A model-based approach to systematic review of research literature

BARAT, Souvik, CLARK, Tony <http://orcid.org/0000-0003-3167-0739>, BARN, Balbir S. and KULKARNI, Vinay

A Model-Based Approach to Systematic Reviews of Research Literature

Souvik Barat
Tata Consultancy Services
Research, India
souvik.barat@tcs.com

Tony Clark
Sheffield Hallam University,
United Kingdom
t.clark@shu.ac.uk

Balbir Barn
Middlesex University, United
Kingdom
b.barn@mdx.ac.uk

Vinay Kulkarni
Tata Consultancy Services
Research, India
souvik.barat@tcs.com

ABSTRACT

A systematic approach to develop a literature review is attractive because it aims to achieve a repeatable, unbiased and evidence-based outcome. However the existing form of systematic reviews such as *Systematic Literature Review* (SLR) and *Systematic Mapping Study* (SMS) are known to be an effort, time, and intellectual intensive endeavour. To address these issues, this paper proposes a model-based approach to *Systematic Review* (SR) production. The approach uses a domain-specific language expressed as a meta-model to represent research literature, a meta-model to specify SR constructs in a uniform manner, and an associated development process all of which can benefit from computer-based support. The meta-models and process are validated using real-life case study. We claim that the use of meta-modeling and model synthesis lead to a reduction in time, effort and the current dependence on human expertise.

Keywords

Literature Review; Systematic Literature Review; Systematic Mapping Study; Meta Modeling; Model Based Literature Review

1. INTRODUCTION

A thorough literature review on a topic establishes a firm foundation for advancing knowledge [25]. It identifies existing research and the areas where research is needed. Systematic Review (SR) methodologies in the form of *Systematic Literature Review* (SLR) [18] and *Systematic Mapping Study* (SMS) [22] methodology are two popular choices for many disciplines such as medicine, genetics, psychology and social science. The rigorous planning, methodical execution of the plan, unbiased outcomes, and repeatable process make SR attractive to the researchers [5, 16, 23].

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However, the general experience of using SR methodologies on Software Engineering (SE) related topics is not equally encouraging. Software research practitioners have raised several concerns including: methodological challenges; usage issues and a steep learning curve. The commonly cited issues are: (i) SR guidelines are time consuming and error-prone [16], (ii) lack of guideline for conducting individual review process steps [17], for example, the guidance on how to eliminate bias[14] from a literature corpus or how to justify the quality of a review outcome, *etc.* (iii) and lack of guidance to adopt a specific SR technique, *i.e.*, when to prefer SMS over SLR or vice versa [10]. Moreover, software researchers have expressed their difficulties to manage and correlate large number of review artefacts those are produced in the various phases of SR.

We have experienced many of the cited concerns ourselves while using SMS and SLR for our primary research[1]. As a course of action, we conducted a tertiary review on SR literature (discussed in section 2), explored solutions proposed in the literature and tried to use them as suggested to overcome the limitations encountered. In our experiment, we combined SMS and SLR as recommended in [13], introduced an iterative approach in conventional SR as suggested in [20] and used snowballing technique[26] in SMS/SLR. Like [21] we experienced significant challenges in combining the relevant concepts of SR within either SMS or SLR ue to their inflexible nature.

This paper proposes an approach that refines conventional SR to combine frequently used concepts of literature reviews and address some of the commonly faced challenges without compromising the rigour, precision and quality outcome of SR. In particular, we propose a domain-specific language (expressed as a meta-model) for representing research literature in a precise term, conceptualise a meta model to describe core concepts of systematic review, and introduce a model-based realisation of systematic review method. Our proposed approach visualises SR production as coordinated model creation (instantiation), model navigation, and model synthesis effort that can largely be carried out by proven modeling and model-processing technologies. The approach is presented in section 3. The use of a model-based approach for conducting SR on SE related topic is new in SR prac-

[1] http://www.tcs.com/research/Pages/Model-Driven-Organization.aspx

Table 1: Validation properties of SR methodology

Property	Topic	Description
Biasness and Threats to validity	Study identification	Finding publications using search string, snowballing [26], *etc,*.
	Literature coverage	Coverage of identified literature and conformance of quasi-gold standard [28].
	Quality evaluation	Assessing the quality of protocol, selected publications and study.
	Data extraction	Data extraction technique, data representation for further processing, and classification technique.
Usability	Repeatable	The same synthesis can be reached even when performed by a different practitioner.
	Structured representation	Structured representation of publication template and study templates
	Representation and Visualisation	Representation and visualization of review artefacts such as publication, intermediate and final review outcomes.
	Traceability	Traceability and analyzability of review artefacts.

tice but it appears promising for a variety of reasons. First, meta-modeling techniques are an effective means of unifying multiple concepts. Second, a resulting model can be imparted with well-defined semantics thus enabling automated processing such as validation, verification, and transformation. Third, it helps in establishing traceability relationships and ensuring consistency of various artefacts. Finally, meta-modeling, model-validation and model-synthesis techniques have been proven across a variety of application domains.

With the proposed approach, we claim to overcome two commonly faced issues: i) error-proneness (due to lack of timely validation), and ii) effort-intensiveness (due to limited scope for automation and inability to establish traceability between review artifacts).

We illustrate the proposed approach and evaluate our claims using a case study that explores existing enterprise models (EM) and evaluates suitability of identified EM techniques for our primary research[1]. The case is presented in section 4. How the proposed method helps in reducing the error-proneness and effort-intensiveness for proving *goodness* of a systematic review is illustrated in section 5. We also evaluate the *goodness* of the review process and review outcome of SR using two *quality properties* namely *biasness* and *threats to validity*, and a set of *usability properties* as depicted in Table 1. Finally, we believe the proposed approach can serve as a foundation for a robust model-based literature review tool. We discuss our plan on future SR tool development by extending the SLRTool [4] in section 6.

2. BACKGROUND

We conducted a tertiary study using SMS methodology to understand the trend of systematic review in SE, review techniques adopted in SE and the experience of the literature review practitioners.

We observed an increasing trend of SR publications in five digital libraries namely *Scopus*, *ScienceDirect*, *IEEE Xplore*, *ACM Digital Library* and *Web of Science* as shown in Fig. 1. We also found homogeneity in adopting SMS and SLR methodology. Primarily the review practitioners from SE followed a three-phase review method that includes

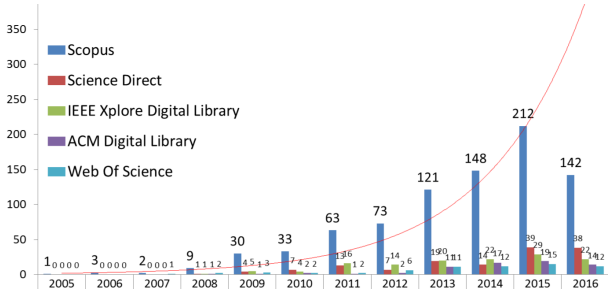

Figure 1: Overview of SR on SR literature

planning, *execution* and *synthesis* and they largely differed in terms of: how a research questions is formed, how the publication corpus is explored, what is the reviewing style, and what is the principal objective of review outcome. For example, the SR that adopted SMS methodology focused on broad research question, reviewed large number of publications, adopted a style which is not as thorough as SLR, and aimed for publication classification leading to a high-level understanding. In contrast, the SR with SLR methodology focused on precise research questions leading to precise outcomes by conducting a thorough review of relatively small number of publications.

