Systematic Literature Reviews of Software Process Improvement: A Tertiary Study

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Abstract. Systematic Literature Review (SLR) is becoming a vital part of present day research in software process improvement (SPI). Nevertheless, there is no available study that provides detail review of the published software process improvement SLRs. **Objective**: The aim of this article is to classify the SLRs of SPI in order to identify the main research areas covered and evaluate the quality of the published SLRs. **Methodology**: A tertiary study was conducted to review the SLRs published by other researchers on the topic of SPI. **Results**: Twenty-four SLR articles were identified in the field of SPI. Results show that the quality of the selected SLRs on SPI is decreasing over the recent years. The most popular research topics are factors affecting SPI and process models. **Conclusions**: This study provides the review and state of the art in the context of SPI research. The results of this article would be of great interest for future SPI researchers by providing in depth understanding of various research areas in SPI. The number of process improvement SLRs is increasing and the overall quality is decreasing, which could lessen their potential impact on SPI practice. Currently, SPI literature is weak in the knowledge areas such as quality and software testing process improvement.

Keywords: Software process improvement · Systematic literature review · Tertiary study · Systematic mapping

1 Introduction

Zahran [1] define SPI as "the discipline of defining, characterizing, improving and measuring software management, better product innovation, faster cycle time, greater product quality and reduced development costs simultaneously". According to O'Connor et al. [2], various process improvement models and techniques have been developed in order to help software organizations to achieve effective management of software development processes. However, regardless of the availability of different

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process improvement models and standards, the success rate of SPI programs is very low [3], i.e. about 30% [4]. Khan and Keung [5] justify it by reporting that little attention has been given to the process improvement activities. Software development organizations have recognized that the failure to effectively direct the software process is one of the main causes of unsuccessful projects [5].

Research to mitigate the issues related to SPI is expanding and SLR approach is increasingly used to explore the available literature. SLR has a long tradition in SPI research and various review studies are conducted using the SLR technique [5–13, 15, 17, 18]. SLR assists the SPI researchers to highlight state of the art in a specific domain. According to Kitchenham [6], SLR is an approach for investigating, classifying, and assessing the existing literature related to a specific research area and questions of interest [7].

Systematic mapping study is a type of SLR that focus on particular research area in order to categorize the resulting literature to present a 'map' of that specific area [6].

Tertiary study approach is used to extract the data and information from available SLRs of a specific research topic. Tertiary studies present information about the number of SLRs published in a particular research field, their quality and main research focus. Several tertiary studies are published in the domain of software engineering [3, 8–13, 17], but none of the published tertiary studies emphasized on SLRs in the context of SPI.

The aim of this research study is to present a tertiary study of published SLRs on SPI between 2004 and October 2015. The time range is based on the deployment of systematic review approach in the field of software engineering in 2004 [7]. This tertiary study will provide a thorough understanding of the available SPI research and assist the researchers by enriching their background knowledge on SPI.

The next section of the paper presents the adopted research methodology. Section 3 highlights the extracted results of the review. In Sect. 4, we discuss threats to validity and our conclusions are presented in Sect. 5.

2 Research Methodology

Systematic literature review is a type of the secondary study that assess all the primary studies "studies which are used for exploring a specific research area" in order to identify, analyze and explore all evidences related to research questions in an unbiased and iterative way [6, 7]. According to Kitchenham [6], SLR has three main phases i.e. "planning the review, conducting the review and reporting the review". The three SLR phases are reported in the following sections.

2.1 Phase 1: Planning the Review

Research Questions. We have followed the previously published tertiary studies [3, 8–13, 17] in order to structure the following research questions.

(RQ1) What SLR studies have been published in the field of software process improvement from 2004 to October 2015?

(RQ2) What software process improvement topics have been discussed?
(RQ3) What is the quality of the available SLR articles on SPI?

Search Process. A comprehensive search process was conducted in order to classify all the available research articles relevant to our questions of interest. We have break down the research questions and extracted the major terms. We have also reported the list of synonyms, abbreviations, and alternative words of the major terms. The keywords and their synonyms were based on the existing literature in the domain of process improvement [1, 2, 4, 5, 14]. The major keywords and their synonyms were concatenated with the help of "OR" and "AND" operators to construct the search strings that were used for the identification of relevant primary studies.

