TUM

TECHNISCHE UNIVERSITÄT MÜNCHEN
INSTITUT FÜR INFORMATIK

Requirements Engineering Improvement Today

Saahil Ognawala, Daniel Méndez Fernández and Stefan Wagner

TUM-I145

Technischer Bericht

FAKULTÄT FÜR INFORMATIK

DER TECHNISCHEN UNIVERSITÄT MÜNCHEN

Requirements Engineering Improvement Today - A Systematic Mapping Study

Saahil Ognawala

Daniel Méndez Fernández

Stefan Wagner (University of Stuttgart)

Abstract

Context Requirements engineering (RE) research has been receiving much attention from industry for many years. As the complexity of the software projects has vastly increased, project managers find it imperative that their RE processes are streamlined in order to extract maximum value. There is a need for specialized requirements engineering process improvement (REPI). However, there are no state-of-the-art studies done in the field of REPI that talk about the established concepts and their feasibility.

Objective We aim to get an overview of the current state of reported research in RE process improvement, in terms of existing solutions, evaluations, experience reports, and opinion papers. A state-of-the-art view of process improvement with special attention on the particularities of RE will help drive efforts towards targeted gaps in research.

Method To get an overview of the state of research in REPI, we conduct a systematic mapping study of the publication space. The collection of papers is first filtered based on the inclusion and exclusion criteria. The list of relevant papers are arranged according to their respective years of publication and then classified according to our research questions like on the research type facet, RE phase discussion or contribution paradigm.

Results Our review of 58 publications shows that until 2002, only a few solutions were proposed to improve RE processes. The research gathered steam after 2002 when more improvement solutions were presented and experiences in their industrial applications could be discussed. Most of these publications dealt with REPI with a focus on activity based improvement in RE.

Conclusion We see from our results that much effort has been spent on activity-based RE improvement based on existing norms, i.e. REPI is mostly done by adapting the activities provided in the norms. However, there is still little known about the problem-driven improvement of RE w.r.t. individual goals and problems while focusing on the quality of the created RE artefacts.

Contents

1 Introduction

Much effort is put by organisations into requirements engineering, which is a discipline dealing with elicitation, design, formalisation and maintenance of the requirements in the software lifecycle. In [4], Beecham et al. infer that most software engineers, academics in software engineering and other related experts agree that requirements form the most critical part of the development process. Companies, therefore, are always looking to improve their RE processes by employing Software Process Improvement (SPI) measures to RE. SPI projects are large, complex restructuring and refinement projects that entail big scale changes in the organisation in terms of personnel, processes, company values and ethics [36]. Due to the very nature of the complexity involved in RE improvement, there is no silver bullet to overcome all requirements related shortcomings in the software lifecycle of a company.

Requirements Engineering is defined and its effects are scoped differently by the researchers in this field. Beecham et al. in [6] define RE processes as *activities performed in the requirements phase that culminate in producing a document containing the software requirements specification.* Sawyer et al. in [56], on the other hand, define RE in the context of critical systems, as *practices for handling requirements for critical systems, such as safety or reliability requirements.* Just as researchers do not agree entirely upon the scope of requirements engineering, there are also varied ideas about the application, methods and efficacies of process improvement in RE.

We found that the first advances in REPI were made in 1995—96, when, first, a need was observed by El Emam et al. in [16] for reliable metrics and methods for exporting methods like SPI to RE, followed by their proposal for a measurement solution in [17]. At the time of publishing our report, it had been almost 20 years since the first steps were taken towards improvement in RE processes, but we still do not have a comprehensive work that gives an overview of the progress made over the years in this particular sphere of software process improvement. In the area of general software process improvement or special branches such as method engineering, there have been works that discuss the state-of-the-art, like [50] and [31]. Such contributions in form of systematic map of the collection of research done towards improvement of RE processes in terms of their efficacy, implementation details, evaluation and experience overviews is, however still missing.

Problem Statement Even though a significant number of contributions have been made in the research field of REPI, we do not have an exhaustive knowledge about the proposed solutions, the problems they address, the scope of evaluation and validation of these solutions and experience reports by prominent contributors with these techniques. There exist works that deal with the larger context of SPI, concerning the state-of-the-art, but none so far for process improvement in RE.

Research Objective We aim to consolidate the current understanding about the state-of-the-art by conducting a systematic mapping study of all contributions towards process improvement in RE.

Contribution We form categories of publications according to facets and contribution paradigms and also derive information about the prominent contributors in the field.

Outline The rest of the report is organised as follows. In Sect. 2, we discuss the related work, the gaps left open, and how our work can possibly fill those gaps. Section 3 presents the details of our study design, the research methodology, and the research questions in detail. In Sect. 4, we present our results structured corresponding to the research questions. Finally, in Sect. 5, we conclude our work and discuss the threats to validity, implications of the study, and future work.

2 Related Work

Requirement engineering emerged as the study of processes and tools to cover all aspects of managing, developing and maintaining the requirements, as a complete lifecycle process. In 1995 and 1996, El Emam et al. published studies [16] [17] that discussed success factors in the requirements engineering process. The authors were confident that once a standardised measure for evaluating an RE process is established, we can direct our efforts towards improving those processes in an empirical fashion.

As there are, to our best knowledge, no systematic literature review or mapping study in the area of REPI at our disposal, we look at the general area of software process improvement (SPI), where there have been a few state-of-the-art studies. In [32], Lavallée et al. investigate the publication space for studies dealing with the effects of SPI on developers. In [48], Rahman et al. deal with publications related to SPI standards and the issues that come up while adopting the standards. Sulayman et al. [59] give a systematic review of papers that discuss SPI in small web based companies. In [64], Unterkalmsteiner et al. lay out a literature review of publications discussing the measurement techniques to evaluate the impact of SPI initiatives. In [35], Müller et al. present a literature analysis with an emphasis on organisational changes that take place during, and as a result of, SPI implementations.

We draw inspiration from the above publications in SPI to create the first system mapping study in the area of requirements engineering process improvement.

3 Study Design

This study is designed by following standard procedures of a systematic mapping study [46] to enumerate the research space and obtain an exhaustive list of publications. This is done in conjunction with the methods of a systematic literature review, which entails a further in-depth analysis of the publications. We begin by defining the research questions which form the core of this study. The next step is to collect and analyse the data, followed by a critical evaluation of the validity procedures.

3.1 Research Questions

To systematically describe the state-of-the-art in *requirements engineering process improvement*, we will answer the following six research questions.

RQ1: Which contributions were made over the years? The first investigation step is to find previous contributions in the field of REPI. This helps us bring ourselves in speed with the state-of-the-art and trace some trends in the research domain.

RQ2: Which software process improvement phases are considered in available contributions? Various publications pertaining to requirements engineering improvement deal with specific software process lifecycle phases, e.g. design or implementation. We will annotate referred papers with one or more of the software process lifecycle (SPLC) phases to get an idea about the stages that a method is relevant to.

RQ3: Is the underlying principle of the available contributions of normative or of problem-driven nature? We categorise a publication as either descriptive (or norm-based) or as problem-based approach. The difference between these two principles is that a descriptive approach aims to find a standardised framework that can be applied to a variety of problems of the nearly same kind while a problem-based approach, on the other hand, is specific to a problem scenario, provided by an individual socio-economic context. We also aim to spot trends in the principle of contributions over the years.

RQ4: What is the research type facet of the available contributions? Under this research question, we structure the contributions according to the research type facets, as introduced by Wieringa et al. [66]. A research type facet is the classification of the research stage in the engineering cycle that is being focussed on in a contribution, i.e. it describes the empirical domain of a contribution such as “solution proposal” or “evaluation paper”. The available research type facet categories are listed in table 3.6. A distribution of the facets over the years shows us a trend of contributions in the area of process improvement. Moreover, assigning a facet type often means a thorough analysis of the paper, rather than just the abstract and introduction text, because generic terms like "study", "evaluation" or "analysis" do not adequately convey the methodologies and extent of the study described in the papers.

RQ5: What paradigm do the contributions focus on? We investigate whether the publication concentrates on the activities that form a RE process or the artefacts created at the completion of various RE activities. As with the other questions listed above, we try to spot trends in the paradigm focus over the years. In many cases, the authors avoid aligning themselves with one or the other, or simply include ideas dealing with none of the two paradigms in particular. In such cases, we do not assign any paradigm focus to the contribution.

RQ6: Are there recognisable prominent contributors and how are they related to each other? Using a social network graph of the cited contributors, we obtain an association graph which can clearly distinguish the authorities in a principle topic of discussion and their relationship with other notable contributors in the domain. This allows to get a picture of trending research (sub-) areas and corresponding key contributors.