The literature presenting SLR and SMS case studies emphasized several benefits such as improved precision, fairness, trustworthiness and auditability of review method and review outcomes. The process for conducting SR is also highlighted as rigorous and repeatable. However, SR is consistently reported as time, effort and intellectual intensive activity in SE. Morover, an important trend we observed in our tertiary study that the research contribution is not uniformly distributed across the research communities. For instance, the 227 publications out of 837 contributions in Scopus digital library (i.e., 27%) are from 10 affiliations/institutions wherein the *Universidade Federal de Pernambuco* has 49 publications and *Keele University* has 38 publications. Similarly 170 publications (20% of total publication) in Scopus digital library are from Brazil. Spain and Sweden are the next in the table with 83 and 76 publications respectively. So there is a clear indication that the use of SR is largely limited to a set of research groups from few institutions and counties. Zhang et.al have reported similar observation based on their tertiary review conducted in 2011 [27]. They used semi-structured interview technique to understand the cause for such low adoption in larger research community. They found that around 50% novice literature review practitioners are unaware of the detailed steps of SR. Knowledge intensiveness, tediousness and error-proneness are the key factors cited for low adoption of SR in SE. Several tertiary reviews [24, 1, 7, 8, 10] are congruent with these observations.

As a course correction, several methodological refinements to SR are suggested [16, 23]. But these advancements are found to be limited to methodological improvements [23]. Thus the experts seem to benefit significantly by these advancements but larger research communities (who are not expert but keen on using SR in their primary research) do not find them beneficial in adopting SR in their research.

A group of expert SR practitioners have advocated tools for conducting SR. Tools, such as SLuRp [6], StArt [11], SLR-Tool [9] and SLRTool[4] to automate the process steps described in Table 2 at varying levels of sophistications. But

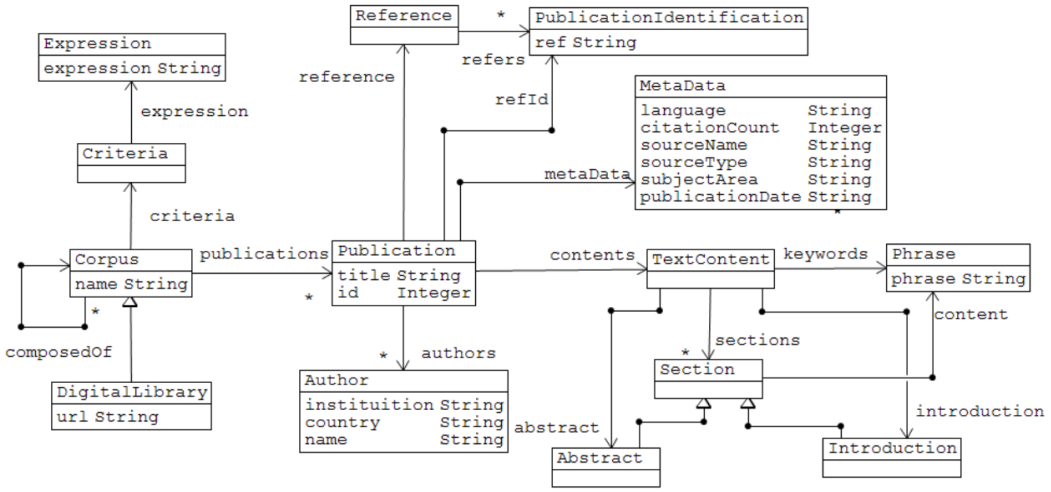

Figure 2: Research Literature Meta Model

Table 2: Process steps of SR

Phase	Associated Process Steps
Planning	1. Defining motivation for conducting SR, 2. Defining research questions, 3. Defining search strategy to identify relevant literature, 4. Defining data capture strategy, and 5. Review of the planning
Execution	1. Select Publications, 2. Assess publication quality, 3. Conduct complete review and extract data, 4. Document review outcomes.
Synthesis and reporting	1. Synthesis of collected data, 2. Documentation and visualization of study reports, 3. Publish Results

the current state of SR tools is not matured enough to help SE researchers to adopt SR in primary research in a seamless manner. Nor is there evidence of any substantial use. Marshall et al. concluded their comparative study on SR tools [21] with a similar observation.

We conducted multiple literature review using SMS and SLR for our primary reviews [19, 3]. We started with traditional literature review (TLR) and moved to SR [2]. Though the quality of review outcomes and evidence produced by SR [2] was significantly high as compared to TLR, it came at a price too. Our experience gathered through reviews using conventional SR and the evidences (gathered through tertiary study) about the lacunae of current form of SR led us to work on SR approach. Our proposed approach that overcomes some of the concerns raised by SE researchers is presented next.

3. APPROACH

We propose a model based approach for conducting systematic review of research literature. The approach is composed of three research contributions: i) a domain-specific language expressed using meta-model (termed as RLMModel) to represent research literature, ii) a conceptual meta-model (SRMModel) to represent the core concepts of SR, and iii) model based realisation of a SR process (SR development process). The RLMModel represents the concepts of publications and digital libraries in a uniform and machine interpretable form. The SRMModel combines frequently used concepts of SR and serves a basis for specifying different

```
exp        ::= metacnstr
           |   phrase in content
           |   phrase holds in content
metacnstr  ::= char
           |   (metacnstr)
           |   metacnstr and metacnstr
           |   metacnstr or metacnstr
           |   not(metacnstr)
char       ::= data op value
op         ::= '=' | '<' | '>' | '!=' | or | and
data       ::= publicationDate
           |   subjectArea
           |   sourceType
           |   citationCount
           |   language
           |   authorCountry
           |   authorInstitution
content    ::= text
           |   section*
section    ::= title
           |   keyword
           |   abstract
           |   intro
           |   papersection
phrase     ::= phrase and phrase
           |   phrase or phrase
           |   not(phrase)
value      ::= number | string
```

Figure 3: Syntax of expression language

artefacts of an SR in relatable, traceable, navigable and analysable form. Proposed SR process ensures the methodological guidelines of supported concepts.

