

Systematic Reviews in Requirements Engineering: A Tertiary Study

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Abstract—There has been an increasing interest in conducting Systematic Literature Reviews (SLR) among Requirements Engineering (RE) researchers in recent years. However, so far there have been no tertiary studies conducted to provide a comprehensive overview of these published SLR in RE. In this paper we present a tertiary study of SLR that focus solely on RE related topics by following the guidelines of Evidence Based Software Engineering. We have conducted both automated search of major online sources and manual search of the RE and SLR related conferences and journals. Our tertiary study has identified 53 distinct systematic reviews published from 2006 to 2014 and reported in 64 publications. We have assessed the resulting SLR for their quality, and coverage of specific RE related topics thus identifying some gaps. We have observed that the quality of SLR in RE has been decreasing over the recent years. There is a strong need to replicate some of these SLR to increase the reliability of their results for future RE research.

Index Terms—Requirements Engineering, Mapping Study, Systematic Literature Review, Tertiary Study

I. INTRODUCTION

In early 1990's, RE emerged as a discipline of its own and dedicated conferences (e.g. ICRE, ISRE, REFSQ) and a journal (REJ) were established to promote the research in RE [1]. RE research community has made significant progress on various fronts and has accumulated a large body of knowledge to deliver new processes, tools, techniques, methods and frameworks [2]. Attempts have been made with traditional reviews (e.g. [1, 2]) as well as systematic reviews to aggregate and present the state of the art on various RE topics, e.g. Elicitation Techniques [3], Requirements change and Evolution [4, 5], and user related issues [6][14].

Systematic Literature Reviews are secondary studies that provide a way of synthesizing the available primary studies in empirical literature on a particular topic [7]. SLR is distinguished from a traditional review as it follows a rigorous and scrupulous procedure for search and selection of the sample studies in review. It is methodical and meticulous process of collecting and collating the acceptable quality published empirical studies based on a systemic protocol to reduce bias and provide transparency to the process. The process is formally documented and hence repeatable. There are three types of SLR [7, 8]:

Conventional SLR: they provide review of a focused and fine-grained research question(s) and would employ quantitative assessment on the results from primary studies.

Systematic Mapping Studies: that aim to find and classify the studies in a specific area and have a broader research question. They are helpful in identifying available primary studies before conducting SLR. They use the same search and selection procedure as conventional SLR but their focus is on the classification of the resulting studies to provide a map of the research in that area. *Tertiary study*: An SLR that aggregates the data and information from a number of existing SLR on a specific topic or area of research is called as Tertiary study [8].

A tertiary study aims to provide information about the available published SLR on a specific topic and tabulate the information regarding these SLR, e.g. the number of SLR published, their quality and the focus of those SLR within the topic of interest. Various tertiary studies have been published in software engineering recently e.g. [8-11], but to the best of our knowledge none of them focus on aggregating the SLR for RE.

In this paper we present for the first time a tertiary study that aims to identify all the SLR published about RE related topics by following EBSE guidelines [7]. Our objective is to present the topics covered by these SLR and the number of primary studies found in those SLR to create a richer picture of the empirical research in RE thus far. Our study has identified 53 distinct Systematic Reviews in RE related areas published from 2006 to 2014 and reported in 64 publications. Our tertiary study reported in this paper is also the first step in our larger research plan for contributing to an updated roadmap of RE following the roadmaps published in 2000 [1] and 2007 [2].

Section II gives details of the Systematic Review Planning and Execution. Section III presents the results of review process and discusses our answers to the research questions. Section IV describes limitations of the results, and section VI states the conclusion and suggests future works.

II. SYSTEMATIC MAPPING TERTIARY STUDY

According to the EBSE guidelines there are three main phases of a Systematic Review [7], planning, execution and reporting results.

A. Planning

During the planning phase we developed a formal protocol containing the details of the strategies for search and selection process, quality assessment, data extraction, data synthesis and data analysis. Our tertiary study was guided by three research questions:

RQ1: What are the main areas of research in RE that have been covered by published SLR?

RQ2: What is the quality of the published SLR in RE like?

RQ3: What are the gaps in the coverage of RE research topics in the published SLR?

To answer RQ1, based on the publication titles and abstracts, we identified topics of SLR and grouped similar studies together under the same category. The reason for this exercise was not only to identify the coverage but also to identify gaps in the RE research (RQ3). The number of primary studies identified by these SLR shows the coverage of empirical work within their area of focus in RE.

To answer RQ2, we assessed both the quality of the SLR and the quality of the publications. We used the quality assessment checklist from previously published tertiary studies (e.g. [8, 9, 11]) for evaluating the SLR as a whole (grouping multiple publications together where applicable). These tertiary studies have utilized the criteria defined by the Centre for Reviews and Dissemination (CDR) Database of Abstracts of Reviews of Effects (DARE), of the York University. It includes four questions for assessing quality of an SLR as shown in Table I. The quality assessment criteria were applied on the whole study rather than on every single publication from that study due to the fact that all required information may not be found in a single publication especially if it is a conference or a workshop paper due to space limitation.

