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Software Requirements Interdependencies: A Systematic Literature Review on Significance, Techniques and Challenges

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Abstract: Requirement prioritisation (RP) is a crucial process in software development, aimed at identifying and addressing key requirements that can resolve challenges encountered during the implementation phase. Effective RP is essential for ensuring that critical requirements are met, and project goals are achieved. However, traditional RP methods often fail to account for the interdependencies between requirements, which can lead to project failures, inefficiencies, and inaccurate prioritisation outcomes. These overlooked interdependencies introduce complexities that, if not properly managed, can trigger cascading issues, ultimately jeopardizing the entire project's success. In this study, we have undertaken a comprehensive systematic literature review that focuses on various RP techniques incorporating requirements interdependencies (RI). By adhering to Kitchenham's well-established review guidelines, we systematically categorized and analyzed these techniques, assessing their approaches to RI implementation as well as their associated benefits and limitations. Our thorough review identified 38 relevant studies, each selected through a rigorous study selection process, to answer the research questions posed. The findings of our research indicate that, despite significant advancements in RP techniques, numerous limitations persist in effectively addressing RI. These findings underscore the necessity for ongoing research and innovation to enhance the RP process. Our study offers valuable insights for researchers and practitioners striving to refine current RP techniques, particularly by emphasizing the critical role of RI in future developments.

Keywords: Requirements Interdependencies, Requirements Prioritization Techniques Challenges, Systematic literature review

1. INTRODUCTION

Requirement gathering is one of most important stages in System Development Life Cycle (SDLC), in which one or more members of the team meet with stakeholders to compile a list of requirements that will be used later in the development process. As requested by the stakeholders, the collected requirements will be converted into project functionalities. However, a problem arises when the list of requirements gets too large and has an influence on the implementation phase, as many requirements will raise the development process's budget, time, and workload.

Table 1. Software project failure rate in 2020

Project Size	Successful	Failed
Large	8%	41%
Medium	9%	31%
Moderate	21%	17%
Small	62%	11%

As shown in Table I, the software project failure rate in 2020, large size projects have the highest failure rate among other project sizes as recorded while only 8 percent management, both of which result in inaccurate requirement [2], [3]. Poor requirements management is responsible for the overall project failure, which is why this issue should not be underestimated [4]. The interdependence of requirements is a significant issue that arises as a result of poor requirements management [5].

Therefore, Requirement Prioritization (RP) was introduced to address project failure issues by determining which requirements are most important to implement within a project's timeframe. [6] While RP helps solve requirement-related problems, it has been observed that existing RP techniques often fail to consider requirement constraints, which affect interdependencies between requirements. [7], Requirement Interdependencies (RI) being describes as the interdependencies of requirements with each other [8]. RI identification is a crucial operation that should be completed as soon as possible as each dependency must be appropriately described [9]. RI may influence numerous decisions and activities during development, which can have a negative impact on project success [10].

This paper is divided into the sections listed below. Section II analyses existing related work to the mentioned topic. Section III depicts the research methodology employed to carry out this SLR. Section IV discusses the

E-mail address: syafiqah_rusli@hotmail.com, rohani@umpsa.edu.my potential threats to the study's validity. Section V gives a clear picture of the study's collected data by answering each research question. Section VI brings the paper to conclusion.

2. RELATED WORK

As Fernandes [11] points out, most individual requirements cannot be clarified in separation because only 20% of them are truly singular. This declaration implies that the majority of requirements are interdependent and affect each other where they are connected in huge group of requirements that handling them individually is impossible [12]. RI is an essential factor in the prioritisation process because dependent requirements can only function properly if their prerequisite requirements are met [13]. As a side effect, disregarding requirements' dependencies during the prioritisation process may have a significant impact. That is when prerequisite requirement was eliminated because it was not classified as a high priority requirement, resulting in an incorrect result.