We consider two widely accepted SR methodologies i.e., SMS proposed by Petersen et al. [22] and SLR recommended by Kitchenham [15] as our methodological foundation. We also adopt the protocol concept defined by EBSE Research Group [14] for describing the format of the research literature and review artefacts, snowballing technique described in [26] for improving search space, the methodological improvements proposed by experienced literature review practitioners such as [16, 23] for incorporating latest methodological developments, and finally incremental and iterative approach suggested by [20] for enabling SR to novice practitioners.

The core concepts of RLMModel, SRModel and SR development process are described below.

3.1 Research Literature Meta Model

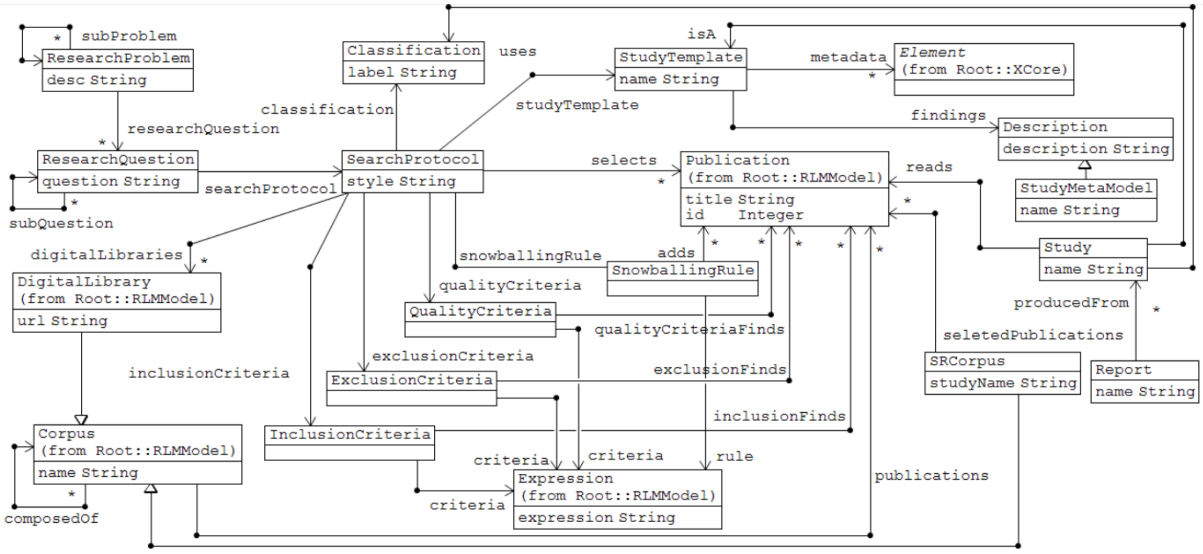

Figure 4: Systematic Review Meta Model

We define a research literature meta-model (*RLMModel*) to describe research literature and literature corpus in a uniform and machine interpretable form. The core concepts of RLMModel are depicted in RLMModel in Fig. 2.

As shown in the figure, the research literature is represented as *Publication*. A Publication has two key identities namely *title* and refId. Attribute *title* captures the *Title* of the Publication and *refID* refers to PublicationIdentification that represents a unique identifier such as *bibliography reference*. Typically, a Publication is contributed by set of *Author* from specific *institution* and *country* and it has three meta-elements namely *MetaData*, *TextContent*, and *References*. *MetaData* describes the characteristics of the Publication such as *Publication Date*, *Subject Area*, *Publication Source*, *Citation Count*, *Language*, etc. We use the properties suggested by EBSE Research Group [14] to form the attributes of MetaData. TextContent describes the content of the Publication. TextContent is typically described using set of *Phrase* where a Phase is a sequence of words or string. The key elements of *TextContent* are *Keywords*, and *Abstract*, *Introduction* and other *Sections*. The *References* are list of PublicationIdentifications of other Publications those are cited in TextContent.

We use the term *Corpus* to represent collection of Publications. Digital libraries that achive publications such as ACM Digital Library, IEEE Xplore, Scopus are specialised Corpus, termed as *Digital Library*. A Corpus (and thus Digital Library) often holds some *Criteria*. It is expected that all Publications belongs to a Corpus must conform to its associated Criteria. We introduce an OCL like expression language to specify required expression to describe Criteria. Element *Expression* represents the textual expression. The key constructs of proposed expression language is illustrated in Fig. 3. The constructs support three kinds of expressions - i) *metacnstr* that describes the evaluation criteria of *MetaData* elements (e.g., publicationDate > 2010), ii) *phrase existence (i.e., phase **in** content)* that evaluates the existence of *Phrase* in *TextContent* (e.g., phrase "Organisation" exists in abstract section), and iii) *meaning existence (i.e., phase **holds in** content*) that judges if set of *Phrases* holds true in a *TextContent* (e.g., paper "describes a case study").

3.2 SR Meta Model

The elements of SR Meta Model (SRMModel) are expressed using the concepts described in RLMModel. As shown in Fig. 4, a literature review starts with a broad problem statement, which we term as *ResearchProblem*. A research problem triggers one or multiple *ResearchQuestion*. A ResearchProblem can have multiple sub-problems; similarly a ResearchQuestion can be elaborated with multiple sub-questions. Association *subProblem* and *subQuestion* specify those relationships.

A ResearchQuestion requires at-least one *SearchProtocol* for conducting reviews. A SearchProtocol can be described sufficiently using eight basic concepts that include *Review Style* (considered as an attribute of SearchProtocol named *style*), *DigitalLibrary*, *InclusionCriteria*, *ExclusionCriteria*, *QualityCriteria*, *SnowballingRule*, *Classification*, and *StudyTemplate*. Attribute *style* captures the review style, such as SMS and SLR style, for conducting reviews. DigitalLibraries describes the (initial) sources of the Publications. Search criteria such as InclusionCriteria, ExclusionCriteria, QualityCriteria help in identifying relevant Publications from selected DigitalLibraries. These criteria also form the Criteria of the new Corpus. Model element SnowballingRule captures snowballing rules as recommended in [26].

We introduce two meta-elements *Classification* and StudyTemplate to represent a *Study* of a Publication. Classification categorizes the Publications and Corpus. StudyTemplate is collection of attributes of Publication element described in RLMModeland and the attributes that capture the findings of a study. Findings can be described using *Description* element wherein a *Description* represent a specific finding using one of the two form:- simple text using the *description* attribute of Description or structured information that can represented using a customized *Meta Model*. A *Study* element is an instance of StudyTemplate and a *Report* is the synthesis of conducted studies which are captured using Study elements.