TABLE I. QA CRITERIA (ADAPTED FROM [8, 9, 11])

QA Criteria	Answers	Scores	Description
QA1: Inclusion / Exclusion Criteria	Yes	1	Explicit inclusion / exclusion criteria defined
	Partial	0.5	Implicit study selection
	No	0	No criteria defined
QA2: Search Space Adequacy	Yes	1	4 or more digital libraries searched as well as additional search strategies applied
	Partial	0.5	3 or 4 digital libraries searched with no extra search strategy
	No	0	2 or below digital libraries or very restricted search
QA3: Quality Assessment of Primary Studies	Yes	1	Explicit quality criteria described and applied
	Partial	0.5	Implicit quality assessment
	No	0	No quality assessment criteria defined or used
QA4: Information regarding Primary Studies	Yes	1	Complete information presented about primary studies
	Partial	0.5	Summary of information presented about primary studies
	No	0	The results of individual studies are not specified

For assessing the individual publication quality, we used Google Scholar citation count as criteria. Citation count is considered as a measure of the impact of the publication on relevant research community. The citation count was checked on 19th May 2014.

We had two major search terms in our study: “Requirements Engineering” AND “Systematic Literature Review”. We conducted pilot testing on the major search terms to identify relevant terms and synonyms used in published literature for them. We also consulted previously conducted tertiary studies and systematic reviews on RE to complete our set of keywords for the search strings. Concatenating all the keywords with Boolean operators resulted in the following search string:

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((requirements engineering OR requirements process OR requirements development OR requirements elicitation OR requirements gathering OR requirements identification OR requirements discovery OR requirements analysis OR requirements specification OR requirements validation OR requirements verification OR requirements testing OR requirements checking OR requirements negotiation OR requirements documentation OR requirements management OR requirements change management ) AND (review of studies OR structured review OR systematic review OR literature review OR systematic literature review OR literature analysis OR in-depth survey OR literature survey OR meta-analysis OR analysis of research OR empirical body of knowledge OR overview of existing research OR body of published knowledge OR mapping OR mapping studies))
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We applied the string on IEEE xplora, ACM DL, Science Direct, Google Scholar and EI Compendex. The string was customized for different online databases according to their interface requirements while keeping the logical order consistent. We did not apply any limit on the year of publication for our results. To triangulate our results we also performed snowball sampling technique and did manual searches of the references in four previously published tertiary studies (i.e. [8-11]). To further ensure the completeness of our review, we also checked the proceedings of the RE and SLR related conferences and journals from 2004 onwards (RE, EASE, ESEM, REFSQ, REJ, ESE and IST).

We filtered out the totally irrelevant studies by scanning the abstracts. The papers that reported normal literature reviews or surveys or bibliographic studies were also excluded from our list. We selected the studies only if they fulfilled all three of the following study selection criteria:

1. They were reported in English.
2. They were Systematic Review, Systematic Mapping Study or meta-analysis.
3. They were focusing on any area within Requirements Engineering.

As recommended in previous tertiary studies ([8-11]) we kept all multiple versions of publications from the same study and grouped them under same study ID as the conference and workshop papers have a page limit and may not be able to explain the whole SLR process in details. Based on the guidance provided in [12], we extracted publication details showing characteristics of the included SLR (i.e. title, authors, year of publication, type of publication, conference / journal name and complete reference, and number of citations to that paper) and information required to answer our three RQs (i.e. number of primary studies, focus of SLR). The grouping of main topics covered by the selected SLR (first column of Table

VI), was done by applying thematic analysis [12] of the titles and abstracts of selected publications.

B. Execution

Appendix A shows the full reference list of the included publications. We assigned them IDs based on the study so that multiple publications from the same study are grouped under the same ID with suffix A, B and C. These studies are referred to by their IDs in the rest of this paper.

The search string was customized to be applied on all the selected digital libraries on the titles. The whole process for primary searches (as presented in Table II) resulted in 267 eligible studies out of which 91 passed the selection criteria described above. The secondary searches found 5 SLR that were not retrieved in the primary search process. S42 was found from [10], S45 from [11], S47 from [9], S34[B] was found from ESE and S44 was found from REJ. S42, S45 and S47 were not retrieved in our primary searches as we applied the search string on the titles of the papers to reduce the huge number of irrelevant results that was expected due to the string being too broad. The titles of these papers did not have required terms of our search string. S44 was found in REJ in November issue and S34[B] was in December issue of ESE. They were not found in the primary search results because the searches were conducted in October 2013. After secondary searches and inclusion/exclusion and discarding duplicates we were finally left with 53 unique SLR from 64 publications.