We have developed the following search strings: (("software process improvement" OR "SPI" OR "software process models" OR "software process standards" OR "software process frameworks" OR "software maturity models") AND ("systematic literature review" OR "SLR" OR "systematic mapping" OR "literature review" OR "meta-analysis" OR "in-depth survey" OR "previous studies" OR "existing literature" OR "review of literature" OR "survey of available literature" OR "in-depth overview" OR "mapping study")).

The search strings were deployed in several digital repositories in order to identify the relevant articles. The selection of repositories was based on previous research experience and suggestions provided by other researchers [13]. A total of five databases were selected, i.e., IEEE, Scopus, Google Scholar, Science Direct and ISI Web of Science. The given combinations of search terms have been used to extract the required results from the selected digital repositories.

Inclusion and Exclusion Criteria. All published studies that focused on SLRs or systematic mapping studies in journals, conferences or books in the domain of SPI were included in the study to the best knowledge. Relevance to the earlier mentioned research questions were the basic consideration.

Research studies that did not explicitly discuss SLRs in the context of SPI were excluded. We have also excluded the Master and PhD dissertations that are not published in journals or conferences. Furthermore, all informal literature surveys were ignored. The duplicated articles were not considered. Additionally, those articles were also excluded that were reported in other languages except English.

Quality Criteria for the studies selection. Quality is the degree to which a specific study minimizes the bias and maximizes the internal and external validity [19]. Quality assessment assists to interpret the results and determine the strength of the elaborated inferences [9]. The most commonly used approaches for quality assessment are checklist [15]. Each primary study was assessed for quality using a checklist (i.e. Database of Abstracts of Reviews of Effects (DARE)) defined by the Centre for Reviews and Dissemination (CDR), York University [16]. The DARE checklist is based on four questions illustrated in Table 1. The same quality assessment approach has been adopted by other researchers [8, 17].

Table 1. Checklist for quality assessment of selected studies.

QA Questions	Score	Description
QA1: "Are the review's inclusion and exclusion criteria described and appropriate?"	1	Explicit inclusion criteria
	0.5	Implicit inclusion criteria
	0	No inclusion criteria
QA2: "Is the literature search likely to have covered all relevant studies?"	1	Extract data from four or more digital libraries with additional search strategies
	0.5	Limited searched of three or four digital libraries with no additional search strategies
	0	Limited search of two digital libraries or restricted search
QA3: "Did the reviewers assess the quality/validity of the included studies?"	1	Applied explicit quality criteria
	0.5	Research question involves quality issues that are addressed by the study
	0	No study quality assessment strategy
QA4: "Were the basic data/studies adequately described?"	1	Clear description of the information for each selected primary study
	0.5	Abstract level information about selected primary studies
	0	The outcomes of the specific studies are not quantified

2.2 Conducting the Review

Primary Studies Selection. A comprehensive search was conducted and a total of 7684 articles were extracted from all the selected databases. The tollgate technique developed by Afzal et al. [18] was applied to the articles selection process, which comprise of five phases as described in Fig. 1. After applying the inclusion and exclusion criteria, a total of 24 primary studies that focused on SLRs of SPI were selected using the tollgate approach [18].

- Phase 1: Search through search terms (7684 articles were selected)
- Phase 2: Title and abstract based inclusion/exclusion (4112 articles were selected)
- Phase 3: Introduction and conclusions based inclusion/exclusion (323 articles were sorted out)
- Phase 4: Full text based inclusion/exclusion (135 articles were filtered)
- Phase 5: Final selection of articles to be included in the primary studies selection (24 articles were selected as a primary studies)

Complete details of the 24 selected primary studies are given in Appendix 1.