Furthermore, it is advantageous for a smaller number of requirements, according to Thakurta [14], since the computational complexity in managing interdependencies increases as the number of requirements increases. Besides that, recognising the interdependencies of the requirements can have a larger impact on implementation decisions and their schedule, aside from the importance to the customer in release planning [15]. This action occurs because of all requirements being interconnected and influencing each other, resulting in requirement interdependencies. It is essential that dependencies not be restricted to only two requirements, although not all dependencies are required in the project [16]. Understanding requirements interdependencies is one of the success criteria in the software development process, and information about requirements interdependencies may be distributed throughout the process [17].

3. RELATED WORK

The SLR is conducted to obtain a comprehensive evaluation of the RI issue by deciding and thoroughly investigating existing published studies by current researchers that are relevant to the topic, so that the challenge can be investigated in greater detail and any suitable solutions for the issues can be identified. The SLR research methodology was established on the standard SLR guidelines proposed by Kitchenham and Charters. [18]

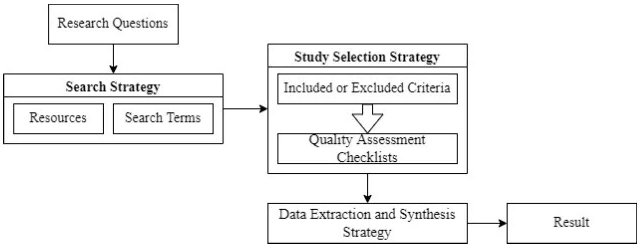
Research Questions
Search Strategy
Resources
Search Terms
Study Selection Strategy
Included or Excluded Criteria
Quality Assessment Checklists
Data Extraction and Synthesis Strategy
Result

Figure 1. SLR-RI Review Protocol [18]

The research review protocol is demonstrated in Figure 1, and it consists of five phases: research questions, search strategy, study selection strategy, data extraction and synthesis strategy, and result.

3.1. Research Questions

The primary objective of this study is to identify and analyse RP issues related to the RI, which is considered a critical aspect in both the implementation and RP processes. An extensive investigation is required to achieve the three objectives, which aid in gathering sufficient information about the significance of RI and RP, existing RP techniques incorporating RI elements, and their constraints. As a guideline for obtaining the mentioned information, three research questions were outlined as follows:

- RQ1: What is the significance of conducting RI in the RP process?
- RQ2: What are current RP techniques involving RI elements and their interdependencies approach, methods, benefits, and limitations?
- RQ3: What are the recommended future sets to overcome the identified limitations?

The SLR aims to demonstrate the value of incorporating Requirement Interdependencies (RI) in the Requirement Prioritization (RP) process. RQ1 seeks to understand the causes of interdependencies and their benefits for improving RP outcomes. RQ2 focuses on gathering and evaluating existing RP techniques that include interdependencies, assessing their limitations, approaches, benefits, and methods. RQ3 aims to identify and investigate RP techniques that effectively address the limitations of current RP methods.

3.2. Research Questions

According Kitchenham and Charters [18], search strategy aims to search primary studies specifically related to research field or issues through any medium. In this research, the search process was done mostly using online platforms which is digital libraries and specific databases as presented in Table 2 where both resources and search term can be searched without any difficulty. These digital libraries were chosen because containing the most useful resources and most publications in this area are published in this platform. Then, using the filtration function, to narrow down the resources from this platform, which were compiled from various types of publications and formats such as conferences, journals, articles, e-books, and workshops.

Table 2. List of Resources

Resource Name	Resource Link
Google Scholar	https://scholar.google.com.my/
Research Gate	https://www.researchgate.net
ScienceDirect	http://www.sciencedirect.com/
IEEE Xplore	https://ieeexplore.ieee.org/
Atlantis Press	https://www.atlantis-press.com
Semantic Scholar	https://www.semanticscholar.org/
SpringerLink	https://link.springer.com/

The target of a systematic review is to trace as many primary studies as possible associated to the research question using an unbiased search strategy. The primary focus of this SLR's resources is from 1998 to 2024, which is why more papers from those years were chosen than from other years. As a result, it is essential to define the correct search terms that are significant for the study using the criteria stated by Barbara Kitchenham [18].