3.2 Case Selection

In [46], Petersen et al. lay out their methodology of a systematic literature review, which starts with an exhaustive search of a publication database with the key concept terms in software engineering. However, for a mapping study like our’s, this seemingly straightforward way falls much short of providing the researchers with a quality result set because of various reasons.

First, merely using context-free keywords like *requirements engineering process*, *process improvement* or *requirement process* matches works from a lot of engineering and non-engineering domains that are irrelevant to our study, e.g. mechanical engineering or business development. Second, in the absence of a prior core selection of papers, we miss out on key concept areas and trends discussed in works that are most helpful to us for evaluation purposes.

To overcome this problem, we do a pre-analysis of a select set of key contributions in the area of *requirements engineering* and make a map of the chief search terms that are closely related to these papers. Next, we perform snowballing on the selected publications, as described by Kitchenham et al. [30]. This gives us a larger initial dataset, such that we now have a list of key contributors as well as the main concept keywords. We can now form the search query strings and modify them based on the quality of search result set (as compared to the initial dataset).

3.3 Data Collection Procedures

Data collection procedure is automated search on established web databases of scientific literature. Keywords present in the initial set of papers, obtained through past state-of-the-art knowledge in *software engineering process improvement* and snowballing, are used to define search query terms. List of prominent contributors in the domain and their publications are also used as a control mechanism to filter out irrelevant search results and tweak the search string in a corresponding manner. The databases used for performing this step are listed below:

- ACM Digital Library
- SpringerLink
- ScienceDirect
- IEEE Xplore

The decision on the above libraries was made on the basis of past experience in literature surveys, particularly in the field of *requirements engineering* and *software engineering process improvement*. We find several contributions appearing in the result base of multiple data sources, due to cross journal/conference publications or citations, and we keep a set of such items occurring only once in our clean group of references. The search engine used to mine a result is recorded as the source even if the original publication point is somewhere else. Another set of notable additions to the contribution data is technical reports or academic studies in form of PhD theses which often do not form a part of search result space in the above listed sources. We look out for such contributions using *Google Scholar*, which has a wider span that indexes titles located in repositories like university databases and other independent publications.

3.3.1 Query Definition

We follow nearly the same query derivation method as described by Kuhrmann et al. [31]. We make a map of the most common keywords and method terms used in the publications that are picked out based on past experience in the *requirement engineering* domain and that are considered to be the most relevant contributions (as decided based on initial selection and the "snowballing" procedure done afterwards). We use these keywords in different combinations and with conjunctive or disjunctive logical operators (*AND* or *OR*) and cross check the resulting search result set to see if it contains contributions by our top contributors in the field. In the beginning, we use the following

approximate keywords: { *requirements engineering, process, improvement, analysis, optimisation, assessment, audit* }.
A key problem that we faced while executing search with our strings was that there are considerable sophistication level differences between the designs of different literature databases. For example some databases like ACM digital library would not perform word *stemming* (even though the advanced search help mentions that they do), some databases like SpringerLink have a limit on the number of disjointed *OR* clauses that can be used in a query and various other such difficulties. To overcome these problems, we came up with search strings for different databases that only differ in their syntactic structure, but should ultimately use the same logical search argument. We list these search strings in table 3.1.

Database Name	Search String
ACM	(Title:("requirements engineering" or "requirements process" or "requirements engineering process" or "requirements practice") and Title:(analysis or analyze or analyzing or assessing or assessment or assess or improving or improvement or improve or optimizing or optimization or optimize or auditing or audit or "process improvement")) and (not "requirements practice analysis")
SpringerLink	("requirements engineering" OR "requirements process" OR "requirements practice") AND (assess OR improve OR audit OR analyze OR optimize)
ScienceDirect	("requirements engineering" OR "requirements practice" OR "requirements process") AND (assess OR assessment OR improve OR improvement OR analyze OR analysis OR optimization OR optimize OR audit) in (abstract, title or keywords)
Google Scholar	allintitle: assessment OR assess OR improvement OR improve OR audit OR optimize OR optimization OR analyze OR analysis "requirements engineering" OR "requirements process" OR "requirements practice" -"requirements practice analysis"
IEEE Explore	((("Document Title":"requirements engineering" OR "requirements practice" OR "requirements process") AND (assess OR improve OR analyze OR optimize OR audit)) NOT "requirements practice analysis")

Table 3.1: Search strings used in different databases

3.3.2 Inclusion and Exclusion Criteria

As the search engine of a publication database forms the only bottleneck in forming a reliable dataset of relevant contributions for the study, it is essential to filter the search results as they are. As the first step, we consider the first 15 result pages (approximately 20 titles per page) when the total result set is deemed to be too large. In addition to being too large for consideration as a whole, the search results' quality starts declining and results begin to become irrelevant for our search strings, once we reach result page

15. Secondly, we also exclude any citation results.

Once we have a set of contributions from the publication databases, we use a list of inclusion (IC) and exclusion (EC) criteria (described in table 3.2) on this dataset before the analysis and voting stage.

IC_1	The contribution directly relates to the improvement in requirements engineering/REPI.
IC_2	The title and abstract refer to the search strings (requirements engineering improvement).
IC_3	The keywords contain related words.
IC_4	The contribution addresses the research questions, i.e. it ..introduces, discusses, compares, or evaluates ... ..approaches or experiences, terms and concepts and/or metrics to... ..improve (assess and/or implement and/or evaluate) requirements engineering processes or artefacts.
EC_1	The topic exclusively addresses software process improvement (without clear linkage to RE).
EC_2	The topic does not address approaches, studies, experiences for improving requirements engineering but new approaches and techniques that are claimed to improve RE as an effect of applying them. (e.g. elicitation techniques)
EC_3	No “scientific publication”, i.e. PowerPoint presentations, abstracts or posters.
EC_4	The contribution’s language is not English.
EC_5	The contribution is not available.
EC_6	The contribution appears multiple times in the result set (see below).
EC_7	The contribution investigates typical (industrial) problems in RE to be addressed by research to improve RE.

Table 3.2: Inclusion and exclusion criteria for the mapping study

3.4 Analysis Procedure

Before presenting the contribution list to all the authors for voting upon the defined research questions, we clean up the dataset even more, using the criteria below.

- Among contributions where the same approach is reported, we only choose one to include in our study; e.g. PhD theses forming a cumulative report of various approaches.
- Papers where several techniques or approaches are reported, are treated as a single contribution.
- Systematic literature reviews are treated as *philosophical papers* because they define and organise existing concepts and approaches, taking a novel view.
- In case of metrics being introduced in a paper that can be applied to both, artefact or activity orientation, the paradigm is set to "N/A".

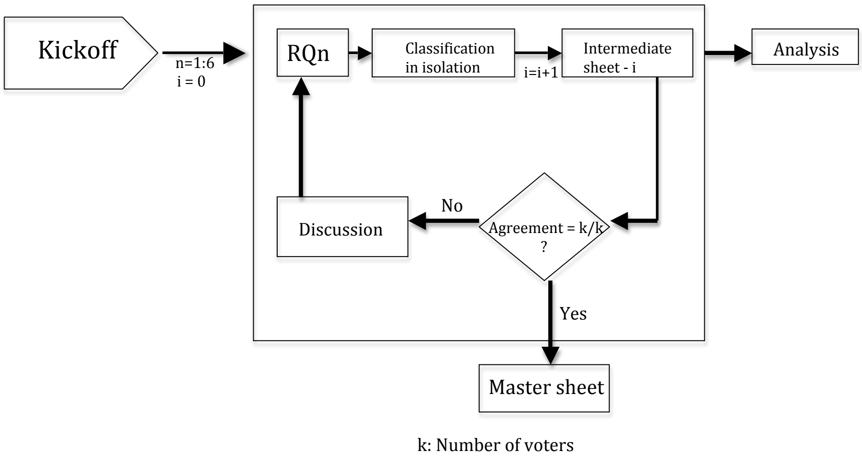

Figure 3.1: Voting process for classification

We also apply simple filtering ideas like not including papers that are not related to computer science, and not including papers where the full text is not available. More importantly, we exclude duplicate texts that seep into the study due to being published in multiple conferences or when they are published in a journal after being at a conference first.

3.4.1 Voting

We do a 5-staged voting procedure on the set of contributions obtained after applying the final pre-voting analysis. In the first stage of voting, we consider all the publications and try to filter out yet more content based on the inclusion and exclusion criteria, as laid out in table 3.2. From the second voting stage, each author categorises every remaining publication based on all 4 "choice" based research questions. The voting procedure allows us, the authors, to put forward arguments regarding our respective choices on the RQs, and a justified consensus is reached by the time the final classification is made. The master worksheet contain entries for which every research question's categorisations for all authors has been agreed upon by voting (refer table 3.3 for the design of actual worksheet we use for this process). Intermediate worksheets are maintained for each round of voting, which contains the then agreement levels on the contributions, on all research questions.
This voting procedure is captured in fig. 3.1.