SRMModel introduces a set of associations to represent the progress of the review process. Association *inclusion-*

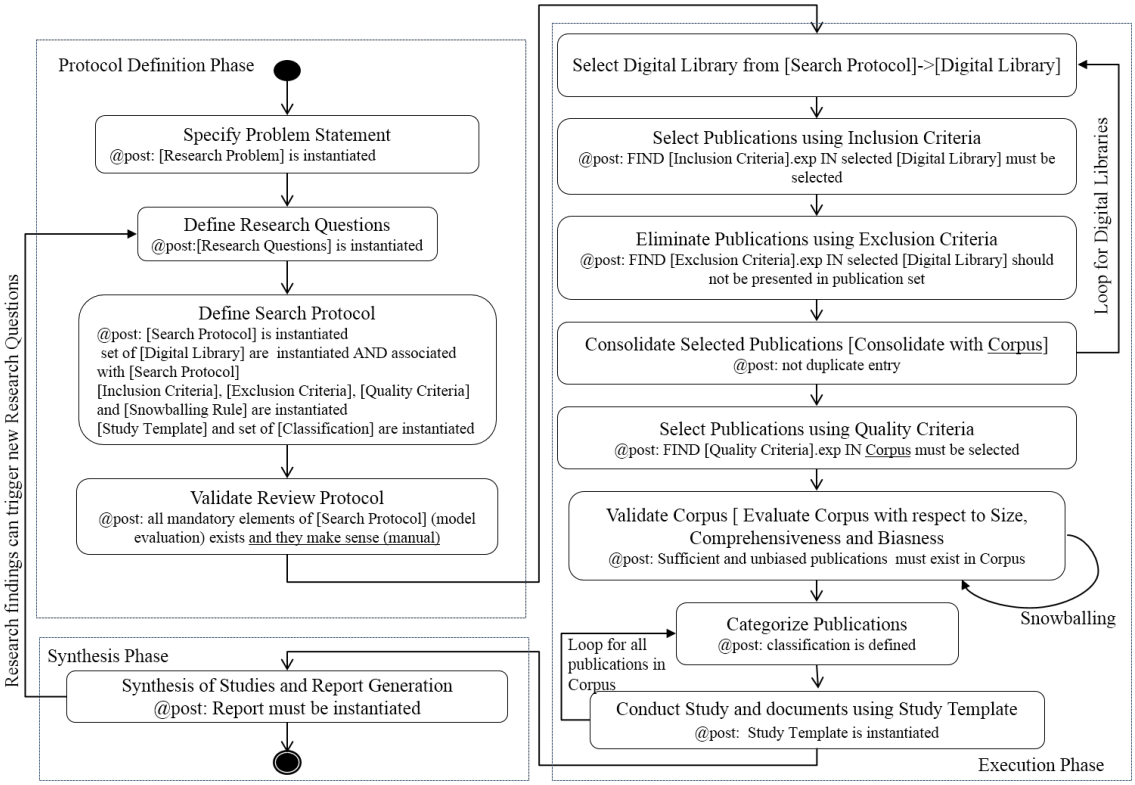

Figure 5: SR Process

Finds and *exclusionFinds* represent the list of Publications selected using InclusionCriteria and ExclusionCriteria respectively. The association *qualifies* represents the list of Publications that conforms to QualityCriteria and association *adds* indicates the Publictions added using SnowballingRule. Association *selects* represents final list of Publications that need to be considered for conducting detailed study.

In this formulation, a SR is systematic way of exploring a set of DigitalLibraries for a set ResearchQuestions (that are originated for specific ResearchProblem) using multiple criteria, collecting evidences for answering ResearchQuestions using standard format specified using StudyTemplate and producing consolidated Report by analysing sufficiently large number of Studies. An SR starts with a large Corpus of Publications collated from multiple DigitalLibraries, produces a reasonable Corpus that satisfies InclusionCriteria, ExclusionCriteria, QualityCriteria and SnowballingRule, and ends with sufficient evidences that are extracted from consolidated Corpus to answer ResearchQuestions. The detailed method for conducting SR using the concepts described using SRMModel is illustrated next.

3.3 SR Process

We define a process for conducting SR by refining three phases SR process that includes *planning*, *execution* and *synthesis* as depicted in Table 2. The refinements are in terms of how these process steps need to be performed using the concepts described using SRMModel. As shown in Fig. 5, the *planning phase* of the review process starts with *Specify Problem Statement*. This step instantiates meta element ResearchProblem. The second process step, *Define research Question*, defines the ResearchQuestions and their sub-questions. The subsequent step specifies eight basic elements of SearchProtocol namely review style, set of DigitalLibrary, InclusionCriteria, ExclusionCriteria, QualityCriteria, SnowballingRule, Classification and StudyTemplate. The InclusionCriteria, ExclusionCriteria and QualityCriteria should be specified using the expression language presented in Fig. 3. The final process step of *planning phase* is *Validate Review Protocol*. This step is considered as the checkpoint of *planning* phase that validates all the mandatory guidelines.

We classify the validation rules into two types - *structural conformance* and *quality conformance*. The structural conformance ensures the structural correctness of the instance model. For example, model of ResearchQuestion must have a SearchProtocol, SearchProtocol must have review *style*, at-least one DigitalLibrary and InclusionCriteria. We use model cardinality and OCL based pre- and post-condition to specify and ensure these structural of validation.

The quality conformance is a qualitative assessment of the model instances. For example, research questions are relevant and well-formed, the InclusionCriteria and ExclusionCriteria are aligned with ResearchQuestions, DigitalLibrary list is exhaustive for a topic, and so on. These validations require precise understanding of ResearchProblem and other model elements thus it is non-automatable task.

The auditing related information can be captured by refining SRMModel. For example, who has done the planning of a review process can be captured by adding *Reviewer* information. Many such extensions are possible and considered in our approach, which are not discussed in this paper.

The execution phase has two logical steps - *select publication* and *conduct study*. *Select publication* logical step creates publication Corpus from selected DigitalLibraries using a series of iterative process steps. Involved process steps