To broaden the search process and expand the number of relevant results to be used in the research, all search terms were both single and combined with the Boolean operators AND, OR. The search terms have been applied to the titles and keywords of papers in digital libraries and databases, which then retrieve papers that are relevant to the research topic. Regardless of the research topic, the following are the example of search terms used:

a. Requirement prioritization (AND/OR) selection

b. Significant (OR/AND) Importance (OR/AND) Impact of requirement interdependency

c. Criteria OR aspect OR attribute of requirement interdependency

d. Challenge OR limitation OR issue of requirement prioritization techniques OR methods OR frameworks, OR approaches

3.2.1. Study Selection Strategy

The study selection strategy is used to decide whether or not the research findings collected during the early phase of the searching must be included [18]. As shown in Figure 2, the study selection strategy is used throughout this analysis by keeping two sub-criteria in mind: inclusion and exclusion criteria, and quality assessment criteria, which are thoroughly explained in the subsection below.

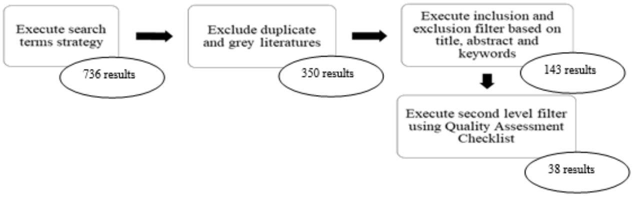
Execute search terms strategy
736 results
Exclude duplicate and grey literatures
350 results
Execute inclusion and exclusion filter based on title, abstract and keywords
143 results
Execute second level filter using Quality Assessment Checklist
38 results

Figure 2. SLR Study Selection Process

3.2.2. Inclusion and Exclusion Criteria

Initially, 736 relevant results were gathered from online libraries and databases. To obtain more specific results based on research questions, some evaluations were required for each collected work. In response to specific research questions, inclusion and exclusion criteria were developed.

Inclusion criteria are the characteristics subjects must have to participate in the research, while exclusion criteria are the characteristics that disqualify them [19]. Table 3 lists various criteria, including language; since this research is in English, only English resources were preferred. The table also specifies excluding duplicates and grey literature, which refers to ongoing or unpublished research that is hard to find [20]. Thus, only 38 relevant results are available after applying inclusion and exclusion during the search process.

Table 3. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
All studies must be conducted in English	Studies written in languages other than English
Studies which may provide information for the research	Unrelated studies to this research field, topic, or research questions
Empirical studies and experience reports based on expert	Duplicate and grey studies

3.2.3. Quality Assessment Checklist

Quality Assessment Checklists (QAC) were used to properly assess each study based on a set of questions that determined whether or not the collection study was truly appropriate for this research [18]. The assessment of the selected studies is performed based on QAC quality questions where the specified research questions were produced related to research focus topic. Each question's type of answer is based on a scale of 2 for Yes, 1 for Moderately, and 0 for No. The questions are listed in Table 4.

Table 4. Quality Assessment Checklists

ID	Question	Answer's Point Score

QA1	Is the study's goal and context sufficiently established?	Yes = 2/
		Moderately = 1/
		No = 0

QA2	Is the study primarily concerned with RQ and/or RI?	Yes = 2/
		Moderately = 1/
		No = 0

QA3	Is the proposed technique/solution clearly elaborated?	Yes = 2/
		Moderately = 1/
		No = 0

QA4	Is the study's conclusion clearly defined?	Yes = 2/
		Moderately = 1/
		No = 0

To address contradictions and reach a consensus, result measurements and descriptions were carried out. Studies with quality scores of less than 4 (less than half of the full quality score of 8) were exempted to guarantee the consistency of the findings. As a result, 42 works were chosen as main research findings for this review. Table 5 lists the studies that were chosen, along with their reference numbers and final quality scores.