The master worksheet provides the authors with an overview of the voting status, so that they may reconsider their evaluations of categorisation. They may also choose to justify their decisions for certain categorisations in the remarks field provided on all individual author worksheets and intermediate worksheets.

Column	Description
Author(Name)	Name of the authors
Title	Title of the paper
Reference	Location of full text
Keywords	Keywords, if listed on source page
Year	Year of publication
Source	Source database paper is picked from
Abstract	Abstract of the paper
RQ2	Choices - [Analysis, Construction, Validation, REPI-LC]
RQ3	Choices - [Normative, Problem-Driven]
RQ4	Choices - [Validation, Evaluation, Solution, Philosophical, Opinion, Experience, Exploratory]
RQ5	Choices - [Artefact Orientation, Activity Orientation, N/A]
Conflict in	Columns not classified the same by all authors

Table 3.3: Master classification sheet

Overall, we aim to have a total agreement of all 3 authors on all research questions before concluding the voting stage, and not merely a simple majority of voters. This often involves further scrutinisation of the publication texts to find answers pertaining to the research question of interest. In many cases, the title and abstract of a publication doesn't fully or correctly indicate the kind of study presented in it which leads us to do a full text review of the paper in order to extract the maximum knowledge to base our categorisation on.
Described below are the valid categories for each choice-based research question.

3.4.2 RQ2: Phase in Contribution

Refers to the lifecycle phase discussed in the paper. The choices are listed in table 3.4.

Phase	Description
Analysis	Works in the analysis phase of requirements engineering.
Construction	Relates to the creation of the actual RE reference process.
Validation	Works in the validation of the RE processes.
RE Process Improvement Lifecycle(REPI-LC)	Provides holistic views on analysis, construction as well as validation and metrics.

Table 3.4: RQ2: Requirements engineering phase referred to in publication

3.4.3 RQ3: Underlying principle

Refers to the contribution provided towards either the problem in question, or a general observation/solution that applies to a wider category of requirement engineering problems. The choices are listed in table 3.5.

Principle	Description
Problem-driven	The solution/approach related context-specific to problem being discussed.
Normative	A standard approach is used that is meant for a wide variety of similar problem in requirements engineering process.

Table 3.5: RQ3: Principle discussion in publication

3.4.4 RQ4: Research type facet

Refers to the classification of the whole publication in the space provided by Wieringa et al. [66] [31]. In addition to the choices described in [66], we define a new category of classification, called Exploratory papers. The choices are listed in table 3.6.

3.4.5 RQ5: Contribution paradigm

Refers to the paradigm of the study presented in a publication. The choices are listed in table 3.7.

3.5 Validity Procedures

To increase the validity of our mapping study, we consider some aspects of result formation and analysis procedure. Firstly, we deal with the peculiarity of publication databases and their ways of processing search strings. Publisher search engines return reliable hits based on a well formed keyword list that results into a *boolean expression*. Databases like IEEE Xplore and ACM are only able to handle up to a certain number of such expressions in disjunction (*OR*) and conjunction (*AND*). Due to this limitation of databases, we have to continuously optimise our search queries in such a way that it matches the requirements of a search engine. In some cases, when there is no explicit error message when these limitations are breached, a preliminary look at the result set may indicate that there is a need to tweak the search string in order to make all substrings play a part in the search.
The second important consideration is that the result set obtained from the publication databases and further filtering might not be complete and exhaustive list of all relevant papers and contributions that have been published in the field of *requirements engineering process*. As we mentioned in section 3.3.2, since we only consider results from the first 15 pages of search, it is possible that we still miss out on some relevant publications.

Category	Description
Validation paper	Techniques investigated are novel and have not yet been implemented on a large scale industrial or academic setting. Mostly includes lab studies, experimental setups etc.
Evaluation paper	Techniques are implemented in a large scale industrial, academic or other real world setting and evaluated based on implementation, benefits, drawbacks, cost benefits etc.
Solution proposal	A solution to a problem is proposed, either novel or an extension to an existing solution. Benefits are expressed in the form of reasoning, argumentation and small scale experimentation.
Philosophical paper	Propose a new way of looking at existing problems by restructuring the field in form of a taxonomy, conceptual framework or systematic literature reviews.
Opinion paper	Present the author's opinion on a problem space, with a critical view on one or more solutions described by other researchers trying to tackle the problem. Benefits and drawbacks of existing techniques are discussed purely based on lines of logical reasoning and authority in the field.
Experience paper	Provides a retrospective view on author's experience in developing, applying and evaluating a certain technique in the field of engineering process improvement.
Exploratory paper	Deals mainly in the problem space with a bird's eye view of the common problems faced by various solutions proposed and the peculiarities of the problem space responsible for their respective advantages and disadvantages.

Table 3.6: RQ4: Research type facet

However, our experience tells us that the general quality and relevance of the results deteriorates as we look further among the search results.
The last validity caveat in this study is that the classification of the papers, particularly that based on research type facets, as done by the authors, might differ significantly from the study type that the authors of the original papers intended them to be. This is a real threat because the voting based classification procedure is prone to human factors and it may have been possible to influence decisions of disagreeing voters in case of a missing consensus. In order to deal with such a possibility we do an in-depth analysis of publications which were classified differently by all voters in the first pass.

Paradigm	Description
Artefact-based	When the improvement activity deals with artefacts produced as a result of requirements engineering steps in-process
Activity-based	When the improvement activity deals with specific activities performed during the requirements engineering process
N/A	When a metric is provided in the paper, which is not artefact or activity based technique description

Table 3.7: RQ5: Study paradigm

4 Results

In this section, we present the results of the mapping study. Table 4.1 gives numbers for each stage of data processing. "Results seen" are all the publications that were considered for the pre-analysis stage of the process. This means all the results returned by the database search using the keywords described in table 3.1 in only the top 20 pages. "Included" papers are the ones that were kept after filtering the seen results in the analysis stage by making use of the inclusion and exclusion criteria defined in table 3.2. As described in the last chapter, we undergo the first round of voting, where we further filter out more publications based on their relevance to our research questions, so as to derive the "Relevant" result set.

Database Name	Total results	Results seen	Included	Relevant
ACM	81	81	23	15
SpringerLink	349	349	31	11
ScienceDirect	132	132	12	2
Google Scholar	276	276	16	11
IEEE Explore	2819217	275	18	15
Misc.	4	4	4	4
Total	2820059	1117	104	58

Table 4.1: Dataset summary

Table 4.2 shows the agreement level among the participating authors, in terms of classification of individual paper according to all research questions. Note that for the first 4 voting stages, we only focus on resolving the classifications based on RQ4. We deal with the remaining research questions after stage 4.

Voting stage	Percent agreement
1^{st}	53.4% (31/58)
2^{nd}	72.4% (42/58)
3^{rd}	86.2% (50/58)
4^{th}	100% (58/58)

Table 4.2: Agreement levels during voting

We now present our results according to each research question, considered separately.

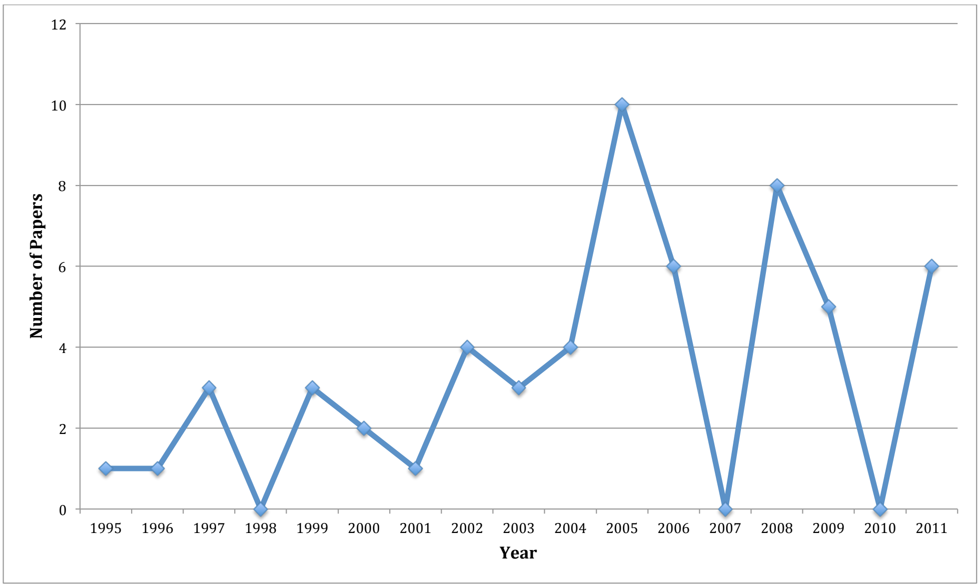

Figure 4.1: Number of contributions over time

4.1 Contributions Over Time (RQ1)

To answer the first research question, we group the relevant contributions based on their year of publication and visualise the results in the form of a line graph (fig. 4.1). The first contribution in the field of *requirements engineering process improvement* was by El Emam et al. [16] in 1995 where the contributors explore the area of requirements engineering process and their views on the feasibility of various measurement methods in the field. El Emam et al. then come up with the first solution proposal to metrics problem in 1996 [17]. The first peak in the number of publications came in 2002 [65], [26], [11], [10]. This was in the form of a few experience reports in the general discipline of *software engineering process improvement* and a subsequent adaption of those techniques to the field of *requirements engineering processes.* The most instrumental peak in publication numbers came between the years 2005 and 2008, when prominent contributors such as Niazi, Sommerville, Gorschek and Niazi published their findings and experiences applying the various metrics and recommended new solutions.