TABLE II. SEARCH EXECUTION AND STUDY SELECTION SUMMARY

Sources	Papers Found	Included Papers
Primary Searches	Google Scholar	87
	IEEE xplore	41
	ACM DL	58
	Science Direct	40
	EI Compendex	37
TOTAL	267	91
AFTER DISCARDING DUPLICATES		58
Secondary Searches	1 new found from [10]	6
	1 new found from [11]	
	1 new found from [9]	
	0 new found from [8]	
	1 new found from REJ	
TOTAL PUBLICATIONS		64
TOTAL STUDIES		53

Out of 64 papers, we were not able to retrieve full paper for two studies i.e. S3 and S8, both of them are theses found on Google Scholar but we were unable to find the full documents. We were able to get PDF file for S40 found from Google Scholar, but unable to find any information regarding the channel of publication. Eight studies have been reported in two publications each (S7, S23, S24, S26, S27, S30, S34, S35) and one study is reported in three publications (S5A, B, and C). One SLR (S2) has extended second version conducted later to update the results.

III. RESULTS AND DISCUSSION

According to the results of our tertiary study, 53 systematic reviews have been performed on various RE topics reported in 64 publications (including conference papers, journal papers, theses, and technical reports). The time period for the

publications in our result is from 2006 till 2014 (Figure 1). There has been a sudden increase in the number of publications since 2009 onwards. In our 64 resultant publications, there are 31 conference papers, 16 journal papers, 4 workshop papers, 4 technical reports, and 8 theses. We were unable to determine the type for one publication (S40) as the full details were not available online. Out of 53 studies there are 12 Systematic Mapping Studies (S4, S6, S7, S9, S10, S12, S21, S34, S43, S44, S45, and S46), one Meta-Analysis (S42), and the rest are all Systematic Literature Reviews.

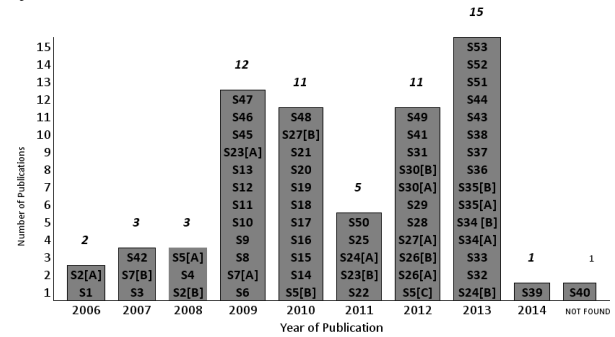


Fig. 1. Yearly distribution of the resulting SLR

TABLE III. TYPES OF PUBLICATION

CONFERENCE PAPERS	S2[A], S4, S5[A], S6, S10, S11, S14, S16, S18, S24[A], S26[B], S27[A], S28, S29, S30[A], S31, S32, S33, S35[B], S36, S37, S39, S42, S45, S46, S47, S48, S49, S51, S52, S53	31
JOURNAL PAPERS	S5[B], S5[C], S7[A], S9, S12, S15, S19, S20, S23[B], S25, S34[A], S34[B], S38, S44, S50, S41	16
WORKSHOP PAPERS	S2[B], S22, S35[A], S43	4
TECHNICAL REPORTS	S23[A], S26[A], S27[B], S30[B]	4
THESES	S1, S3, S7[B], S8, S13, S17, S21, S24[B]	8
UNKNOWN	S40	1

RQ1: What are the main research areas in RE that have been covered by the SLR?

Table IV shows the classification of the SLR according to their scope of study within RE for assessing the primary studies. 33 studies provided only state of the art within the area of RE that they focused whereas 7 SLR collected primary studies for assessing methods, 7 focused on Techniques, 4 on Tools and 1 each on Framework and Technology.

Table V presents the topics covered in RE by the resulting 53 studies and the coverage of primary studies by these SLR (column '# of PS'). The number of primary studies in the SLR reported in RE range from highest 4089 (meta-analysis in S42) to lowest number 5 (S27). S42 provides meta-analysis of all publications of RE for the period of 1963-2006 regardless of being empirical or not. Four SLR have reported more than 200 primary studies in their area of focus within RE. S21 has reported 364 primary studies, S25 found 281, S24 found 242 and S4 found 240. According to Table VI these four SLR focus on the Value based Requirements Engineering (S21), User Requirements Notation (S25), state of the art in RE (S24), and Requirements Prioritization (S4). Five studies have found primary studies between 100 to 200 (S30 → 100, S20 → 118, S29 → 125, S7 → 149, S43 → 177). There are four studies that

found less than 10 primary studies in their area of focus (S1 → 8, S13 → 9, S14 → 8, S27 → 5). There are two possible explanations for the small number of primary studies that these four SLR have reported. Either these are neglected areas in empirical RE research or the SLR had limitations in locating all the relevant primary studies.