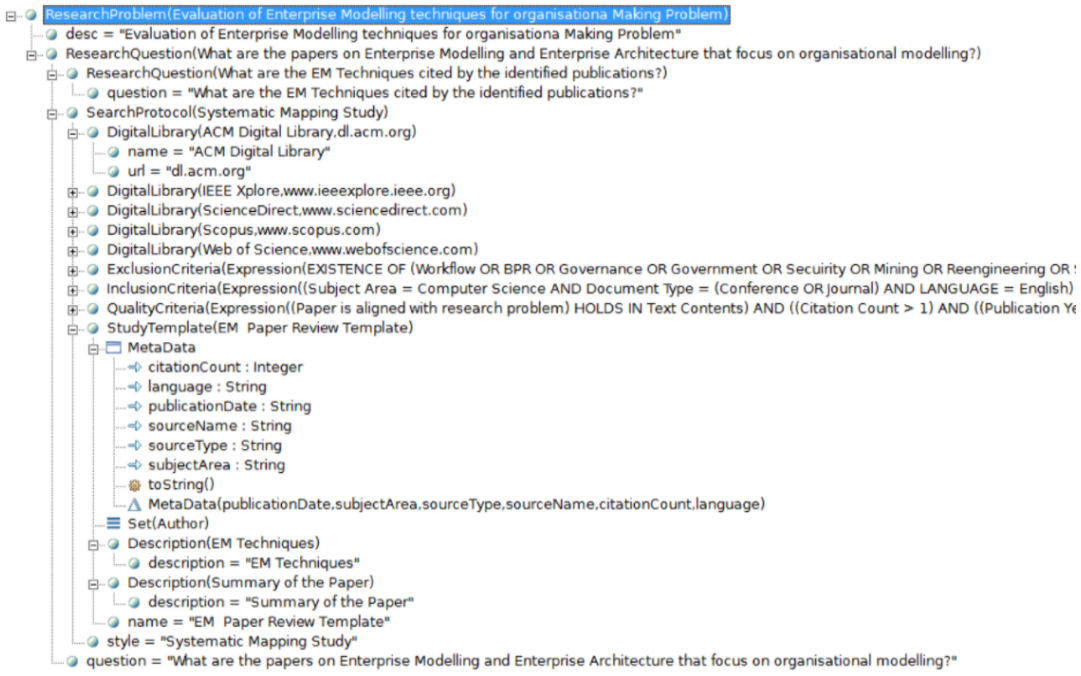

Figure 6: Planning phase specific SR Model - An instance of SRMModel

are: *Select Digital Library*, *Find Publication using Inclusion Criteria*, *Eliminate (irrelevant) Publications using Exclusion Criteria* and *Consolidate Selected Publications*. *Select Digital Library* process step selects one DigitalLibrary from set of DigitalLibrary that are associated with SearchProtocol and translates InclusionCriteria and ExclusionCriteria into DigitalLibrary specific search strings (that can be used for searching specific publications from the digital libraries). The process steps *Find Publication using Inclusion Criteria* and *Eliminate Publications using Exclusion Criteria* apply InclusionCriteria and ExclusionCriteria on DigitalLibrary and establish *inclusionFind* and *exclusionFind* links respectively. The process of for searching Publications from multiple DigitalLibrary is shown as an iterative loop in Fig. 5, but it can be done in parallel as well. *Consolidate Selected Publications* process step validates and consolidates the list of publications that need to be considered for evaluating QualityCriteria.

We propose to read title, Abstract, and Introduction sections of a Publication to assess QualityCriteria. *Select Publications using Quality Criteria* process step evaluates QualityCriteria and establishes *qualify* links.

The next step of *select publication* logical step is *Validate Corpus*. This step removes duplicate entries, validates selection process, confirms the list of Publications that need to be considered for detailed study and establishes *selects* links. Essentially this process step construct a new Corpus for subsequent review process. If required, one can perform forward snowballing [26] to add more publications to Corpus. This step also establishes *refers* links between Publications (if one Publication refers other Publication). We recommend this time- and effort intensive activity as this relationship says a lot about the biasness of newly constructed Corpus. Significant percentage of Publications in a Corpus from a group of Authors or large number of Publications connected through *refers* links is an indication of biased Corpus. The verification of quasi-gold standard [28] to evaluate the comprehensiveness of a Corpus can be performed in this step.

The next logical step of execution phase is *conducting study* on selected *Publications* or constructed Corpus. The involved activities of this step are to read title, Abstract and Introduction sections of a Publication to decide a Classification, conduct detailed study of the Publication using review style specified in SearchProtocol and record conducted study by instantiating StudyTemplate into Study. The conducting study can be done in parallel by segmenting publication Corpus into multiple clusters.

The final phase of the review process is the summarization, synthesis and reporting. The quantitative statistical analyses, qualitative sense making, and theory building activity are often considered for synthesizing research findings of Study instances and producing meaningful Report.

As shown in Fig. 5, a review report can conclude a review or it can raise other set of ResearchQuestions. This loop back mechanism enables iterative and incremental review process as oppose to linear review method followed in conventional SR.

We illustrate our approach using a case study on reviewing the state-of-the-art of enterprise modeling related research contributions. Next section presents this illustration.

4. ILLUSTRATING CASE STUDY

As part of our primary research initiative, we are working towards a technological infrastructure to support organisational decision-making [19, 3]. We have conducted multiple literature reviews to explore the state-of-the-art and state-of-the practice of organisational decision-making, the modelling and analysis capabilities of Enterprise Modeling [2], exploration of Actor Model of Computation [12] in the context of organisation decision making, and so on. A systematic review (SR) to explore Enterprise modeling (EM) related literature for evaluating the suitability of EM techniques in the context of organisational decision-making using conventional Systematic Mapping Study (SMS) methodol-

ogy is presented in [2]. This section illustrates the same SR using proposed approach.

A brief problem statement that motivate a literature review is summarised as follows:

One of the key challenges modern organisations face is how to make effective decisions within a dynamic environment. Precise understanding of various aspects of the organisation such as goals, organisation structure, operational processes, historic data and the stakeholders of the organisation is necessary to arrive at effective decisions. Current industry practice of decision making relies heavily on human experts using tools such as spreadsheets, word processors, and diagram editors. The state-of-the-art of enterprise modeling (EM) and Enterprise Architecture (EA) related research contributions claim precise representation and sophisticated analysis capabilities for enterprises. Thus leveraging existing EM approaches in a meaningful manner could be a way to improve the state-of-the-practice of organisational decision-making.

We consider this statement as ResearchProblem (RP1) of a SR that we illustrate in this paper. The research problem RP1 triggers several research questions, such as: *What are the publications on EM techniques that focus on enterprise modeling? What are the existing EM modeling techniques? What are their characteristics? What kinds of analysis are supported by EM approaches? Are they capable of supporting organisational decision-making?* so on. he Three phases of SR to explore a research question using our proposed approach is illustrated below:

4.1 Planning Phase

The planning phase formalizes the research questions and research protocol for conducting literature review. The process step *Specify Problem Statement* instantiate ResearchProblem RP1 as shown in Fig. 6. Next step *Define Research Questins* instantiate a broad ResearchQuestion RQ1- *What are the papers on Enterprise Modelling (EM) and Enterprise Architecture (EA) that focus on enterprise modelling?* and a sub-ResearchQuestions- RQ1.1 - *What are the EM techniques cited by identified papers?* Process step *Define Search Protocol* defines the complete specification of ResearchProtocol using the SRMModel. As shown in the figure, the process step selects *Systematic Mapping Study* as the review Style, chooses five DigitalLibraries namely Scopus, ACM Digital Library, IEEE Xplore, ScienceDirect and Web of Science as initial Corpus to identify EM related Publications and defines InclusionCriteria, ExclusionCriteria and QualityCriteria to form a new Corpus for conducting detailed study. All criteria are specified using the expression language specified in Fig. 3. In this review, the InclusionCriterion IC1 =[*(subjectArea = Computer Science AND documentType = (Conference Paper OR Journal) AND language = English) AND EXISTENCE OF ("Enterprise Architecture" OR "Enterprise Model" OR "Enterprise Modelling" OR "Enterprise Modeling") IN TextContent)*] is very broad as it is designed to find all Enterprise Modeling (EM) and Enterprise Architecture (EA) related Publication from *Computer Science Subject Area* and published in *Conference* or *Journal* in *English Language*. The ExclusionCriterion EX1 = [*EXISTENCE OF ("workflow" OR "BPR" OR "governance" OR "government" OR "security" OR "mining" OR "re-engineering" OR "Six Sigma" OR "SOA" OR "mashups" OR "Web Service" OR "Cloud" OR "data warehouse" OR "ERP" OR "SAP" OR "Digital Media" OR "MIS" OR OR "RFID" OR "sensor network" OR "network management" OR "LAN" OR "database" OR "network infrastructure" OR "NAS") IN TextContent)*] is designed to eliminate EM Publications that are irrelevant for this study. We consider Publications that solely focus on workflow, process mining, security, and infrastructure related topics as not much relevant to organisational decision making. Two constraints are defined as part of QualityCriteria, they are: (i) paper should be aligned with the ResearchProblem RP1 and (ii) paper should be cited by at least one refereed paper (excluding self-citation) if it is published before 2014. The former quality criterion checks the relevance and the latter validates minimum acknowledgment from research community.

Table 3: Example of Search String

Inclusion Criteria	Exclusion Criteria
`TITLE-ABS-KEY (Enterprise Architecture OR Enterprise Model OR Enterprise Modelling OR Enterprise Modeling) AND (LIMIT-TO(DOCTYPE,"cp") OR LIMIT-TO(DOCTYPE,"ar") OR LIMIT-TO(DOCTYPE,"ch") OR LIMIT-TO(DOCTYPE,"bk")) AND (LIMIT-TO(SUBJAREA,"COMP")) AND (LIMIT-TO(LANGUAGE, "English")) AND (LIMIT-TO(SRCTYPE,"p") OR LIMIT-TO(SRCTYPE,"j"))`	`(TITLE-ABS-KEY (Enterprise Architecture OR Enterprise Model OR Enterprise Modelling OR Enterprise Modeling) AND NOT ALL ("security" OR "governance" OR "government" OR "mining" OR "re-engineering" OR "BPR" OR "Six Sigma" OR "SOA" OR "mashups" OR "Web Service" OR "Cloud" OR "data warehouse" OR "ERP" OR "SAP" OR "Digital Media" OR "MIS" OR "workflow" OR "RFID" OR "sensor network" OR network management OR "LAN" OR "database" OR "network infrastructure" OR "NAS")) AND (LIMIT-TO(DOCTYPE,"cp") OR LIMIT-TO(DOCTYPE,"ar") OR LIMIT-TO(DOCTYPE,"ch") OR LIMIT-TO(DOCTYPE,"bk")) AND (LIMIT-TO(SUBJAREA,"COMP")) AND (LIMIT-TO(LANGUAGE,"English")) AND (LIMIT-TO(SRCTYPE,"p") OR LIMIT-TO(SRCTYPE,"j"))`

Process step *Define Search Protocol* process step also defines the StudyTemplate for conducting reviews. In this case, we select a set of attributes suggested by by EBSE Research Group [14] that includes Authors and their institute and country, and other MetaData such as publicationDate, subjectArea, language, citationCount, sourceType and sourceName. In addition, we consider two attributes namely *EM Technique Referred* and *Summary of the Publication* to capture the list of cited EM techniques and high-level description of the publication respectively.

The final step of planning phase, i.e., *Validate Review Protocol* step, validates structural and quality conformances. The structural conformances are validated while instantiating SRMModel and the quality conformances are evaluated through manual review.

This phase executes the review plan described in Fig. 6 through two logical steps as described in section 3.2. The first logical step *select publications* explores Scopus, ScienceDirect, Web of Science, ACM Digital Library and IEEE Xplore DigitalLibrary and finds relevant Publications by querying transformed *search strings* of associated InclusionCriteria and ExclusionCriteria wherein the process step *Select Digital Library* transform InclusionCriteria and ExclusionCrteria into search strings. As an example, we show the transformed search strings for Scopus DigitalLibrary in

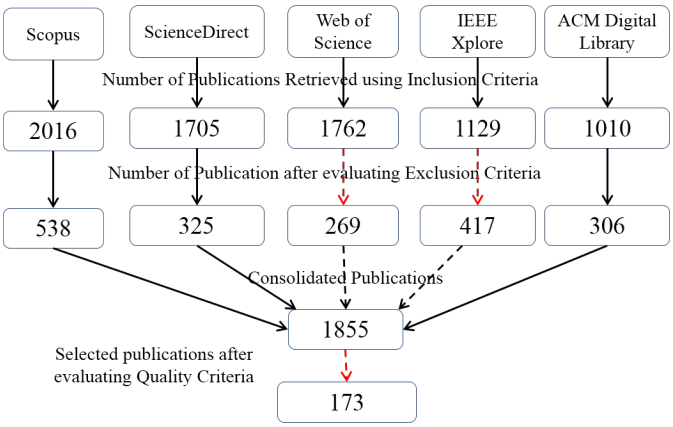

Figure 7: Progression in execution phase

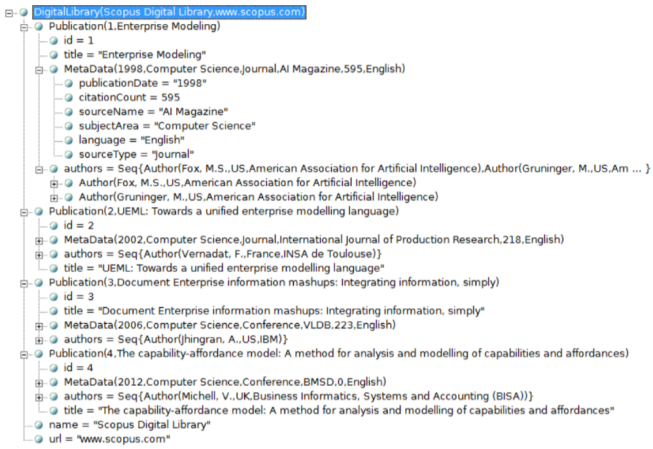

Figure 8: A representative view of Scopus

Table 3. The transformed search strings of other DigitalLibrary can be found in appendices section[2]

4.2 Execution Phase

The process step *Select Publication using Inclusion Criteria* find the Publications that satisfy the InclusionCriteria expression. A sample representation of Publications selected from Scopus DigitalLibrary is depicted in Fig. 8. The process step *Eliminate Publication using Exclusion Criteria* eliminates Publications from list of selected Publications. For example, the Publication with id 3 will be eliminated from list of Publication depicted in Fig. 8 as its *title* contains the Phrase 'mashups' (a Phrase in Exclusion Criteria expression).