4.2 Process Improvement Phases Considered (RQ2)

As described in the previous chapter, to answer this question we categorize papers according to the requirement process phase that the described methods/evaluations are applied to, viz. analysis, construction, validation or REPI-LC. Fig. 4.3 depicts the distribution of all publications according to the process improvement phase discussed therein. Fig. (4.2) shows year wise distribution of all contribution phases.

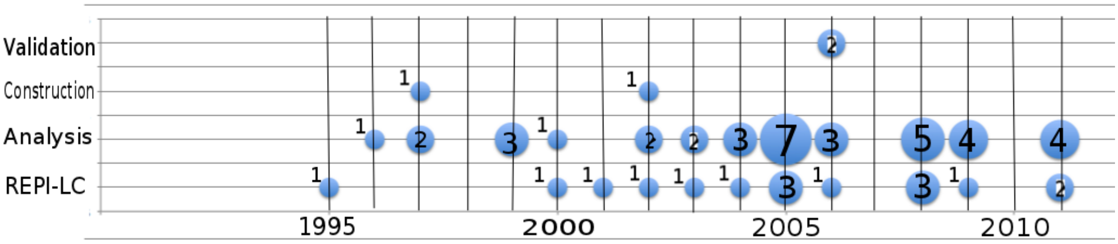

Figure 4.2: Year-wise phase distribution

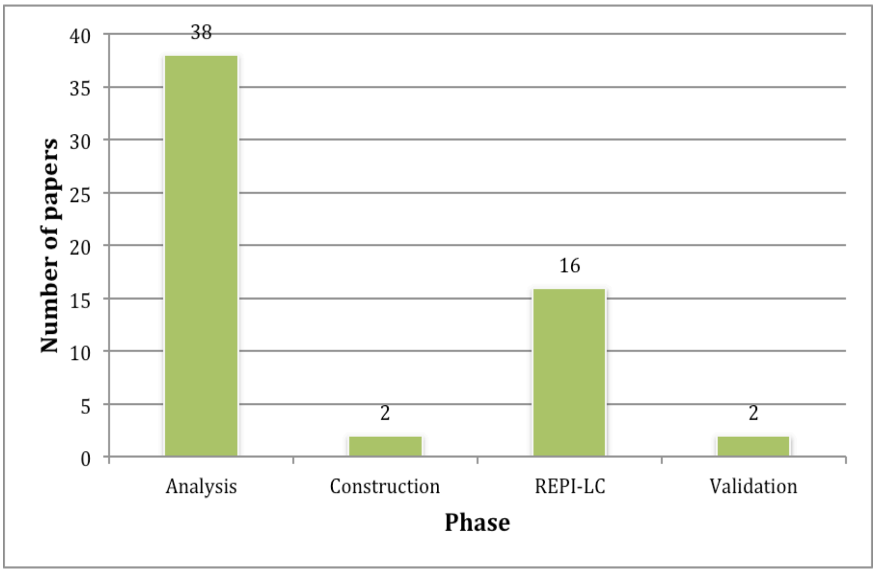

Figure 4.3: Phase of contribution

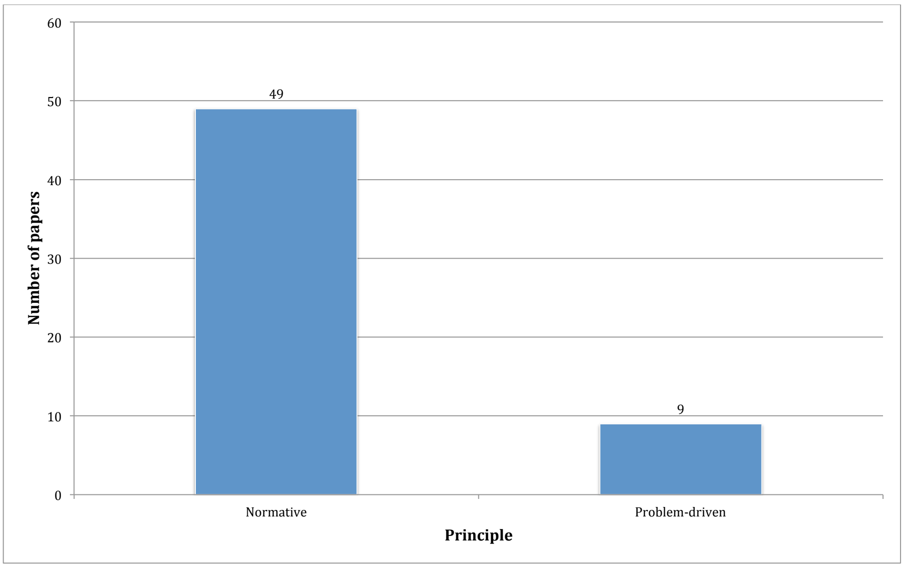

Figure 4.4: Underlying principle

4.3 Underlying Principle (RQ3)

We answer the question of underlying principle in a publication by segregating them based on the solution type discussed in the paper. The type can either be a normative procedure/metric or problem-specific procedure. We, then, arrange all the contributions according to their principles (as in fig. 4.4).

4.4 Research Type Facet (RQ4)

To answer the question of how the research type facets of contributions in REPI have been distributed over time and contributing author space, we first arrange the categorisation and visualise all facets against each other (fig. 4.5). As with the previous research questions, we also make a year wise distribution of all research type facets (fig. 4.6) to see the trend in research along the maturity years of *requirements engineering process* domain.

4.5 Contribution Paradigm (RQ5)

Next, we categorise the publications based on the paradigm of the study described therein. These activities may either outline solutions or evaluations to improve the artefacts produced at the conclusion of various *requirements engineering process* steps, or to improve the activities leading to the creation of such artefacts. In some cases, where a metric is described such that it may not be possible to categorise it as activity or artefact-based, the paper is marked as "N/A".
We look at a distribution of the contribution paradigms against each other (fig. 4.7).