TABLE IV. CLASSIFICATION OF THE SCOPE OF THE RE SLR

State of the art on the topic within RE	S1, S4, S6, S8, S9, S10, S11, S12, S15, S19, S20, S21, S24, S25, S27, S28, S29, S30, S31, S33, S34, S35, S37, S38, S41, S42, S43, S44, S45, S48, S51, S52, S53	33
Methods	S3, S5, S7, S14, S18, S23, S32	7
Techniques	S2, S13, S16, S36, S46, S49, S50	7
Tools	S26, S39, S40, S47	4
Frameworks	S22	1
Technology	S17	1

TABLE V. TOPICS AND NUMBER OF PRIMARY STUDIES COVERED IN RE SLR (NM=NOT MENTIONED, NF=NOT FOUND)

Grouping of main topics of SLR	S-ID	Focus of SLR within the main topic	# of PS	Year
Non Functional Requirements	S14	Data Quality Requirements in a Software Product Development	8	2010
	S15	Security Requirements Engineering	51	2010
	S17	Decision support material to incorporate quality requirements technologies	18	2010
	S18	Quality Requirements Management	46	2010
	S28	Cloud Computing Security Requirements	55	2012
	S33	Cloud Computing Security Requirements and Solutions	57	2013
Complete RE Process	S12	Technology transfer decision support in requirements engineering research	97	2009
	S24	Empirical Evidence in Requirements Engineering	242	2013
	S42	A quantitative assessment of requirements engineering publications–1963–2006	4089	2007
	S43	25 years of Requirements Engineering in Brazil	177	2013
Model Driven Development	S16	Requirements Engineering techniques in model-driven development	65	2010
	S23	Transformation approaches between user requirements and analysis models	29	2011
	S40	Model-based Requirements Engineering Tool for Embedded Systems	28	NF
Knowledge Management and RE	S26 *	Wikis for Distributed Requirements Engineering	29	2012
	S36	Knowledge Creation in Requirements Engineering	36	2013
	S39 *	The Impact of Knowledge Sharing Platforms in Distributed Requirements Engineering Scenarios	17	2014
	* S26, S39: Overlapping with 'Knowledge Management and RE'			
RE in GSD	S6	Requirements Engineering in Distributed Software Development Environment	12	2009
	S45	Risks and safeguards for the requirements engineering process in global software development	36	2009
	S51	Situational factors affecting Requirement Engineering process in Global Software Development	NM	2013
	* S26, S39: Overlapping with 'Knowledge Management and RE'			
RE in Software Product Lines	S19	Requirements Engineering for Software Product Lines	49	2010
	S20	Requirements for Product derivation support	118	2010
Requirements Management	S22	Goal Oriented Requirements Management frameworks for business process compliance	88	2011
	S47	Requirements Management Tools	28	2009
Multi Agent Systems	S10	Requirements engineering in the development of multi-agent systems	58	2009
Requirements Reuse	S11	Requirements Reuse	18	2009
Value based RE	S21	Value Based Requirements Engineering	364	2010
Virtual Reality Systems	S37	The Relationship between Requirements Engineering and Virtual Reality Systems	12	2013
Web Engineering	S48	RE in Web Engineering	13	2010
Creativity in RE	S49	Creativity Techniques for RE	25	2012
Requirements Elicitation	S2	Requirements Elicitation Techniques	26+13	2008
	S38	Automated Requirements Elicitation	36	2013
	S50	Requirements Elicitation Techniques	30	2011
Stakeholders and users	S5	Stakeholder Identification Methods in Software Requirements	45	2012
	S34	User Involvement and System Success	58	2013
	S35	User Involvement in Requirements Engineering and System Success	87	2013
Requirements Prioritization	S1	Software Requirements Prioritization	8	2006
	S4	Requirements prioritization based on benefit and cost prediction	240	2008
	S13	The effectiveness of requirements prioritization techniques for a medium to large number of requirements	9	2009
	S31	Software Requirements Triage and Selection	23	2012
	S32	Software Requirements Selection and Prioritization Using SBSE Approaches	30	2013
Meta Modelling	S8	Requirements Meta Models	100	2009
Software Requirements Specifications	S9	Generation of requirements specifications from software engineering models	24	2009
	S25	User Requirements Notation	281	2011
	S46	Software Requirements Specifications Techniques	46	2009
Requirements Verification / Validation / Evaluation	S7	Identification and classification of software requirement errors	149	2009
	S30	Requirement-based Software Testing With the UML	100	2012
Requirements Traceability	S3	Requirements Tracing	NF	2007
	S41	Requirements Traceability	52	2012
Requirements Change Management	S27	Causes of Requirements Change	5	2012
	S29	Requirements Evolution	125	2012
RE Education	S44	Requirements Engineering Education	79	2013
Mobile Learning	S53	A requirements catalog for mobile learning environments	198	2013
Checklist for RE	S52	Comprehensive Integrated Checklists for Requirements Engineering and Software Project Management	323	2013

RQ2: What is the quality of the published SLR in RE like?