Data Extraction. The first author of this study has executed the search strings and selected the 24 SLRs by applying the inclusion and exclusion criteria. The third author has reviewed and reported the references, number of citations (CI), research focus (RF) and number of primary studies (PS) cited by the selected 24 SLR studies. The quality assessment process has been carried out by the first and third authors. The

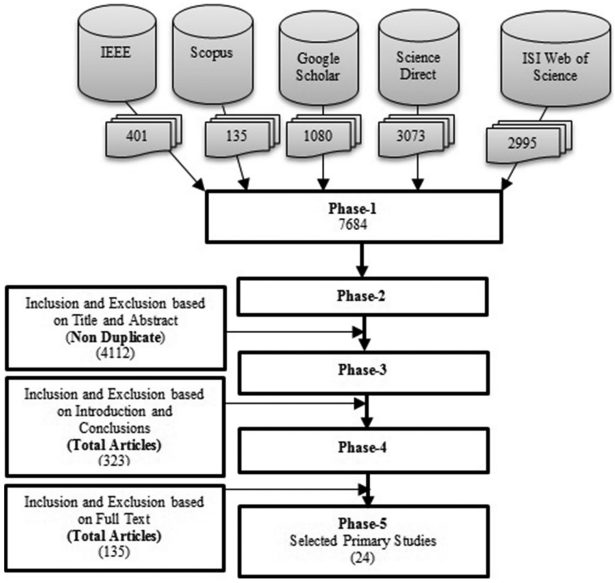

Fig. 1. Tollgate approach for articles selection.

second and fourth authors have reviewed and updated the quality assessment score for each selected SLR. The results and analysis phases have been mainly done by the first and third author. A complete list of all the 24 selected primary studies with the extracted information is provided in Appendix 1.

Data Synthesis. We have performed the data synthesis by aggregating the extracted data using a simple frequency analysis technique. We have not rejected the papers of the same authors discussed the results on the same topic in multiple papers. We are sure that conference papers have limited space, which do not allow the authors to discuss all the results.

The results extracted from all the selected articles were reported together and all the research questions were explicitly evaluated against these results.

3 Reporting the Results

In this section, all the extracted results in relation to each of the research questions are addressed.

(RQ1) What SLR studies have been published in the field of software process improvement from 2004 to October 2015?

Appendix 1 presents the results of the 24 selected SLRs on SPI. Eleven (45%) articles were published in conferences and 13 (54%) articles were published in journals. Among the 24 selected SLRs, [SL6] has cited the minimum number of primary studies (i.e. 4) and [SL24] has quoted a maximum number of 404. Citation of the SLRs ranged from 0 [SL1, SL5, SL11, SL12, SL21, SL23] to 193 [SL3] including self-citation. The articles having no citation are recently published SLR studies (2012-2015). As this tertiary study was conducted in 2015, therefore we have not found any citation for the given six articles. Three articles [SL1, SL5, SL12] have low quality assessment scores

and it might be the reason that they have no citation. The reaming three SLRs [SL11, SL21, SL23] are published in 2014-2015 and we believe that they will have multiple citations in the coming years.

Figure 2 demonstrates the year wise distribution of the selected primary studies. The first SLR on SPI was published in 2007 and the number recorded a gradual increase after 2009 until there was a distinct decrease in 2013. Since 2013, there has been an incessant increase of SLRs on SPI and 5 SLRs were published in 2015.

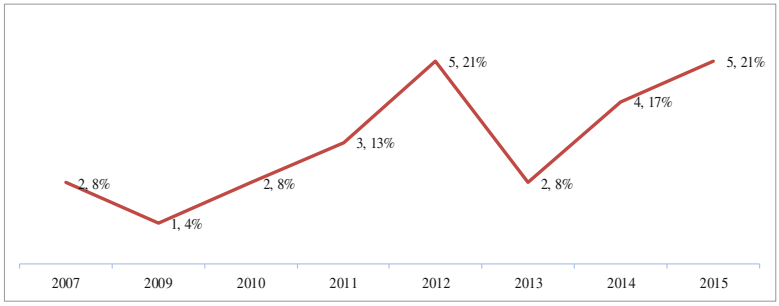

Fig. 2. Tollgate approach for articles selection.

(RQ2) What software process improvement topics have been discussed?