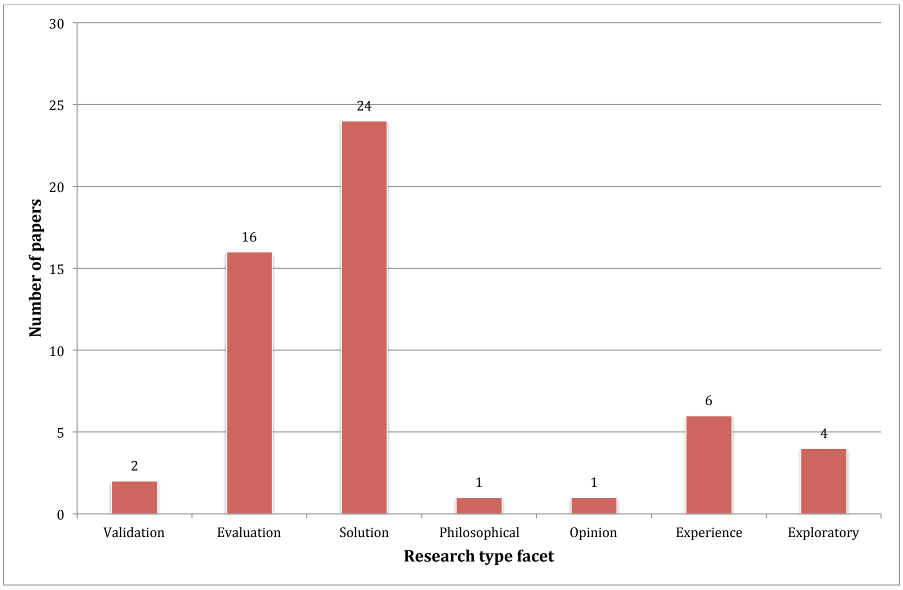

Figure 4.5: Research type facets

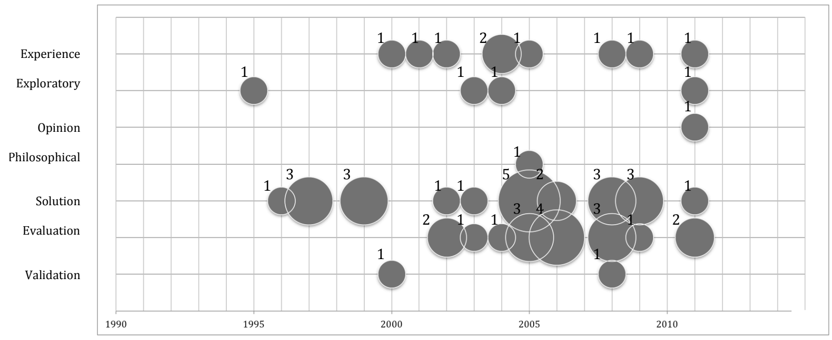

Figure 4.6: Year-wise research type facet distribution

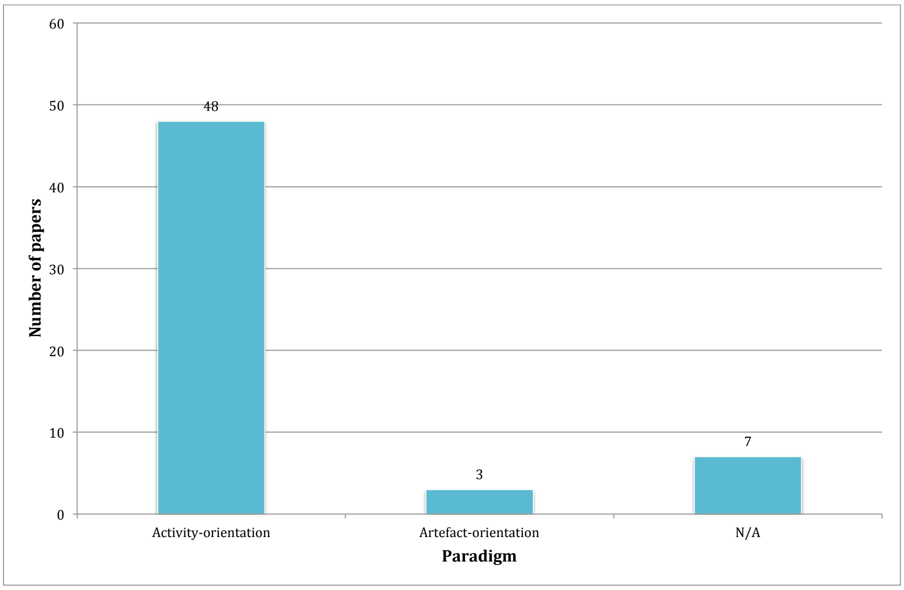

Figure 4.7: Contribution paradigm

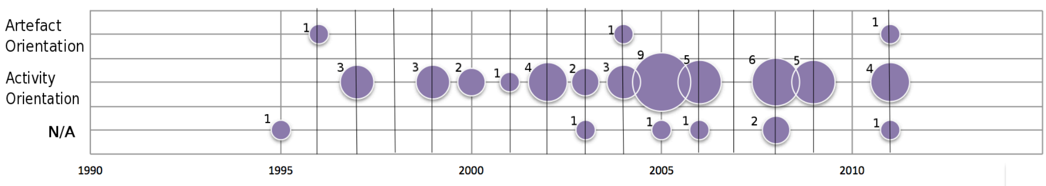

Figure 4.8: Year-wise contribution paradigm distribution

The year wise paradigm distribution is represented in fig. 4.8.

Figure 4.9 shows the distribution of contributions based on their underlying principles, against the paradigm.

4.6 Contributors and Relationships (RQ6)

To answer this research question, we make a social network of contributors in the field of *requirements engineering process improvement* and their relationships with each other (fig. 4.10). This social network is a collection of nodes (representing individual contributors) and edges (representing any publication done together between the participating nodes/contributors). This social network clearly shows that there are some leading researchers in this domain who have provided the most number of studies and have been dominant forces in driving this research forward over the years. Looking at the color distribution of this social graph, one can also deduce a community structure among the contributors.

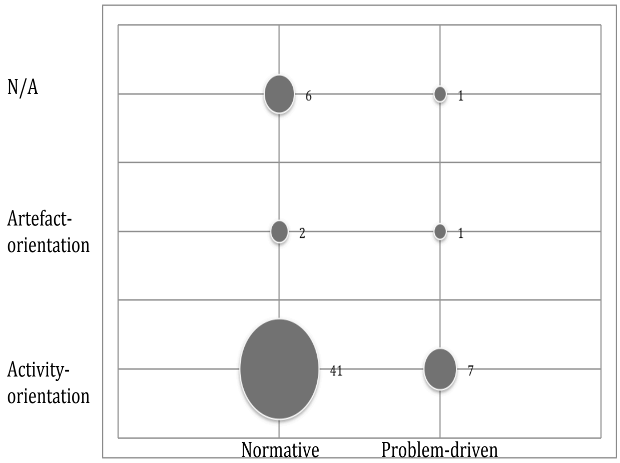

Figure 4.9: Underlying principle vs. paradigm

Key contributors and their contributions according to research questions: The key researchers' contributions distributed according to their research type facets, contribution paradigms and underlying principles are also shown in tables 4.3, 4.4 and 4.5 respectively.

Author	Validation	Evaluation	Solution	Philosophical	Opinion	Experience	Exploratory
Sawyer	0	0	5	0	1	0	0
Sommerville	0	1	5	0	0	0	0
Gorschek	0	3	1	0	0	0	0
Hall	0	1	3	0	0	0	0
Kauppinen	0	2	0	0	0	1	1
Niazi	1	0	2	0	0	0	1
Total	1	7	16	0	1	1	2

Table 4.3: Mapping of key contributors to research type facet

Sawyer and Sommerville [52], [53], [54], [55], [56] are two prominent contributors to REPI. In 1997, Sawyer et al. published a guideline with good practices that should be employed for RE process improvement. In [56], Sawyer et al. described their Requirements Process Maturity Model that extends on their previous good practices guide similar to CMM.
Beecham et al. also introduced a specialised version of CMM specific to software processes, and describe a REPI model in [5]. In [4], Beecham et al. evaluate their improvement model by conducting a study with experts in the RE field.
Kauppinen et al. presented an industrial survey [28] that exemplifies the challenges faced

