S62	Daneva, M.	2004	ERP Requirements Engineering Practice: Lessons Learned
S63	Doerr, J. and Paech, B. and Koehler, M.	2004	Requirements engineering process improvement based on an information model
S64	Jiang, L. and Eberlein, A. and Far, B.H.	2004	Case studies on the application of the CORE model for requirements engineering process assessment
S65	Niazi M., Shastry S.	2003	Critical Success Factors for the Improvement of Requirements Engineering Process
S66	Beecham, S. and Hall, T. and Rainer, A.	2003	Building a requirements process improvement model
S67	Gorschek, T. and Wohlin, C.	2003	Identification of Improvement Issues Using a Lightweight Triangulation Approach
S68	Kauppinen, M. and Aaltio, T. and Kujala, S.	2002	Lessons Learned from Applying the Requirements Engineering Good Practice Guide for Process Improvement
S69	Calvo-Manzano Villalón J.A., Agustín G.C., Gilabert T.S.F., De Amescua Seco A., Sánchez L.G., Cota M.P.	2002	Experiences in the Application of Software Process Improvement in SMES
S70	Damian, D. and Zowghi, D. and Vaidyanathasamy, L. and Pal, Y.	2002	An Industrial Experience in Process Improvement: An Early Assessment at the Australian Center for Unisys Software
S71	Daneva, M.	2002	Using Maturity Assessments to Understand the ERP Requirements Engineering Process
S72	Kauppinen, M.	2002	A Practical Framework for Systematic Improvement of Requirements Engineering Processes
S73	Kauppinen M., Kujala S.	2001	Starting improvement of requirements engineering processes: An experience report
S74	Emam K.E., Birk A.	2000	Validating the ISO/IEC 15504 measure of software requirements analysis process capability
S75	Houdek, F. and Pohl, K.	2000	Analyzing Requirements Engineering Processes: A Case Study
S76	Sawyer P., Sommerville I., Viller S.	1999	Capturing the benefits of requirements engineering
S77	J. Andrade; J. Ares; O. Dieste; R. Garcia; M. Lopez; S. Rodriguez; L. Verde	1999	Creation of an automated management software requirements environment: A practical experience
S78	Sawyer, P. and Sommerville, I. and Kotonya, G.	1999	Improving Market-Driven RE Processes
S79	Williams, D.W. and Hall, T. and Kennedy, M.	1999	A Framework for Improving the Requirements Engineering Process Management
S80	Williams, D. and Kennedy, M.	1999	A Framework for Improving the Requirements Engineering Process Effectiveness
S81	Regnell, Björn; Beremark, Per; Eklundh, Ola	1998	A market-driven requirements engineering process: Results from an industrial process improvement programme
S82	Sawyer, P. and Sommerville, I. and Viller, S.	1997	Requirements Process Improvement through the Phased Introduction of Good Practice
S83	Sawyer, P. and Sommerville, I. and Viller, S.	1997	Improving the Requirements Process
S84	Grosz, G. and Rolland, C. and Schwer, S. and Souveyet, C. and Plihon, V. and Si-Said, S. and Achour, C.B. and Gnaho, C.	1997	Modelling and engineering the requirements engineering process: An overview of the NATURE approach

S85	El Emam, K.; Madhavji, N.H.	1996	An instrument for measuring the success of the requirements engineering process in information systems development
S86	El Emam, K. and Madhavji, N.H.	1995	Measuring the success of requirements engineering processes

Information about authors / Информация об авторах

Silvia ALMEIDA, Master of Science, Analyst. Research interests: Information Analysis, Project Management, Process Improvement.

Сильвия АЛЬМЕЙДА, магистр наук, аналитик. Область научных интересов: анализ информации, управление проектами, совершенствование процессов.

Abraham DÁVILA is a Principal Professor of the Computer Engineering program and is a Doctoral Candidate in Software Engineering, in the field of process improvement. Field of scientific interests: Software engineering, Software quality process, Software quality product, Education in software engineering, innovations based on software.

Авраам ДАВИЛА – профессор программы компьютерной инженерии и докторант в области программной инженерии. Область научных интересов: программная инженерия, процесс качества программного обеспечения, образование в области программной инженерии, инновации на основе программного обеспечения.