Table 5. Quality Assessment Checklist's Result

	Reference	QA1	QA2	QA3	QA4	Overall score
1.	[21]	2	2	2	2	8
2.	[14]	2	2	2	2	8
3.	[22]	2	2	2	2	8
4.	[23]	2	2	2	2	8
5.	[12]	2	1	2	2	7
6.	[24]	2	1	2	1	6
7.	[25]	2	2	2	2	8
8.	[26]	2	2	2	2	8
9.	[27]	2	1	1	2	6
10.	[28]	2	1	1	2	6
11.	[29]	2	1	2	1	6
12.	[30]	2	1	1	1	5
13.	[11]	2	1	1	2	6
14.	[31]	2	1	1	2	6
15.	[32]	2	2	2	2	8
16.	[33]	2	1	1	2	6
17.	[34]	2	2	2	2	8
18.	[35]	2	2	2	2	8
19.	[36]	2	2	2	2	8
20.	[13]	2	1	1	2	6
21.	[37]	2	1	1	2	6
22.	[16]	2	1	1	2	6
23.	[10]	2	1	1	2	6
24.	[38]	2	1	1	2	6
25.	[9]	2	1	1	2	6
26.	[39]	2	2	2	2	8
27.	[40]	2	2	2	2	8
28.	[41]	2	2	2	2	8
29.	[42]	2	2	2	2	8
30.	[43]	2	2	2	2	8
31.	[44]	2	2	2	2	8
32.	[45]	2	2	2	2	8
33.	[46]	2	2	2	2	8
34.	[47]	2	2	2	2	8
35.	[48]	2	2	2	2	8
36.	[49]	2	2	2	2	8
37.	[50]	2	2	2	2	8
38.	[51]	2	2	2	2	8

3.2.4. Data Extraction and Synthesis Strategy

The main goal of data extraction is to create forms that accurately track researchers' details using primary sources [19]. Mendeley software was used for data extraction in this research. This process is essential to answer the research questions and meet study quality criteria. Each resource was thoroughly examined for meaningful information relevant to the research questions. During data synthesis, declarations from data extraction are retrieved. The evidence gathered, whether quantitative or qualitative, addressed the research questions. For RQ1, data on the significance of RI in RP is thoroughly investigated to demonstrate its impact on the RP process and implementation.

Furthermore, a list of existing RP techniques that consider RI elements is identified and critically discussed, covering their interdependencies criteria, methods, advantages, and disadvantages to address RQ2. Finally, RQ3 is explained about the recommended future sets that can be used to overcome the identified limitation as stated in RQ2.

4. THREATS TO VALIDITY

The main threat to the validity for this research is the lack of relevant literature, as few studies fully cover both RI and RP as expected. Researchers in the RI sub-area of RP often use various terms like interconnection or linked to describe requirements dependency relationships, causing inconsistency. This inconsistency complicates finding appropriate results since these terms are used in fields beyond Software Engineering, such as Manufacturing. To address this, we used carefully crafted search strings with alternative keywords and Boolean conjunctions, implemented incrementally with advanced digital library search functions. Reference lists from primary studies were also used to find additional relevant studies, which greatly aided the research.

Another threat is that some relevant studies were written in languages other than English, despite having English titles. This caused confusion during the search process, as seemingly relevant studies could not be used due to language barriers. To overcome this, a double-check method was used after excluding non-English studies and grey literature. While this process was exhausting, it was essential to obtain good references and avoid unnecessary discoveries.

5. RESULTS AND DISCUSSION

This section demonstrates the findings and discussions of this SLR, beginning with an outline of the primary resources chosen. Regarding that, the data collected from the SLR is clearly explained in answer to research questions.