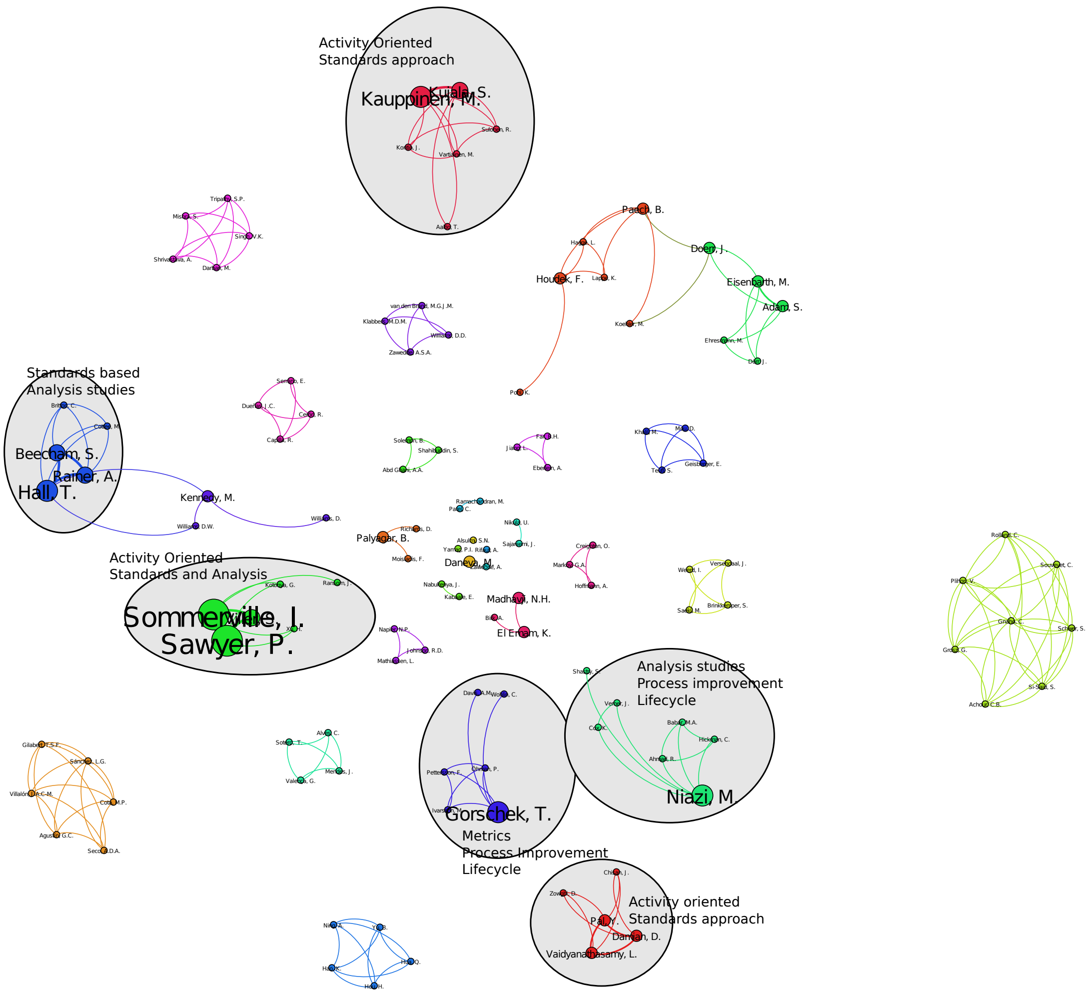

Figure 4.10: Authors and relationships. Focus on clusters summarized in tab. 4.3.

Author	Artefact-oriented	Activity-oriented	N/A
Sawyer	0	6	0
Sommerville	0	6	0
Gorschek	0	2	2
Hall	0	4	0
Kauppinen	0	4	0
Niazi	0	3	1
Total	0	25	3

Table 4.4: Mapping of key contributors to contribution paradigm

Author	Problem-driven	Normative
Sawyer	1	5
Sommerville	1	5
Gorschek	1	3
Hall	0	4
Kauppinen	0	4
Niazi	0	4
Total	3	25

Table 4.5: Mapping of key contributors to underlying principle

by the companies when streamlining their requirements engineering processes. In [26], [27], [29], Kauppinen et al. describe a practical framework for improving RE processes and detail their experiences in applying those measures in industrial settings.

Other notable groups of researchers, viz Gorschek et al. [18], [19], [20], Niazi et al. [37], [38], [39], [40], Damian et al. [9], [10], Dörr et al. [13], [14] etc. have emerged lately on the scene, and they have produced notable works in the area of metrics, lifecycle improvements and activity oriented approaches in RE process improvement.

5 Conclusion

With this systematic mapping study, we provided an overview of the current state-of-the-art in the field of requirements engineering process improvement. We decided to stay clear of discussing technical details of the contributions in terms of their feasibility, extent of validation and real-world impact.

As we can see from the contribution distribution over time, RE process improvement is a relatively young research area. We propose that this can be attributed to the increase in complexity of software projects as well as the size of organisations. This has lead to an emerging need of having the requirements process streamlined, in accordance with the existing SPI frameworks. After a rigorous voting procedure over all research questions, we found that the majority of publications analysed were solution proposals. There is a notable lack of retrospective analysis in the context of the process improvement techniques that were formulated from ground-up or evaluation of existing techniques. As one would expect though, the majority of evaluation research was done with or after the spike in solution proposals.
We also see that most contributions fall under the activity-orientation paradigm, where the stress is on the process steps that lead to the creation of requirement artefacts or documents. There have been two works by Svahnberg et al. [60] [61] where they describe and evaluate a unified maturity model for requirements engineering processes. But we decided to exclude this publication from our study, since we only include works up to 2012. While there are 7 publications that focus upon the metrics to be used for measuring process improvements methods, there are only a few papers that focus on the artefacts, themselves.
To close the gap for normative approaches in the direction of artefact-driven analyses, there is a need for more research that gives actual guidance on improvement [34]. This leads us to conclude that the understanding of artefacts and their production during the REPI lifecycle is underwhelming at the moment, and we might see an increase in reliable metrics when researchers focus on the artefact creation.

Impact/Implications Through our contribution, we showed show the wide chasm between a real need for process improvement measures in RE for both big and medium scale organisations, and the actual amount of work being done in the area. On implication we

Figure 5.1: Term cloud (formed from abstract texts)

draw from our results is that the area of REPI research needs more studies in the form of experience reports, validated measures and examples of problem-based approaches to explore and underpin possibilities, benefits and shortcomings in REPI as well as its alignment in a general SPI context. We would benefit from problem-driven studies that focus on the whole REPI lifecycle, preferably using artefact based approaches, because there is a notable lack of research work in this direction.

Limitations This study purely focuses on obtaining a state-of-the-art picture in process improvement in RE and hence, as such, does not try to answer deeper, more conceptual and technical questions related to the techniques evaluated. Also, we do not create taxonomies or conceptualise approaches and methods that connect the analysed works. Furthermore, we refrain from providing new solutions, metrics or evaluation measures ourselves, as this study was supposed to be limited to an investigation into existing publications in REPI space.

Future Work This report is missing so far critical interpretations of the results of all research questions. The research questions were designed to adequately capture all parameters of a contribution w.r.t its alignment towards a research type facet, paradigm of study, phases included etc., but there were only single sets of categories allowed in each direction.
Looking at the results of this research, we believe there is a need for more artefact-oriented research on requirements engineering. Additionally, more experience reports, validated solutions or metrics and adaptations of SPI methods to REPI would be a welcome reform in industrial environments where process improvement in RE is usually seen as a burdensome endeavour. Since REPI is context-sensitive (subjective), this is of special importance.

6 Appendix

Title	Year	Ref.
A Practical Framework for Systematic Improvement of Requirements Engineering Processes	2002	[26]
A practitioner's guide to light weight software process assessment and improvement planning	2008	[47]
An Efficient Evaluation of Requirements Engineering Process Maturity Assessment and Improvement	2008	[63]
An empirical study of industrial requirements engineering process assessment and improvement	2005	[58]
Capturing and Reusing Rationale Associated with Requirements Engineering Process Improvement: A Case Study	2006	[44]
Case studies on the application of the CORE model for requirements engineering process assessment	2004	[24]
Combining Perceptions and Prescriptions in Requirements Engineering Process Assessment: An Industrial Case Study	2009	[36]
Identification of Improvement Issues Using a Lightweight Triangulation Approach	2003	[20]
Implementing Requirements Engineering Processes: Using Cooperative Self-Assessment and Improvement	2008	[14]
Lessons Learned from Applying the Requirements Engineering Good Practice Guide for Process Improvement	2006	[27]
Requirements engineering process improvement: an industrial case study	2011	[33]
Requirements Engineering Supporting Technical Product Management	2006	[18]
Tackling the Complexity of Requirements Engineering Process Improvement by Partitioning the Improvement Task	2005	[41]
Understanding the Dynamics of Requirements Process Improvement: A New Approach	2011	[72]
Using an expert panel to validate a requirements process improvement model	2005	[4]
Using Maturity Assessments to Understand the ERP Requirements Engineering Process	2002	[11]
Validating Requirements Engineering Process Improvements - A Case Study	2006	[43]

Table 6.1: Contributions for research type facet "Evaluation research" by year

Title	Year	Ref.
An Industrial Experience in Process Improvement: An Early Assessment at the Australian Center for Unisys Software	2002	[10]
Analyzing Requirements Engineering Processes: A Case Study	2000	[23]
ERP Requirements Engineering Practice: Lessons Learned	2004	[12]
Experience with content-based requirements engineering assessments	2011	[62]
Lessons Learned from Best Practice-Oriented Process Improvement in Requirements Engineering: A Glance into Current Industrial RE Application	2009	[1]
Requirements Engineering and Downstream Software Development: Findings from a Case Study	2005	[9]
Requirements engineering process improvement based on an information model	2004	[13]
Requirements engineering process improvement: a knowledge transfer experience	2008	[3]
Starting Improvement of Requirements Engineering Processes: An Experience Report	2001	[28]

Table 6.2: Contributions for research type facet "Experience paper" by year

Title	Year	Ref.
A systematic approach to requirements engineering process improvement in small and medium enterprises: an exploratory study	2011	[25]
Critical Success Factors for the Improvement of Requirements Engineering Process	2003	[40]
Implementing requirements engineering processes throughout organizations: success factors and challenges	2004	[29]
Measuring the success of requirements engineering processes	1995	[16]

Table 6.3: Contributions for research type facet "Exploratory research" by year

Title	Year	Ref.
Maturing Requirements Engineering Process Maturity Models	2011	[52]

Table 6.4: Contributions for research type facet "Opinion paper" by year

Title	Year	Ref.
Requirements engineering processes improvement: a systematic view	2005	[42]