We applied the Quality Assessment criteria described in Table I on all the studies. Figure 2 shows the distribution of the number of studies in different quality scores. Out of 53 we were able to retrieve 51 studies on which we could apply quality criteria (as we couldn't find full sources of S3 and S8). 42 studies out of 51 have scored 2 or above out of 4. Figure 3 represents the number of studies classified according to the scores for each quality assessment question (see Table I).

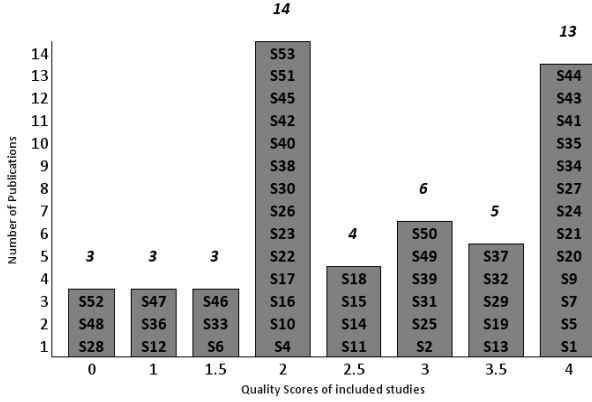


Fig. 2. Quality score distribution of the resulting SLR

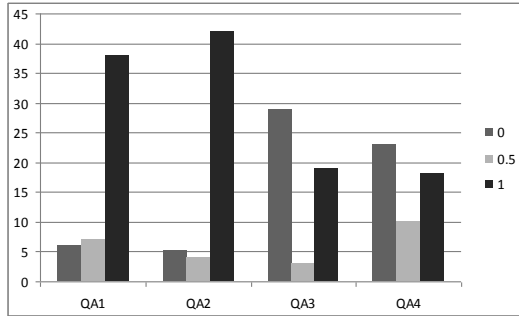


Fig. 3. Quality score distribution for each QA check from Table I

Table VI shows the most highly cited publications. For citations of all the studies see Appendix A. Regardless of the quality score, the highly cited papers are the ones published in prestigious conferences and journals related to RE and SLR community (i.e. RE, REJ, IST). S2[A] from Alan Davis et. al. published in 2006 has been cited 154 times showing a significant interest in the results of their SLR from RE research community. Figure 4 shows the average of the quality scores of the publication over the span of the years of their publication. Although in all years the quality of the SLR has average score of above 2, there is a decrease in quality score after 2009 with the increase in the number of SLR studies being published (Figure 2 and 4).

In previously published tertiary studies [8, 9], it was observed that the average quality scores of all the SLR in Software Engineering has increased over the years. According to Figure 1, for SLR in RE there is a sudden increase in the publications in 2009, but if we look at Figure 4, the average quality of the published SLR has decreased starting from the same year. One of the reasons in the decrease of the quality can be inferred from Figure 3. It shows that over half of the SLR

have ignored to assess the quality of the included primary studies (QA3) and also neglected to provide an overview or summary of the included primary studies (QA4). The distinguishing factor of an SLR against a traditional literature review is the rigor of process but if the researchers would overlook this aspect then the results would not be as reliable and useful to the RE community. This is a serious issue worthy of further consideration because if the quality of the included primary studies is not assessed then there can be serious threats to the validity of the results produced by those SLR.

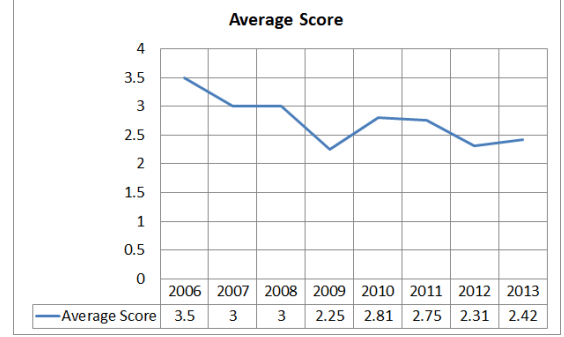


Fig. 4. Average of Quality Scores against the year of publication of SLR

TABLE VI. TOP 10 HIGHLY CITED SLR

S-ID	GS Citations	Pub channel	QA Score
S2[A]	154	RE	3
S7[A]	61	IST	4
S4	58	RE	2
S25	51	JS	3
S20	50	IST	4
S23[B]	46	REJ	2
S50	43	ITSE	3
S15	42	CSI	2.5
S9	41	IST	4
S46	41	ESEM	1.5

RQ3: What are the gaps in the coverage of RE research topics in the published SLR?

In answering this questions we were interested in three types of gaps in the SLR on RE. First, we considered the anomalies and potential conflicts in the reported number of primary studies in the SLR on the same topic by different authors in different years. Second, we were concerned about the small number of reported primary studies in some of the SLR. Finally, we observed some of the well known areas of RE research that seem to have been neglected by researchers who have conducted SLR.