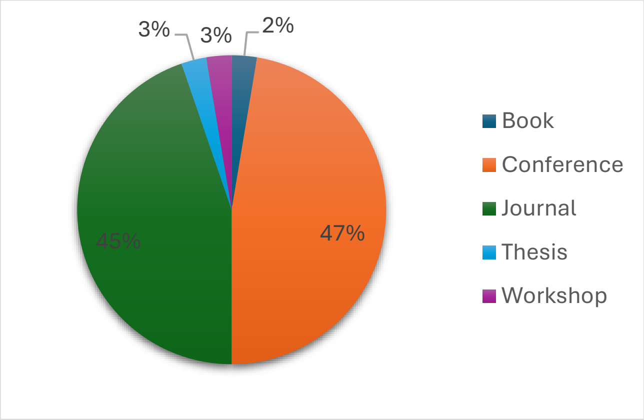

Figure 3. Percentage of the Selected Resources Publication Channels

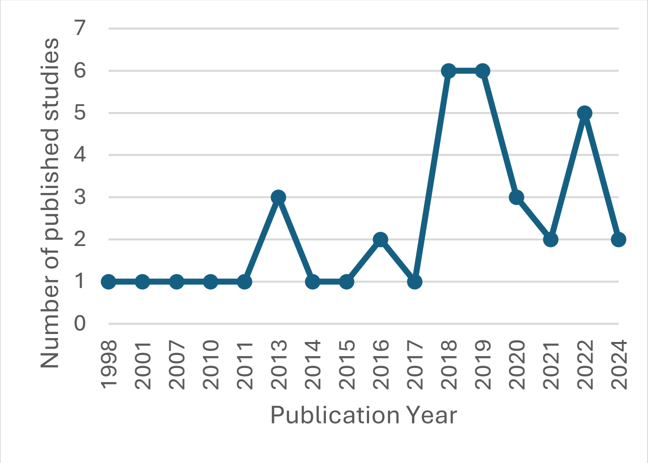

Figure 4. Publication Years of Selected Research Studies

5.1. Overview of selected primary research studies

This section presents the outcomes and discussion of the SLR along with a comprehensive summary of the selected resources. A total of 38 studies were identified as primary sources, comprising 18 conference papers, 17 journal articles, 1 book chapter, 1 published thesis, and 1 workshop paper. The results and discussions of the SLR are elaborated in this section, with a detailed overview of the selected resources. As depicted in Figure 3, the distribution of these sources is represented in percentage terms as follows: conference papers account for 47%, journal articles for 45%, while the published thesis and workshop papers each constitute 3%, and the book chapter represents 2%.

5.2. What is the significance of conducting RI in the RP process? (RQ1)

Making decisions among several or many options is also very common in the software development process, because projects frequently encounter challenges with budgets, shortage of time, and human resources, so not all requirements can be implemented when the project has a massive number of requirements. This situation is frequently resolved by prioritisation, so that only high-priority requirements can be implemented. Out of the declaration that deduction operation in terms of maintaining the project's success rate, the interdependencies aspect must not be neglected [27]. As noted by Jarzebowicz [12]. RI is one of the other RP criteria that many organisations or teams recognise.

According to a survey conducted by Nurdiani, et.al [7], 13 out of 21 respondents agreed that their projects are successful because they consider RI element during project development. RI is an inherent characteristic of software development which play important role in system analysis [13]. Understanding RI is one of the success factors by improve iteration planning and coding effort in the software development process [37]. Interdependence problems arose when the connected requirements are not selected during the prioritisation process. This requires reworking in the design, development, and testing of the software because the risk of the project failing is considerable [16].

Besides, RI are addressed and should be explored from traceability perspective for change impact analysis [16]. Traceability support is critical to overcome these problems which existing traceability tools provide functionality to store the relationship between requirements [38], [52]. Expert knowledge must be included into the decision-making process by identifying all interdependencies as support along the way. [38]. Developing the wrong features in the wrong order frequently results in system failure or problems during the development process [34].