Table 6.5: Contributions for research type facet "Philosophical paper" by year

Title	Year	Ref.
A Framework for Improving the Requirements Engineering Process Effectiveness	1999	[67]
A Framework for Improving the Requirements Engineering Process Management	1999	[68]
A Meta-model for Requirements Engineering in System Family Context for Software Process Improvement Using CMMI	2005	[8]
A Model for Requirements Change Management: Implementation of CMMI Level 2 Specific Practice	2008	[39]
An instrument for measuring the maturity of requirements engineering process	2005	[37]
An instrument for measuring the success of the requirements engineering process in information systems development	1996	[17]
Building a Case for a Dynamic Requirements Process Improvement Model	2011	[71]
Building a requirements process improvement model	2003	[5]
Capturing the Benefits of Requirements Engineering	1999	[56]
Defining a Requirements Process Improvement Model	2005	[6]
Experiences in the Application of Software Process Improvement in SMES	2002	[65]
Goal-Driven requirements engineering for supporting the ISO 15504 assessment process	2005	[49]
Improvement proposal for a Software Requirements Management Process	2006	[70]
Improving Market-Driven RE Processes	1999	[53]
Improving the Requirements Process	1997	[54]
Knowledge-activity-based requirements engineering processes improvement framework	2009	[2]
Modelling and engineering the requirements engineering process: An overview of the NATURE approach	1997	[21]
Process Improvement in Requirements Management: A Method Engineering Approach	2008	[7]
Re-defining the Requirements Engineering Process Improvement Model	2009	[57]
Requirement Process Establishment and Improvement: From the Viewpoint of Cybernetics	2005	[69]
Requirements engineering: In search of the dependent variables	2008	[19]
Requirements Process Improvement through the Phased Introduction of Good Practice	1997	[55]
Story Card Maturity Model (SMM): A Process Improvement Framework for Agile Requirements Engineering Practices	2009	[45]
Using Patterns for Sharing Requirements Engineering Process Rationales	2006	[22]

Table 6.6: Contributions for research type facet "Solution proposal" by year

Title	Year	Ref.
A measurement framework for assessing the maturity of requirements engineering process	2008	[38]
Validating the ISO/IEC 15504 measure of software requirements analysis process capability	2000	[15]

Table 6.7: Contributions for research type facet "Validation research" by year

Bibliography

[1] S. Adam, J. Doerr, and M. Eisenbarth. Lessons Learned from Best Practice-Oriented Process Improvement in Requirements Engineering: A Glance into Current Industrial RE Application. In *Fourth International Workshop on Requirements Engineering Education and Training*, 2009.

[2] S.N. Alsulmi. *Knowledge-activity-based requirements engineering processes improvement framework*. PhD thesis, Lancaster University, 2009.

[3] C. Alves, G. Valença, T. Sotero, and J. Mendes. Requirements engineering process improvement: a knowledge transfer experience. In *Proceedings of 2008 ACM Symposium on Applied Computing*, pages 619–623. ACM, 2008.

[4] S. Beecham, T. Hall, C. Britton, M. Cottee, and A. Rainer. Using an expert panel to validate a requirements process improvement model. *Journal of Systems and Software*, 76:251–275, 2005.

[5] S. Beecham, T. Hall, and A. Rainer. Building A Requirements Process Improvement Model. Technical report, University of Hertfordshire, 2003.

[6] S. Beecham, T. Hall, and A. Rainer. Defining a requirements process improvement model. *Software Quality Control*, 13:247–279, 2005.

[7] S. Brinkkemper, I. Weerd, M. Saeki, and J. Versendaal. Process improvement in requirements management: A method engineering approach. In *Requirements Engineering: Foundation for Software Quality*, volume 5025, pages 6–22. SpringerLink, 2008.

[8] R. Cerón, J.C. Dueñas, E. Serrano, and R. Capilla. A Meta-Model for Requirements Engineering in System Family Context for Software Process Improvement Using CMMI. *Product Focused Software Process Improvement*, pages 173–188, 2005.

[9] D. Damian, J. Chisan, L. Vaidyanathasamy, and Y. Pal. Requirements engineering and downstream software development: Findings from a case study. *Empirical Software Engineering*, 10:255–283, 2005.

[10] D. Damian, D. Zowghi, L. Vaidyanathasamy, and Y. Pal. An Industrial Experience in Process Improvement: An Early Assessment at the Australian Center for Unisys

Software. In *International Symposium on Empirical Software Engineering*. IEEE, 2002.

[11] M. Daneva. Using maturity assessments to understand the erp requirements engineering process. In *IEEE Joint International Conference on Requirements Engineering*. IEEE, 2002.

[12] M. Daneva. Erp requirements engineering practice: Lessons learned. *IEEE Software*, pages 26–33, 2004.

[13] J. Doerr, B. Paech, and M. Koehler. Requirements Engineering Process Improvement Based on An Information Model. In *12th IEEE International Requirements Engineering Conference*, pages 70–79. IEEE, 2004.

[14] J. Dörr, S. Adam, M. Eisenbarth, and M. Ehresmann. Implementing requirements engineering processes: Using cooperative self-assessment and improvement. *IEEE Transactions on Software Engineering*, pages 71–77, 2008.

[15] K. El Emam and A. Birk. Validating the iso/iec 15504 measure of software requirements analysis process capability. *IEEE Transactions on Software Engineering*, 26:541–566, 2000.

[16] K. El Emam and N.H. Madhavji. Measuring the Success of Requirements Engineering Processes. In *Proceedings of the Second IEEE International Symposium on Requirements Engineering*, number 204–211, 1995.

[17] K. El Emam and N.H. Madhavji. An Instrument for Measuring the Success of the Requirements Engineering Process in Information Systems Development. *Empirical Software Engineering*, 1:201–240, 1996.

[18] T. Gorschek. *Requirements Engineering Supporting Technical Product Management*. PhD thesis, Blekinge Institute of Technology, 2006.

[19] T. Gorschek and A.M. Davis. Requirements engineering: In search of the dependent variables. *Information and Software Technology*, 50:67–75, 2008.

[20] T. Gorschek and C. Wohlin. Identification of improvement issues using a lightweight triangulation approach. In *European Software Process Improvement Conference*, 2003.

[21] G. Grosz, C. Rolland, S. Schwer, C. Souveyet, V. Plihon, S. Si-Said, C.B. Achour, and C. Gnaho. Modelling and Engineering the Requirements Engineering Process: An overview of the NATURE Approach. *Requirements Engineering*, 2:115–131, 1997.

[22] L. Hagge, F. Houdek, K. Lappe, and B. Paech. *Rationale Management in Software Engineering*, chapter Using Patterns for Sharing Requirements Engineering Process Rationales, pages 409–427. SpringerLink, 2006.

[23] F. Houdek and K. Pohl. Analyzing Requirements Engineering Processes: A Case Study. *IEEE Transactions on Software Engineering*, pages 983–987, 2000.

[24] L. Jiang, A. Eberlein, and B.H. Far. Case studies on the application of the CORE model for requirements engineering process assessment. In *Canadian Conference on Electrical and Computer Engineering*, pages 323–326. IEEE, 2004.

[25] E. Kabaale and J. Nabukenya. A Systematic Approach to Requirements Engineering Process Improvement In Small and Medium Enterprises: An Exploratory Study. In *Product-Focused Software Process Improvement*, volume 6759, pages 262–275. SpringerLink, 2011.

[26] M. Kauppinen. A practical framework for systematic improvement of requirements engineering processes. Technical report, Helsinki University of Technology, 2002.

[27] M. Kauppinen, T. Aaltio, and S. Kujala. Lessons learned from applying the requirements engineering good practice guide for process improvement. In *Software Quality - ECSQ*, volume 2349, pages 73–81. SpringerLink, 2006.

[28] M. Kauppinen and S. Kujala. Starting improvement of requirements engineering processes: An experience report. In *Product Focused Software Process Improvement*, volume 2188, pages 196–209. SpringerLink, 2001.

[29] M. Kauppinen, M. Vartiainen, J. Kontio, S. Kujala, and R. Sulonen. Implementing Requirements Engineering Processes Throughout Organizations: Success Factors and Challenges. *Information and Software Technology*, 46:937–953, 2004.

[30] B. Kitchenham, O. Pearl Brereton, D. Budgen, M. Turner, J. Bailey, and S. Linkman. Systematic literature reviews in software engineering - a systematic literature review. In *Information and Software Technology*, volume 51, pages 7–15, 2009.

[31] Marco Kuhrmann, Daniel Méndez Fernández, and Michaela Tiessler. A mapping study on method engineering: first results. In *Proceedings of the 17th International Conference on Evaluation and Assessment in Software Engineering*, pages 165–170. ACM, 2013.