1) **Anomalies:** In some cases, there are doubts about the number of primary studies included in the SLR as they are not providing a consistent view. For example, in Table V, for Requirements Prioritization, S1 has reported 8 primary studies from 1996 to 2005, whereas S4 has reported 240 primary studies from 1996 to 2007. It is indeed very surprising to have found additional 232 published empirical studies on requirements prioritization in a span of just two years. When we look at the procedure followed by these two SLR (S1 and S4), although both of them were looking for empirical studies on requirements prioritization but they have searched with different search terms in their search strings, covered different

number of data bases (S1 has searched 8 sources whereas S4 has searched 14) and devised different inclusion/exclusion criteria. This raises concerns on the validity of SLR process adopted by S1 and also on the usefulness of the results for future RE researchers if they do not provide a complete and correct coverage within their area of focus.

Another example is the SLR on the state of the art in RE (S24) that has included 242 studies from the entire body of the empirical RE research literature. However, in Table V we see that S4 has 240, S21 has 364 and S25 has 281 primary studies on specific topics within RE. If a researcher is focusing on a specific topic within RE, then the number of included primary studies reported should have been a subset of the primary studies that were included in the state-of-the-art for the entire RE research literature (S24). The fact that this is not the case in these examples raises serious concerns both about the strict compliance to the EBSE guidelines as well as the reliable coverage of the published literature. There is a strong need for replicated studies on the similar topics to verify these results. If the protocol for the conduct of SLR is readily available, then replication of studies should be straightforward.

2) Lack of primary studies: The number of selected primary studies in table V is not uniform under all the related topics. Some topics report in excess of 300 primary studies whereas in others we observe less than 10 primary studies. For example, Data quality requirements (S14) and causes of requirements change (S27) have the lowest number of primary studies selected. This could be due to two possible explanations: (a) the procedure followed by these SLR was not effective enough to find all the relevant primary studies, or (b) these are indeed neglected areas of empirical RE research and imply a need for further empirical exploration by the RE research community.

3) Ignored RE areas by SLR: We concede that the classification provided in Table V is neither exhaustive nor complete, as it does not represent all the areas of RE-related research covered in the literature. It only represents those RE research areas that our selected SLR has covered. For example, goal-oriented requirements engineering, requirements engineering in law, and requirements modeling notations have been the subject of many publications but not covered by any SLR so far. However, mapping the topics covered by the SLR against those suggested by [1, 2] for future research has enabled us to identify some of the current gaps in the RE research as described above. According to the RE roadmap by Chang and Atlee [2] published in 2007, further research within some ‘hotspot’ areas in RE have been suggested. Their roadmap was published around the time when RE researchers started showing interest in conducting systematic reviews. Among the identified topics by Chang and Atlee [2] for further research, the SLR in our results have addressed *Security Requirements*, *RE education and curricula development*, *Requirements Reuse*, *Global and Distributed RE*. The SLR have not covered the topics of *Requirements Scaling*, *RE for self-management systems*, *effects of system environment on RE* and *effectiveness of RE research in practice*. Nuseibeh and Easterbrook [1] have highlighted two important areas within

RE: *conflict resolution among requirements and requirements negotiation*, which are not covered by any SLR so far.

IV. LIMITATIONS OF THE STUDY

Though we have succeeded to closely follow the search strategy based on the guidelines of EBSE to ensure the completeness of our sample, but there is always a small risk that there would be some papers that were not included in our data collection due to their unavailability in electronic resources or because they may not have used the relevant keywords in their title or abstract. To mitigate this risk, we have attempted to triangulate our results with secondary searches. Out of the 64 included papers, we were unable to retrieve the publication details of one SLR (S40). We decided not to exclude this SLR in current results as we were interested to know any SLR conducted in all areas of RE that is available online. But for our future work for contributing to the development of a new roadmap of RE we will not be considering the non peer-reviewed studies or SLR with low quality score in our work.

To answer RQ1, we extracted the topics from the titles and abstracts of the selected SLRs. Then the first author grouped the extracted topics and appropriately named each group as listed in Table V. Although the other two authors then reviewed these names given to each group and agreed on the final names but it is possible that other researchers may select different titles for naming each group. In our future analysis of the RE SLRs, we plan to provide a short description for each group to provide further clarification of what is included in each group. For RQ2, as mentioned above, we have closely followed the quality assessment criteria recommended by the EBSE guidelines. Hence the quality of our quality assessment is as good as what those guidelines have provided. We anticipate that in future as the EBSE community evolves and matures, these guidelines may further be enhanced and improved thus increasing the confidence in the SLR quality assessment. We have also observed that the most cited SLR in RE, S2[A] from Davis et. al., does not show the highest quality score. Finally, for RQ3, we conceded that our gap analysis is neither complete nor exhaustive and it merely presents our preliminary observations. To make this a complete list requires deeper analysis of all selected primary studies.