Moreover, incorporating RI into the RP process resulted in a more effective and successful output because the function of requirements can be promises. After all, the correlation between RP and RI remains intact. However, according to Carlshamre [27], a large number of interdependencies makes it difficult to uncover and handle dependencies. Interdependencies between requirements are also ambiguous, which the relationship of requirements can be critical to identified. To accomplish this, Dahlstedt [53] stated that specify the requirements is the best option, where we should focus on the most important requirements, or grouping the requirements based on their implications on the system is preferable.

Due to the overheads involved in maintaining traceability of requirements, Ramesh and Jarke [54] emphasise that it is neither feasible nor desirable to maintain relationship between all related requirements and output produced during the development process. Instead, it is more practical to identify the critical requirements and focus on storing the necessary traceability information for the requirements [52].

Consequently, the likelihood of enhancing the success rate of the development or RP process may be relying on the identification of RI and the strategy employed to keep the complexity of the process tolerable.

In conclusion, the RI element is proven to be significant in research and project during RP techniques and should be considered throughout the process [50]. However, many developers or researchers choose to neglect the RI element due to the increased complexity it introduces to project development. Consequently, the perceived impact of the RI element lessens in the developers' perspective, given the additional time and energy required for its implementation.

5.3. What are current RP techniques involving RI elements and their technique, interdependencies implementation, benefits, and limitations? (RQ2)

The primary goal of RQ2 is to explore and survey current RP techniques that will help us with our study in terms of interdependencies. Each of the recognized techniques was thoroughly evaluated on several characteristics, including their RP technique used, interdependence implementation, benefits and limitations.

There are fourteen RP techniques that took interdependencies into account during the prioritisation process which are Collaborative Dependency-Based Ranking (CDBR) [36], Collaborative Method [35], DRank [39], Improved Highly-configurable system (HCS) [40], Interactive Requirements Prioritization [41], Intuitionistic Fuzzy Approach (IFS) [42], Majority Voting Goal-Based Approach (MVGB) with Vertical Binary Search [49], Mathematical Programming Technique [43], [55], Multi-Aspects Based Requirement Prioritization Technique [44], Novel Collaborative Requirement Prioritization Approach [45], Quantitative study of RP criteria using model ordinal data [50], Software-Supported Requirements Prioritization in Distributed Scrum Projects [46], Software Requirements Prioritization Method Based on Qualitative Assessment and Cost-Benefit Prediction (OurRank) [47], and Value-Based Requirements Prioritization Technique (VBRP) [48]. As shown in Table 6 in Appendix presents the result of analysing the existing RP techniques use a variety of RI approaches, each with its own set of benefits and limitations.

The dependency implementation is varied from one RP technique to another in this review, to match it with the RP methods used to prioritise the requirements. Figure 5 displays three different interdependent approaches. The independence approaches were categorised according to how they were used during the RP process.

- Dependency graph: The dependencies between requirements are displayed in graph form to help visualise the relationship.
- Dependency classification: The dependencies of requirements are divided into groups based on dependency type.
- One of RP factor: Dependencies serve as one of the primary components during the RP process that are compatible with the RP methods employed.

There are six RP techniques that use dependency graphs during the RP process from the mentioned interdependence implementation. Each of RP techniques have one thing in common: they all involve stakeholders and experts during the RP process. That is why a graph form is used to depict the dependency so that both experts and stakeholders can comprehend the relationship between requirements during analysis and decision-making process [36], [41], [42].

Following that, there are three RP techniques that employ a dependency classification approach but both of techniques apply the concept in completely different manner. For Collaborative Method, the dependency is divided into multiple groups, each of which indicates how the requirements are truly connected to one another, which influence the requirements weight [35]. Meanwhile, for the RP techniques using ordinal model data apply dependency in terms of option “Yes” or “No” to indicate the impact of dependency throughout the RP process [50]. Apart from that, the dependency also classified as whether the relationship is direct or indirect based on specific aspects which become the main part of RP techniques [44].