Results provided in Table 2 show that SLRs on SPI focus on five key areas, i.e. (1) factors (2) small and medium-sized enterprises (SMEs) (3) process models (4) software quality and (5) testing. Among all the topics, *factors and process models* were highlighted as the most common SPI topics as 8 SLRs were classified under each category. Articles discussed under the *factors* category have reported different success factors and barriers that might influence the design and execution of the SPI activities in the software industry. They also proposed various practices to address the identified success factors and barriers.

Eight SLRs discussed various aspects of SPI process models. For example, [SL13] reviewed the existing SPI problems and developed criteria for multimodal SPI solutions. The capability maturity model (CMM) and capability maturity model integration (CMMI) process models were the main research focus of articles [SL16, SL22]. One study [SL12] looked into the state of the art on SPI models and identified the strength of evidence from empirical work reported within SPI literature. Article, [SL15] provided in depth knowledge about the implementation of SPI models in a distributed environment and [SL19] gave a brief view of process improvement models for developing service based applications. One SLR, [SL24] has reported the implementation of process improvement models in a game development environment.

Research in SMEs was found to be the third most important research area. Six SLRs have discussed the concept of SPI in SMEs and covered various aspects of SPI in the domain of SMEs. Two SLRs [SL6, SL8] presented the current state of research in SPI models and techniques used by web development in SMEs. Two studies [SL11, SL14] highlighted the existing literature for SPI initiatives in establishing new companies. Existing SPI approaches used in SMEs were reported in [SL3] and the need for SPI implementation in the domain of SMEs was examined in [SL4].

Table 2. SPI research topics covered in selected SLRs

ID	Type	Citation	No. of primary studies	Research focus
SL1	Conference	0	10	Factors
SL2	Conference	4	28	
SL5	Conference	0	100	
SL7	Conference	17	26	
SL10	Journal	94	148	
SL18	Journal	28	60	
SL20	Journal	1	29	
SL23	Journal	0	38	
SL3	Journal	193	45	SMEs
SL4	Conference	6	Not mentioned	
SL8	Conference	13	8	
SL11	Conference	0	11	
SL14	Journal	24	43	
SL6	Conference	19	4	
SL9	Conference	8	7	Process models
SL12	Conference	0	400	
SL13	Journal	11	78	
SL15	Journal	54	26	
SL16	Journal	6	81	
SL19	Journal	29	57	
SL22	Journal	98	49	
SL24	Conference	1	404	
SL17	Journal	1	74	Software quality
SL21	Journal	0	18	Software testing

One study, [SL17] focused on up to date state of the art regarding the contribution of SPI implementation towards the improvement of product quality. In [SL21], the authors underlined available software testing process improvement approaches and their characteristics.

(RQ3) What is the quality of the available SLR articles on SPI?

Quality assessment (QA) criteria discussed in Table 1 were used to assess all the selected SLRs. Figure 3 shows the list of the scores for each SLR against the four quality assessment questions (Table 1). A total of 24 SLRs were selected and their QA scores were calculated by adding the assessment score against the four QA questions.

Table 3 reported the percentage and numbers of the selected SLRs against each QA question.

QA1 emphasized on the clear description of inclusion and exclusion criteria. Eleven articles (45.8%) have explicitly indicated the inclusion and exclusion criteria while ten articles (41.6%) discussed it partially. Total three studies (12.5%) did not consider the inclusion or exclusion criteria for their SLRs.