V. CONCLUSION AND FUTURE WORK

The tertiary study reported in this paper has identified 53 unique SLR from 64 publications in the period 2006-2014. This paper represents the first ever tertiary study in the RE research literature. As such we anticipate that the data gathered and the results presented in this paper would be of great value to future RE researchers, in particular for doctoral students to provide an effective starting point for an overview of all the researched areas so far in RE. Furthermore, we have been able to identify various research gaps from our mapping that is beneficial for those interested in selecting fruitful areas of RE research. In this paper, we have also identified some of the anomalies in the results of already published SLR in RE that highlight potential opportunities for SLR replication in the

future. Almost half of the selected SLR for our study have ignored to evaluate the quality of the primary studies included in their reviews. Careful attention should be paid to quality assessment criteria by future researchers.

This study is the first step in our research plan for contributing to an updated roadmap of RE following the roadmaps published in 2000 [5] and 2007 [4]. We are planning to retrieve all the citations from the published SLR and create a larger repository to combine the results within all the topics of RE in order to assess the strength of these areas for the future generations of RE researchers. Furthermore, we would like to contribute to the online RE bibliography created by Alan Davis [13] that is up to 2010 by updating the database to include publications from 2010 to 2014 [6].

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APPENDIX A: Included Studies

ID	Complete Reference	citation
S1	K. A. Khan, 'A systematic review of software requirements prioritization', Masters Thesis Blekinge Inst. Technol. Ronneby Swed., 2006.	7
S2	A. Davis, O. Dieste, A. Hickey, N. Juristo, and A. M. Moreno, 'Effectiveness of requirements elicitation techniques: Empirical results derived from a systematic review', in 14th IEEE International Conference Requirements Engineering, 2006, pp. 179–188.	154
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S3	C. Radl, "'A systematic literature review on requirements tracing approaches"; Betreuer/in (nen): S. Biffl, M. Heindl; Institut für Softwaretechnik und interaktive Systeme, 2007.'	0
S4	A. Herrmann and M. Daneva, 'Requirements prioritization based on benefit and cost prediction: An agenda for future research', in 16th IEEE International Requirements Engineering, 2008, pp. 125–134.	58
S5	C. Pacheco and I. Garcia, 'Stakeholder Identification Methods in Software Requirements: Empirical Findings Derived from a Systematic Review', in The Third International Conference on Software Engineering Advances, ICSEA'08., 2008, pp. 472–477.	10
	C. Pacheco and I. Garcia, 'Systematic Literature Review applying to Stakeholder Identification Methods in Requirements Engineering', IET Software, August, 2010.	0
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S6	T. Ebling, J. L. N. Audy, and R. Prikladnicki, 'A Systematic Literature Review of Requirements Engineering in Distributed Software Development Environments', in ICEIS (3), 2009, pp. 363–366.	6
S7	G. S. Walia and J. C. Carver, 'A systematic literature review to identify and classify software requirement errors', Information and Software Technologies, vol. 51, no. 7, pp. 1087–1109, 2009.	61
	G. S. Walia and J. C. Carver, "Development of a requirement error taxonomy as a quality improvement approach: A systematic literature review," Department of Computer Science and Engineering, Mississippi State University, MSU-070404, 2007.	0
S8	F. Molina, J. Pardillo, C. Cachero, and A. Toval, 'A systematic review of requirements metamodels', Technical report, University of Murcia, 2008. Available online at http://www.lucentia.es/index.php/MRM , 2009.	1
S9	J. Nicolás and A. Toval, 'On the generation of requirements specifications from software engineering models: A systematic literature review', Information and Software Technologies, vol. 51, no. 9, pp. 1291–1307, 2009.	41
S10	D. Blanes, E. Insfran, and S. Abrahão, 'Requirements engineering in the development of multi-agent systems: a systematic review', in Intelligent Data Engineering and Automated Learning-IDEAL 2009, Springer, 2009, pp. 510–517.	6
S11	F. B. de Azambuja, R. M. Bastos, and A. P. T. Babelo, 'Systematic Review of Requirements Reuse', in SEKE, 2009, pp. 67–72.	0
S12	M. Ivarsson and T. Gorschek, 'Technology transfer decision support in requirements engineering research: a systematic review of REj', Requirement Engineering, vol. 14, no. 3, pp. 155–175, 2009.	32
S13	Q. Ma, 'The effectiveness of requirements prioritization techniques for a medium to large number of requirements: a systematic literature review', AUT University, 2009.	12
S14	C. Guerra-García, I. Caballero, and M. Piattini, 'A Systematic Literature Review of How to Introduce Data Quality Requirements into a Software Product Development', in ENASE, 2010, pp. 12–19.	0
S15	D. Mellado, C. Blanco, L. E. Sánchez, and E. Fernández-Medina, 'A systematic review of security requirements engineering', Computer Standards Interfaces, vol. 32, no. 4, pp. 153–165, 2010.	42
S16	G. Loniewski, E. Insfran, and S. Abrahão, 'A systematic review of the use of requirements engineering techniques in model-driven development', in Model driven engineering languages and systems, Springer2010, pp. 213–227.	30