Moreover, the use of dependency as a primary factor in RP is quite prevalent among various RP techniques, each of which applies it in a unique manner. Four RP techniques identified incorporate dependency as a key component in their equations for calculating priority values [43], [47], [48], [55]. In contrast, the Improved Highly configurable system (HCS) technique utilizes dependency as a comparative criterion for assessing the technique's performance [40].

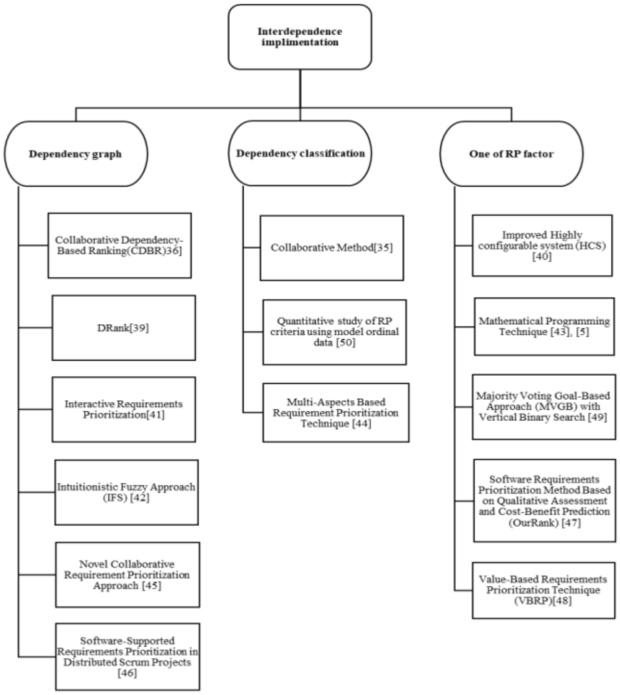
Interdependence implimentation
Dependency graph
Dependency classification
One of RP factor
Collaborative Dependency-Based Ranking(CDBR)36]
DRank[39]
Interactive Requirements Prioritization[41]
Intuitionistic Fuzzy Approach (IFS) [42]
Novel Collaborative Requirement Prioritization Approach [45]
Software-Supported Requirements Prioritization in Distributed Scrum Projects [46]
Collaborative Method[35]
Quantitative study of RP criteria using model ordinal data [50]
Multi-Aspects Based Requirement Prioritization Technique [44]
Improved Highly configurable system (HCS) [40]
Mathematical Programming Technique [43], [5]
Majority Voting Goal-Based Approach (MVGB) with Vertical Binary Search [49]
Software Requirements Prioritization Method Based on Qualitative Assessment and Cost-Benefit Prediction (OurRank) [47]
Value-Based Requirements Prioritization Technique (VBRP)[48]

Figure 5. Classification of Interdependence approaches

In conclusion, the impact of interdependencies in RP techniques is significant, as the RI element plays a crucial role in the decision-making process, particularly when stakeholders may exhibit bias, a challenge that is often difficult to handle. Despite the interdependent nature of the fourteen RP techniques discussed, the techniques are still capable of producing effective outcomes. However, the limitations of these techniques, including errors and inflexibility, persist regardless of whether the RI element is considered. These limitations arise from the techniques' adaptability issues when applied to case studies other than those used during the initial study phase. Nevertheless, it is important to acknowledge that managing the interdependencies between requirements is a complex task that demands considerable effort to ensure accurate results.