The count of identified Publications for each process step is depicted in Fig. 7. The InclusionCriterion collectively select 7622 Publications (with multiple duplicate entries) and ExclusionCriteria short-list 1855 Publications. Supported advanced search capabilities of DigitalLibrary are exploited to find Publications.

The QualityCriteria are evaluated by studying title, MetaData, Abstract and Introduction sections of the Publications selected after evaluating ExclusionCriteria. From earlier example, the Publication with id 4 will be eliminated by QualityCritera as the Publication published before 2014 and doesn't have any citationCount. In this study, the QualityCriteria selects 173 Publications. Finally, the *Validate Publication* step validates selected publication and constructs a Corpus for detailed study. A sample Corpus with selected Publications from initial Publication list (depicted in Fig. 8) is shown in Fig. 9 for illustration purpose.

[2]available at https://www.researchgate.net/publication/305481180_Appendices_of_Paper__Enterprise_Modeling_as_an_Aid_to_Complex_Dynamic_Decision_Making_A_Systematic_Mapping_Study

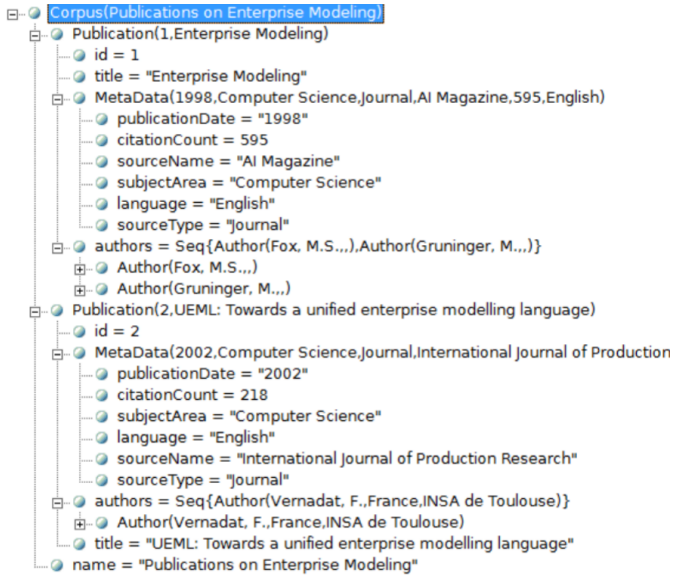

Figure 9: A representation of Corpus

The second logical step *conduct study* is performed on 173 Publications (this number is a high but we continued with it as our motive was to cover the breadth of the topic). The study is conducted using SMS review style and the review findings are captured in the form of Study by instantiating StudyTemplate defined in *Protocol Definition* phase.

4.3 Synthesis Phase

The synthesis phase analyzes all Study model captured in *execution phase* and answers ResearchQuestions formulated in the SearchProtocol in the form of a Report. The final outcomes of the review synthesis answering two research questions are briefly discussed below:

Answers to RQ 1 - What are the papers on Enterprise Modeling (EM) and Enterprise Architecture (EA) that focus on organisation modelling?

As shown in Fig. 7, 173 Publications satisfy the criteria defined in SearchProtcol SP1. The complete list of Publications can be found in appendices section and the detailed report on review findings for ResearchQuestions RQ1 and RQ1.1 can be found in [2]. The consolidation of *EM techniques* attribute of 173 publication studies collectively report 29 EM techniques as an answer to sub-question - *What are the EM techniques cited by those publications?* Table 4 describes identified EM techniques. The useful references associated with identified EM techniques are also listed in appendices section.

We conducted trend analysis on final selection of 173 publications by considering the attributes values of of Study models such as country, institute, publicationYear, etc. In brief, these publications are contributed from 35 countries

Table 4: Identified EM Approaches

Zachman Framework, ArchiMate, Department of Defense Architecture Framework (DoDAF), The British Ministry of Defence Architecture Framework (MoDAF), The Open Group Architecture Framework (TOGAF), ARIS, Extended Enterprise Modeling Language (EEML), Enterprise Knowledge Development (EKD),MoKI, Knowledge Acquisition in automated specification (KAOS), i, Business Motivation Model (BMM),Business Process Model and Notation (BPMN), Integrated enterprise modeling (IEM), Unified Modeling Language (UML),Perdue Enterprise Reference Framework (PERA), GRAI Integrated Methodology (GIM), Computer Integrated Manufacturing Open Systems Architecture Framework (CIMOSA),Generalized Enterprise Reference Architecture and Methodology (GERAM), Design and Engineering Methodology for Organizations (DEMO), Multi-Perspective Enterprise Modelling (MEMO), Integration DEFinition (IDEF), European Interoperability Framework (EIF), Semantics of Business Vocabulary and Rules (SBVR), System Dynamics, Unifed Enterprise Modeling Language (UEML), Systemic Enterprise Architecture Methodology (SEAM), Event-driven process chain (EPC), and Reference Model of Open Distributed Processing (RM-ODP)*

involving 161 institutions in time span of 1987 to 2016. The complete Report of this review, which is conducted using conventional SMS methodology, can be found in[2].

This experiment was conducted for illustrating and validating proposed approach. We used the RLMModel and SRMModel meta-models and SR method described in section 3 to conduct this SR. In this section, we illustrated proposed approach by repeating the SR which was conducted using conventional SMS methodology. The benefits of proposed approach is discussed in section 6. Prior to illustrate the benefit, we briefly discuss the implementation options and out implementation strategy that we have chosen for this case study.

5. IMPLEMENTATION

The proposed approach realises the systematic review process as a series of model creation, model instantiation, model transformation and model evaluation activities.

In particular, the *Protocol Definition* phase is modeling of ResearchQuestions and SearchProtocol as shown in Fig. 6. The *explore publication* logical step of *Execution* phase comprises three activities: i) transform InclusionCriteria and ExclusionCriteria into DigitalLibrary specific search strings as illustrated in Table. 3, ii) apply transformed search strings into DigitalLibraries to find relevant Publications, and iii) construct a new Corpus with set of Publications that satify the condition *(InclusionCriteria AND NOT(ExclusionCriteria) AND QualityCriteria)*. The logical step *conduct study* is for reading Publications from Corpus and instantiating StudyTemplate. The *synthesis* phase navigates and analyses Study models and produce a Report. The possible implementation options of these activities and our implementation strategies are highlithed in the Table 5.