S17		P. Saripalli, 'Decision support material to incorporate quality requirements technologies: a systematic literature review and industrial interviews', Norwegian University of Science and Technology, 2010.	0
S18		R. B. Svensson, M. Host, and B. Regnell, 'Managing quality requirements: A systematic review', in Software Engineering and Advanced Applications (SEAA), 2010 36th EUROMICRO Conference on, 2010, pp. 261–268.	15
S19		V. Alves, N. Niu, C. Alves, and G. Valença, 'Requirements engineering for software product lines: A systematic literature review', Information and Software Technologies vol. 52, no. 8, pp. 806–820, 2010.	39
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S21		N. Jan and M. Ibrar, 'Systematic mapping of value-based software engineering-a systematic review of value-based requirements engineering', Technical report, Master Thesis no: MSE-2010: 40, Karlskrona, Sweden, 2010.	1
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S23	A	T. Yue, L. C. Briand, and Y. Labiche, 'A systematic review of transformation approaches between user requirements and analysis models' Carleton University, TR SCE-09-03, 2009	0
	B	T. Yue, L. C. Briand, and Y. Labiche, 'A systematic review of transformation approaches between user requirements and analysis models', REJ., vol. 16, no. 2, pp. 75–99, 2011.	46
S24	A	T. Ambreen, M. Usman, N. Ikram, and M. Bano, 'Evidence in Requirements Engineering: A Systematic Literature Review Protocol', in ICSEA 2011, The Sixth International Conference on Software Engineering Advances, 2011, pp. 576–580.	0
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S25		Amyot, Daniel, and Gunter Mussbacher. "User requirements notation: The first ten years, the next ten years." Journal of Software 6.5 (2011): 747-768.	51
S26	A	H. Lai, R. Peng, D. Sun, F. Shao, Y. Liu, and Y. Ni, 'A systematic review of Re-specific wikis for distributed requirements engineering', Wuhan Univ. Wuhan China Tech Rep, vol. 2012530, 2012.	1
	B	Lai, Han, et al. "A Survey of RE-specific Wikis for Distributed Requirements Engineering." 2012 Eighth International Conference on Semantics, Knowledge and Grids (SKG), IEEE, 2012.	1
S27	A	M. Bano, S. Intiaz, N. Ikram, M. Niazi, and M. Usman, 'Causes of requirement change-A systematic literature review', in 16th International Conference on Evaluation & Assessment in Software Engineering (EASE 2012), pp. 22–31.	1
	B	Muneera Bano, Salma Intiaz, Naveed Ikram, Muhammad Usman, and Mahmood Niazi, "Systematic Literature Review for Causes of Requirements Change", Technical Report: TR/2010-01, ISSN: 1353-7776, School of Computing and Mathematics, Keele University, Keele, UK, 2010	0
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S29		J. Li, H. Zhang, L. Zhu, R. Jeffery, Q. Wang, and M. Li, 'Preliminary results of a systematic review on requirements evolution', in Evaluation & Assessment in Software Engineering (EASE 2012), 16th International Conference on, 2012, pp. 12–21.	3
S30	A	N. Asoudeh and Y. Labiche, 'Requirement-based Software Testing With the UML: A Systematic Mapping Study', in ICSEA 2012, The Seventh International Conference on Software Engineering Advances, 2012, pp. 623–629.	1
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S33		P. Höner, 'Cloud Computing Security Requirements and Solutions: a Systematic Literature Review', 19th Twente Student Conference on IT, June 24th, 2013, Enschede, The Netherlands. Copyright 2013, University of Twente, Faculty of Electrical Engineering, Mathematics and Computer Science.	0

S34	A	U. Abelein, H. Sharp, and B. Paech, 'Does Involving Users in Software Development Really Influence System Success?', IEEE Software vol. 30, no. 6, pp. 17–23, 2013.	0
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S44		Ouhbi, Sofia, Ali Idri, José Luis Fernández-Alemán, and Ambrosio Toval. "Requirements engineering education: a systematic mapping study." Requirements Engineering: p.1-20. November 2013	0
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S46		Condori-Fernandez, N. et al. "A Systematic Mapping Study on Empirical Evaluation of Software Requirements Specifications Techniques", ESEM, 502-505, IEEE, 2009.	41
S47		Rainera, Austen, Sarah Beechamb, and Ceil Sanderson. "An assessment of published evaluations of requirements management tools." Proceedings of the 13th international conference on Evaluation and Assessment in Software Engineering. British Computer Society, 2009.	4
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S50		Dieste, Oscar, and Natalia Juristo. "Systematic review and aggregation of empirical studies on elicitation techniques." IEEE Transactions on Software Engineering 37.2 (2011): 283-304.	43
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