[32] Mathieu Lavallée and Pierre N. Robillard. The impacts of software process improvement on developers: A systematic review. In *Proceedings of the 2012 International Conference on Software Engineering*, pages 113–122. IEEE Press, 2012.

[33] G.A. Markov, A. Hoffmann, and O. Creighton. Requirements Engineering Process Improvement: An Industrial Case Study. In *Requirements Engineering: Foundation for Software Quality*, pages 34–37. SpringerLink, 2011.

[34] Daniel Méndez Fernández and Roel Wieringa. Improving requirements engineering by artefact orientation. In *Product-Focused Software Process Improvement*, volume 7983 of *Lecture notes in Computer Science*. Springer Berlin Heidelberg, 2013.

[35] Sune Dueholm Müller, Lars Mathiassen, and Hans Henrik Balshøj. Software process improvement as organizational change: A metaphorical analysis of the literature. *Journal of Systems and Software*, 83:2128–2146, 2010.

[36] N.P. Napier, L. Mathiassen, and R.D. Johnson. Combining Perceptions and Prescriptions in Requirements Engineering Process Assessment: An Industrial Case Study. *IEEE Transactions on Software Engineering*, 35(5):593–606, 2009.

[37] M. Niazi. An Instrument for Measuring the Maturity of Requirements Engineering Process. In *Product-Focused Software Process Improvement*, volume 3547, pages 574–585. SpringerLink, 2005.

[38] M. Niazi, K. Cox, and J. Verner. A Measurement Framework for Assessing the Maturity of Requirements Engineering Process. *Software Quality Journal*, 16:213–235, 2008.

[39] M. Niazi, C. Hickman, R. Ahmad, and M.A. Babar. A model for requirements change management: Implementation of cmmi level 2 specific practice. In *Product-Focused Software Process Improvement*, pages 143–157. SpringerLink, 2008.

[40] M. Niazi and S. Shastry. Critical success factors for the improvement of requirements engineering process. In *SERP International Conference*, 2003.

[41] U. Nikula and J. Sajaniemi. Tackling the complexity of requirements engineering process improvement by partitioning the improvement task. In *Australian Software Engineering Conference*. IEEE, 2005.

[42] A. Ning, H. Hou, Q. Hua, B. Yu, and K. Hao. Requirements Engineering Processes Improvement: A Systematic View. In *Unifying the Software Process Spectrum*, volume 3840, pages 151–163. SpringerLink, 2006.

[43] B. Palyagar and F. Moisiadis. Validating Requirements Engineering Process Improvements - A Case Study. In *First International Workshop on Requirements Engineering Visualization*. IEEE, 2006.

[44] B. Palyagar and D. Richards. *Rationale Management in Software Engineering*, chapter Capturing and Reusing Rationale Associated with Requirements Engineering Process Improvement: A Case Study, pages 391–408. SpringerLink, 2006.

[45] C. Patel and M. Ramachandran. *Handbook of Research on Software Engineering and Productive Technologies*, chapter Story Card Maturity Model (SMM): A Process Improvement Framework for Agile Requirements Engineering Practices, pages 61–54. IGI Global, 2009.

[46] K. Petersen, R. Feldt, S. Mujtaba, and M. Mattsson. Systematic mapping studies in software engineering. In *Proceedings of the 12th international conference on Evaluation and Assessment in Software Engineering*, pages 68–77, Swinton, UK, UK, 2008. British Computer Society.

[47] F. Pettersson, M. Ivarsson, T. Gorschek, and P. Öhman. A Practitioner's Guide to Light Weight Software Process Assessment and Improvement Planning. *Journal of Systems and Software*, 81:972–995, 2008.

[48] A.A. Rahman, S. Sahibuddin, and S. Ibrahim. A study of process improvement best practices. In *Information Technology and Multimedia (ICIM), 2011 International Conference on*, pages 1–5, 2011.

[49] A. Rifaut. Goal-driven requirements engineering for supporting the iso 15504 assessment process. In *Software Process Improvement*, volume 3792, pages 151–162. SpringerLink, 2005.

[50] I. Riuz-Rube, J.M. Dodero, M. Palomo-Duarte, M. Ruiz, and D. Gawn. Uses and applications of spem process models. a systematic mapping study. *Journal of Software Maintenance and Evolution: Research and Practice*, 2012.

[51] P. Runeson and M. Höst. Guidelines for conducting and reporting case study research in software engineering. *Empirical Software Engineering*, 14(2):131–164, 2009.

[52] P. Sawyer. *Requirements Engineering for Sociotechnical Systems*, chapter Maturing Requirements Engineering Process Maturity Models. Idea Group Inc., 2011.

[53] P. Sawyer, I. Sommerville, and G. Kotonya. Improving market-driven re processes. In *VTT Symposium*, volume 195, 1999.

[54] P. Sawyer, I. Sommerville, and S. Viller. Improving the requirements process. Technical report, Cooperative Systems Engineering Group, 1997.

[55] P. Sawyer, I. Sommerville, and S. Viller. Requirements process improvement through the phased introduction of good practice. *Software Process Improvement and Practice*, 3.1:19–37, 1997.

[56] P. Sawyer, I. Sommerville, and S. Viller. Capturing the benefits of requirements engineering. *IEEE Transactions on Software Engineering*, 1999.

[57] B. Solemon, S. Shahibuddin, and A.A. Abd Ghani. Re-defining the Requirements Engineering Process Improvement Model. In *16th Asia-Pacific Software Engineering Conference*, pages 87–92. IEEE, 2009.

[58] I. Sommerville and J. Ransom. An Empirical Study of Industrial Requirements Engineering Process Assessment and Improvement. *ACM Transactions on Software Engineering and Methodology*, 14:85–117, 2005.

[59] M. Sulayman and E. Mendes. An extended systematic review of software process improvement in small and medium web companies. In *Evaluation Assessment in Software Engineering (EASE 2011), 15th Annual Conference on*, pages 134–143, 2011.

[60] Mikael Svahnberg, Tony Gorschek, ThiThanLoan Nguyen, and Mai Nguyen. Unirepm: a framework for requirements engineering process assessment. *Requirements Engineering*, pages 1–28, 2013.

[61] Mikael Svahnberg, Tony Gorschek, ThiThanLoan Nguyen, and Mai Nguyen. Unirepm: validated and improved. *Requirements Engineering*, (85–103), 2013.

[62] S. Teufl, M. Khalil, D. Mou, and E. Geisberger. Experience with content-based requirements engineering assessments. In *19th International Requirements Engineering Conference*, pages 345–346. IEEE, 2011.

[63] S.P. Tripathy, S. Mishra, A. Shrivastava, V.K. Singh, and M. Darbari. An Efficient Evaluation of Requirements Engineering Process Maturity Assessment and Improvement. In *2nd National Conference INDIACom*. INDIACom, 2008.

[64] M. Unterkalmsteiner, T. Gorschek, A.K.M.M. Islam, Chow Kian Cheng, R.B. Permadi, and R. Feldt. Evaluation and measurement of software process improvement: A systematic literature review. *IEEE Transactions on Software Engineering*, 38(2):398–424, 2012.

[65] J.A.C-M. Villalón, G.C. Agustín, T.S.F. Gilabert, A.D.A. Seco, L.G. Sánchez, and M.P. Cota. Experiences in the application of software process improvement in smes. *Software Quality Journal*, 10:261–273, 2002.

[66] R. Wieringa, N. Maiden, N. Mead, and C. Rolland. Requirements engineering paper classification and evaluation criteria: a proposal and a discussion. In *Requirements Engineering*, volume 11, pages 102–107. Springer-Verlag, 2006.

[67] D. Williams and M. Kennedy. A framework for improving the requirements engineering process effectiveness. In *9th Annual International Symposium on System Engineering*, 1999.

[68] D.W. Williams, T. Hall, and M. Kennedy. A framework for improving the requirements engineering process management. *Software Quality Journal*, 8:133–147, 1999.

[69] H. Xu, P. Sawyer, and I. Sommerville. Requirement process establishment and improvement: From the viewpoint of cybernetics. In *29th Annual International Computer Software and Applications Conference*. IEEE, 2005.

[70] P.I. Yamaç. *Improvement proposal for a Software Requirements Management Process*. PhD thesis, The Middle East Technical University, 2006.

[71] A. Zawedde. Building a Case for a Dynamic Requirements Process Improvement Model. *International Journal of Computing and ICT Research*, pages 25–33, 2011.

[72] A.S.A. Zawedde, M.D.M. Klabbers, D.D. Williams, and M.G.J.M. van den Brand. Understanding the dynamics of requirements process improvement: A new approach. In *Product-Focused Software Process Improvement*, volume 6759, pages 276–290. SpringerLink, 2011.