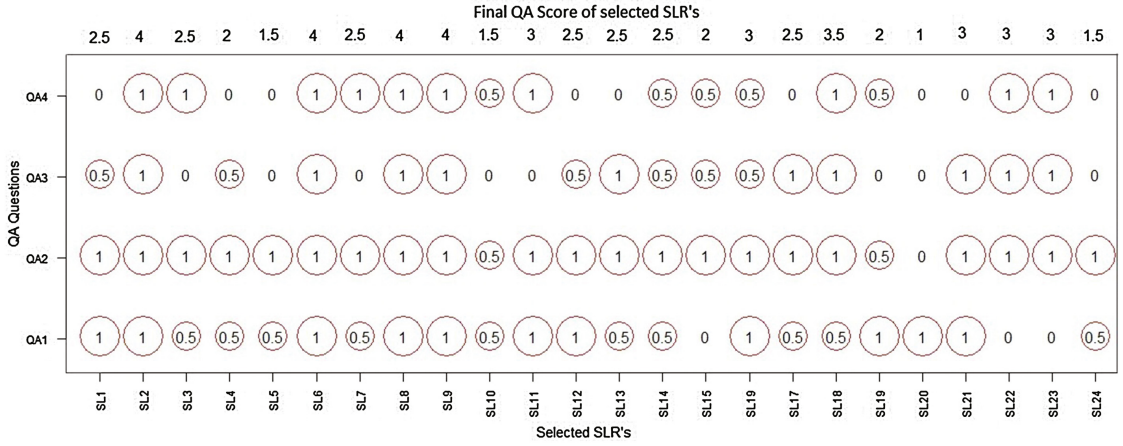

Fig. 3. Tollgate approach for articles selection.

Table 3. SPI research topics covered in selected SLRs

ID	Quality assessment criteria	Yes/1	Partially/ 0.5	No/0
QA1	"Are the review's inclusion and exclusion criteria described and appropriate?"	11 (45.8%)	10 (41.6%)	3 (12.5%)
QA2	"Is the literature search likely to have covered all relevant studies?"	21 (84.5%)	2 (8.3%)	1 (4.1%)
QA3	"Did the reviewers assess the quality/validity of the included studies?"	10 (41.6%)	6 (25.0%)	8 (33.3%)
QA4	"Were the basic data/studies adequately described?"	10 (41.6%)	5 (20.8%)	9 (37.5%)

QA2 inquires whether the SLRs have covered all the relevant studies or not. Most of the SLRs succeeded (84.5%), while (8.3%) of them gave partial details about the relevant studies. One study (4.1%) didn't consider QA2 for their SLR.

QA3 tackles the quality assessment of the selected primary studies. Results demonstrate that (41.6%) of the SLRs have clearly assessed their selected primary studies and (25%) of the articles have embarked on partial assessment. The result for QA3 shows that (33.3%) of the SLRs did not define quality assessment criteria for primary studies.

Results for QA4 demonstrate that (41.6%) of the SLRs have adequately described the primary studies and (20.8%) gives partial details. The results illustrate that in total (37.5%) of the selected SLRs did not provide any information about their selected primary studies.

Based on the above discussion, we could argue that majority of the selected primary studies (84.5%) have explicitly fulfilled the assessment criteria of QA2 (Table 3). The QA2 focused on the search strategy to extract the most relevant studies. It means that most of the SLR studies have selected the appropriate search criteria and they have mined the most relevant studies.

We have also concluded that, (41.6%) of the selected SLRs have partial inclusion and exclusion criteria (QA1) and (33.3%) have failed to evaluate the quality of the

included primary studies (QA3). As shown in Table 3, (41.6%) SLRs did not provide complete overview of the included primary studies (QA4).

It illustrates that most of the 24 SLRs have not completely satisfied the quality assessment criteria (Table 3). It is known that the main difference between SLR and the traditional literature review is the rigor process [10], where the ignorance of this factor will likely not yield reliable and useful results. This issue needs further consideration in the domain of SPI SLRs. It is because if the selected primary studies could not fulfill the QA criteria, then there might be serious threats to the validity of the results presented by the SLRs [10].

4 Threats to Validity

Most of the SLR data were collected by the first and third authors and there exists a high risk that two researchers could be biased and frequently extracting wrong data. In view of such threat, the remaining authors were involved to randomly check the different steps involved in this tertiary study. Nevertheless, the random checks of the authors have not been reported in the sense of review manner, time, effort and impacts of the checks.

Additionally, we might have missed some of the related keywords and their synonyms to develop a complete set of search strings. It may cause to miss numerous numbers of related articles of process improvement. However, we corroborated our search strategy against previous tertiary studies [3, 8–13, 17] and track our tertiary study considering all SLRs in SPI.