As depicted in the table, we are using xModeler[5] for creating models (by instantiating LRMModel and SRMModel) in *Protocol Definition* phase. However, one can use any meta-modeling tool to realise proposed approach. In our realisation, we used xModeler to represent the Corpus of 173 *Publications*. A sample Corpus with two Publications

[5]http://www.eis.mdx.ac.uk/staffpages/tonyclark/Software/XModeler.html

Table 5: Implementation Options

	Activity	Implementation Options	Chosen Option
Planning	Model Research Question and Research Protocol	1. Use of modeling tool. 2. Spreadsheet	xModeler
Execution	Transform search criteria into search strings	Automated translation using M2T[3] technique. 2 Manual transformation	Manual transformation
	Evaluate metadata_evel and phrase_existence expressions	1. Manual, 2. Use of digital library specific search capability, 3. Use generic web search capability such as Python Scrapy[4]	Digital library specific search capability
	Execute meaning_existence expression	1.Manual interpretation, 2. Sophisticated machine learning algorithm, deep learning	Manual Interpretaion
	Create and update Corpus	1. Use of modeling tools, 2. use of Spreadsheet	xModeler
	Read publication	Manual	Manual
	Instantiate Study Template	1. Use of Spreadsheet, document, 2. Use of modeling tools	use of xModeler
Synthesis	Evaluatiion of *Studies* and prepare *Report*	1. Manual interpretation. 2. Modeling tool assited interpretation	xModeler assisted interpretation and manual report generation

is shown in Fig. 9 for illustration purpose. We used semi-automated technique to apply search strings on digital libraries and manual effort to evaluate quality criteria. The population of Corpus from selected publications, instantiation of StudyTemplate by reading Publications and syntesis of Study models to produce Report activities are manual at present. However, population of Corpus and synthesis activity can be automated to a large extent by using scripting language supported by xModeler.

6. ANALYSES AND DISCUSSION

We support iterative and incremental approach, use SMS and SLR methodologies across iterations, and leverage modeling and model processing technique in a systematic form. Further we visualise a literature review process as step-wise instantiation of SRMModel. The planning activity is instantiation of SRMModel and defining new meta-model (e.g., meta-model type study template), execution is instantiation of *Publications* of RLMModel and population of *Study Template*, and synthesis is model-synthesis(of instances of SRMModel and *Study Templates*).

We conducted 2 literature reviews using conventional SLR and SMS methodologies and using proposed approach. Our observations is that the iterative and incremental approach improve the precision and the use of SMS and SLR in concert help in managing complex research questions. The use of snowballing along with search-string based approach ensure better search coverage (and thus manage threats to validity better). The model-based realisation improve specifics to use SR effectively. The classification of validations and

conceptualisation structural conformance improve the scope for automation (hence the reduction of effort and time) and reduce error-proneness. Moreover, seamless traceability between various artefacts reduce the effort for correlation and sense-making; higher abstraction of the artifacts improve the visualization (and thus interpretation); analysable representation of review artefacts enable rigorous analysis and complex synthesis. The use of meta-modeling as study template also improve the automated synthesis.

We evaluated proposed approach based on its ability to ensure the *quality* and *usability* properties described in table 1. Our analysis is illustrated below:

Biasness: Biasness on *study identification*, *literature corpus*, *quality evaluation* and *data extraction* (as shown in table 1) significant impact the quality of review outcome. Evaluating biasness in conventional SR mostly manual and thus effort- and time- intensive activity. Proposed approach enforces constraints on publication database and validates selection counts (structural conformance) from each digital library to manage study identification biasness. The literature corpus biasness can be evaluated using *refers* association and finding list of publications from an author or a group of authors. We say a publication corpus is biased if the large percentage of publications are connected with *refers* association and/or large percentage of publications in a corpus are from same group of authors. Data extraction biasness can be managed by enforcing *Study Template* definition.

Threats to validity: Providing convincing justification to *threats to validity* for study identification, literature coverage, quality evaluation and data extraction improves the confidence of a review outcome. We argue that proposed approach provides better support to manage *threats to validity*. The constraints can be defined at meta-model level and ensured through model-validation techniques. For example, minimum number of selected publications for each stage i.e., number of publications linked with *inclusionFinds*, *exclusionFinds* and *select* associations in RLMModel.

Repeatability: The proposed approach is a refinement of conventional SRs thus it is repeatable. The mode-based realisation further improves the repeatability as the process is essentially series of model instantiation, model navigation, model extraction and model validation activities.

Structured Representation: SMS and SLR methodologies use table and text based template to represent extracted information. These representation techniques are restrictive in two senses - a) limitation of the format: Text has no structure and thus interpretation of a text is vulnerable to human interpretation; the table is restrictive in representing complicated relationships. We propose a meta-modeling technique for information representation, and b) synthesis of collected data: unstructured and semi-structured data has less power than models. We propose to use OCL, QVT and Model-to-Text transformation techniques to validate captured information and transform them into appropriate form.

Traceability: Establishing traceability between various artefacts in conventional SR is managed by individual review team. In particular, there is no specific recommendation or guideline. Poor traceability significantly impacts the review time and quality. The application of model-based approach helps in establishing the traceability within and across iterations of a literature review.

Visualization: The model-based approach for representing review artefacts, such as studies, enables model-to-model and model-to-text transformation. Thus automated transformation of review artefacts into a form that can be used by visualization tools is possible with proposed approach.

In addition to these standard properties, two other properties are equality important for SR and proposed approach score better as compare to conventional SR:

Usability: Conventional SR mostly uses a linear approach starting from problem statement and research question to review output. This is an effective approach for expert literature review practitioners but it is unlike that novice practitioners will get everything right in first attempt. We propose an iterative style review where practitioners can start with simple research question adopting one review style and subsequently they can shift to more complex research questions with different review style.

Accountability and change management: Model based approach improves the accountability of the review process by storing additional information in model. The change management can be introduced by supporting model version management. These are well-researched area in modeling community.

7. CONCLUSION

In this paper, we presented a model-based realisation of SR in terms of meta-models and a precise process definition. We illustrated the same using a case study which was also repeated using TLR, conventional SMS and proposed approach. We found that the review outcomes with SMS were significantly better than with TLR. The proposed approach led to even better outcomes in that:

- Availability of all artefacts in a model form enables analysis, easy navigation as well as traceability thus reducing burden on reviewers and review time. It also helped in establishing properties such as biasness, corpus quality, validity of threats etc. Use of visualisation, model-transformation and validation techniques improved precision in synthesis and report generation.
- Combining necessary concepts of SR in a meta-model form improves the usability. Incorporating snowballing technique into SR led to better search coverage. Supporting a hybrid approach through integration of SLR and SMS led to improved precision. Precise definition of process steps, semi-automated model validation, and model-synthesis led to improved quality.
- Enabling iterative and incremental approach for conducting SR helps in managing complexity of SR

We believe the proposed approach serves as a foundation for a robust literature review tool. An implementation strategy using xModeler and advanced search capability of digital libraries is briefly highlighted in this paper. We aim to extend SLRTool [4] with the proposed approach. In this regard, we have evaluated the possibility of using model-based techniques such as meta-modeling, model-validation, model-visualisation, model-to-text and model-to-model transformation in prospective process steps. We are now exploring the use of natural language processing and text mining techniques to further improve the automation. We also have plan to introduce this approach to the researchers from industry and academia who have less experience in SR production as suggested in [20].

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