We have addressed RQ2 by classifying the identified articles based on the reported research topics. A possible threat to the validity of this study is that, we have not found a specific framework that could be used to map the identified articles into the five categories of research topics (Table 2). We were not able to formally validate the classification. However, all of the authors were involved in the informal mapping process.

Finally, this SLR study might suffer from over-constraints in the search terms. Due to this limitation, the study may have missed additional aspects of SPI that were not previously examined using SLR approach.

5 Conclusions

Twenty four SLRs that were conducted between 2004 and October 2015 in the domain of SPI have been successfully selected. It is a first attempt to conduct a tertiary study for SPI related studies. The collected data and the results presented in this paper could be of great value for future SPI researchers, in particular for doctoral students who may need an effective starting point for an overview of all the research areas so far in SPI. Furthermore, limitations of the existing SPI related SLRs were discussed. It is beneficial for those who are keen to select interested research areas of process improvement.

The most common concerns of the SLRs are research areas of factors and SPI process models. Most of the selected SLR studies have discussed success factors and their impacts on SPI implementation, as well as various process models. It suggests

that, currently researchers might have great interest in these two research areas and these are the most active research topics in the domain of SPI.

The quality of the selected SLRs decreased over time because most of the SLRs neglected to thoroughly assess the quality of their selected primary studies. The absence of this quality assessment factor will likely not bring reliable and useful results. Therefore, researchers should put strong emphasis on the implementation of quality assessment criteria.

With these considerations, we hope to increase the knowledge of available literature regarding SPI and the actual state of the research based on systematic reviews. The analysis of the results suggests that a few knowledge areas of SPI like quality and software testing process have not yet become the focus of researchers. With this study, it is hoped that researchers would investigate the SPI research areas that until now still receive limited attention or have not yet been explored.

In the future, we will update this tertiary study by considering the SLRs published after October 2015. This research work will also be extended by conducting secondary search from reviewing the primary studies of the 24 selected SLR studies. Detailed analysis upon the data extraction completion from the secondary search can be performed. The remaining steps of thematic synthesis will be applied to come up with a model for the themes.

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Appendix 1

See Table 4.

Table 4. Selected Primary Studies

ID	Reference	CI	RF	PS
SL1	Bayona, S., Calvo-Manzano, A.J., Feliu. S.T.: Review of critical success factors related to people in software process improvement. European Conference on Software Process Improvement. Springer Berlin Heidelberg (2013)	0	Factors	10
SL2	Bayona, S., Calvo-Manzano, A.J., Feliu. S.T.: Critical success factors in software process improvement: A systematic review. International Conference on Software Process Improvement and Capability Determination. Springer Berlin Heidelberg (2012)	4	Factors	28

(*continued*)

Table 4. (*continued*)

ID	Reference	CI	RF	PS
SL3	Pino, J.F., García, F., Piattini, M.: Software process improvement in small and medium software enterprises: a systematic review. Software Quality Journal. 16(2), 237–261 (2007)	193	SMEs	45
SL4	Claudia, V., Mirna, M., Jezreel, M.: Characterization of software processes improvement needs in SMEs." IEEE International Conference on Mechatronics, Electronics and Automotive Engineering (ICMEAE) (2013)	6	SMEs	Nil
SL5	Mirna, M., Jezreel, M., Brenda, D., Claudia, V.: Software Process Improvement from a Human Perspective. New Perspectives in Information Systems and Technologies, Springer International Publishing, 287–298 (2014)	0	Factors	100
SL6	Sulayman, M., Mendes, E.: A systematic literature review of software process improvement in small and medium web companies. International Conference on Advanced Software Engineering and Its Applications. Springer Berlin Heidelberg (2009)	19	SMEs	4
SL7	Lavallée, M., Robillard, N.P.: The impacts of software process improvement on developers: A systematic review. Proceedings of the 34th international conference on software engineering (2012)	17	Factors	26
SL8	Sulayman, M., Mendes, M.: An extended systematic review of software process improvement in small and medium web companies. 15th Annual Conference on Evaluation & Assessment in Software Engineering (EASE) (2011)	13	SMEs	8
SL9	García-Mireles, A.G., Moraga, A.M., García, F.: Development of maturity models: a systematic literature review. 16th Annual Conference on Evaluation & Assessment in Software Engineering (EASE), 279–283 (2012)	8	Process Models	7
SL10	Unterkalmsteiner, M., Gorschek, T., Moinul Islam, A.K.M., Cheng, K.C., Permadi, B.R., Feldt, R.: Evaluation and Measurement of Software Process Improvement— "A Systematic Literature Review" IEEE Transaction on Software Engineering, 38(2), 398–424 (2012)	94	Factors	148
SL11	Almomani, T.A.M., Basri, S., Mahamad, S., Bajeh, O.A.: Software Process Improvement Initiatives in Small and Medium Firms: A Systematic Review. IEEE 3rd International Conference on Advanced Computer Science Applications and Technologies (ACSAT), (2014)	0	SMEs	11

(*continued*)

Table 4. (*continued*)

ID	Reference	CI	RF	PS
SL12	Bano, M., Ikram, N.: Software process improvement: a systematic literature review. 15th IEE International Multitopic Conference (INMIC) (2012)	0	Process Models	400
SL13	Kelemen, D.Z., Kusters, R., Trienekens, J.: Identifying criteria for multimodel software process improvement solutions based on a review of current problems and initiatives. Journal of software: Evolution and Process 24 (8), 895–909 (2011)	11	Process Models	78
SL14	Paternostera, N., Giardinoa, C., Unterkalmsteinera, M., Gorscheka, T., Abrahamssonb, P.: Software development in startup companies: A systematic mapping study. Information and Software Technology 56(10), 1200–1218 (2014)	24	SMEs	43
SL15	Prikladnicki, R., Audy, N.L.J.: Process models in the practice of distributed software development: A systematic review of the literature. Information and Software Technology 52(8), 779–791 (2010)	54	Process Models	26
SL16	Silva, S.F., Santana, F., Peres, L.A., Azevedo, Mde. I., Ana Vasconcelos, Paula, L.F.A, Kamei, K.F., Meira, Lde, R.S.: Using CMMI together with agile software development: A systematic review. Information and Software Technology, 20–43 (2015)	6	Process Models	81
SL17	García-Mireles, A.G., Moraga, A.M., Garcia, F., Piattini, M.: Approaches to promote product quality within software process improvement initiatives: A mapping study. Journal of Systems and Software, 150–166 (2015)	1	Software Quality	74
SL18	Müller, D.S., Mathiassen, L., Balshøj, H.H.: Software Process Improvement as organizational change: A metaphorical analysis of the literature. Journal of Systems and Software 83(11), 2128–2146 (2010)	28	Factors	60
SL19	Lane, S., Richardso, I.: Process models for service-based applications: A systematic literature review. Information and Software Technology 53 (5), 424–439 (2011)	29	Process Models	57
SL20	Zarour, M., Abran, A., Desharnais, M.-J., Alarifi, A.: An investigation into the best practices for the successful design and implementation of lightweight software process assessment methods: A systematic literature review. Journal of Systems and Software. 180–192 (2015)	1	Factors (Best practices)	29

(*continued*)

Table 4. (*continued*)

ID	Reference	CI	RF	PS
SL21	Afzal, W., Alonec, S., Glocksienc, K., Torkar, R.: Software test process improvement approaches: A systematic literature review and an industrial case study. Journal of Systems and Software. 1–33 (2015)	0	Testing	18
SL22	Staples, M., Niazi, M.: Systematic review of organizational motivations for adopting CMM-based SPI. Information and software technology 50(7), 605–620 (2007)	98	Process Models	49
SL23	Niazi, M.: A comparative study of software process improvement implementation success factors. Journal of Software: Evolution and Process 27(9), 700–722 (2015)	0	Factors	38
SL24	O'Hagan, O.A., Coleman, G., O'Connor, V.R.: Software development processes for games: a systematic literature review. European Conference on Software Process Improvement. Springer Berlin Heidelberg (2014)	1	Processes	404

Article title (TL), Total number of citations (CI), Main research focus (RF), Number of primary studies (PS)

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