5.4. What are the recommended future sets to overcome the identified limitations? (RQ3)

Following the discussion of existing RP techniques in RQ1 and RQ2, it appears that RI serves a significant part in decision-making during the implementation phase to ensure the success rate of establishing a project, as well as during the RP process. The primary goal of the study is to gather solid knowledge about the limitations of currently available RP techniques. It has been noticed that existing techniques continue to have limitations related to bias issues, user errors, and being inflexible for various case studies. As a result, a new RP technique capable of overcoming the stated restrictions should be developed. The new RP technique should come with the features as follows:

i. Divide stakeholders and experts based on their backgrounds during data collection. Create separate data collection platforms for each group, such as stakeholders and experts. Use expert knowledge to develop standard criteria for measuring each characteristic. Ensure that the platforms are connected to avoid bias and erroneous.

ii. Implementation of flexible algorithm for decision-making that works with multiple case studies. Use generic attributes of appropriate range which involve stakeholders and experts to determine priority values, which helps to address issues with rigid RP techniques.

6. DISCUSSION

The overview provides information on RI and RP research and explains how RI is applied in existing RP techniques. RI aims to ensure a successful project without requirements management issues. The study concludes that RI is essential for identifying and determining project requirements. Dependencies are crucial in the RP process to understand relationships between requirements before prioritising them. Even a small mistake in removing a requirement can cause project failures due to its dependency on other requirements. Traceability helps identify these dependencies. Using traceability information, the development team can easily recognize interdependencies across requirements.[52].

In recent studies, twelve distinct RP techniques have been identified and critically analysed, each demonstrating unique objectives, advantages, and limitations. It has been established that the RI element can be effectively integrated into various RP techniques, with three specific RI implementations highlighted in the study. Most RP techniques prefer to represent the dependency between requirements through graphical or graph-based forms, as these methods are generally easier to comprehend. Another prevalent approach involves incorporating dependency as part of an equation, though this implementation varies significantly depending on the specific equation used. These findings underscore the versatility and adaptability of RP techniques in accommodating interdependencies, highlighting the importance of selecting the appropriate method to enhance the effectiveness of the prioritization process.

However, a notable limitation identified across these RP techniques is the presence of bias, which becomes increasingly difficult to mitigate, especially when stakeholders with diverse backgrounds are involved. The challenge of avoiding bias is further compounded by the inherent difficulty in achieving unanimous agreement among stakeholders. Additionally, the adaptability of existing RP techniques has emerged as a concern, as many of these techniques are specifically tailored to the case studies utilized during the research phase. These limitations underscore the need for developing more flexible and universally applicable RP techniques that can accommodate diverse stakeholder perspectives while minimizing bias.

In conclusion, some recommendation is proposed to overcome the limitations of RP techniques as stated where that future research focuses on developing methods that not only overcome these challenges but also incorporate the strengths of existing RP techniques. By doing so, the effectiveness and applicability of RP processes can be significantly enhanced, leading to more successful project outcomes and better requirements management practices.

7. CONCLUSION

This paper aims to thoroughly examine the role of the RI in the RP process. It evaluates how RI impacts RP, reviews existing RP techniques incorporating RI elements, and assesses their methodologies, benefits, limitations, and interdependencies. A SLR approach was employed, following a protocol that includes research questions, search strategy, study selection, data extraction and synthesis, and results.

Initially, research questions were formulated to guide the review, leading to the selection of 38 relevant studies. Data from these studies were analysed to address the research questions. The review findings indicate that RI is crucial for the success and implementation of RP processes. Existing RP techniques with RI elements were reviewed for their methodologies, benefits, and limitations. Identified limitations include user error, inflexibility to different dependency types, overreliance on expert judgment, and the inclusion of irrelevant requirements. These issues underscore the need for further investigation and improvements in RP techniques, specifically focusing on enhancing the RI component.

ACKNOWLEDGEMENTS

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APPENDIX

See Table 6.

Table 6. Analysis of the RP Techniques in terms of their RI approach, benefits, and limitations

Technique	RI implementation	Benefits	Limitations
Collaborative Dependency-Based Ranking (CDBR) [36]	Dependency flow graph	• Capable of producing accurate requirement ordering based on the collaborative effort of both stakeholders and developers, which considers the execute-before-after dependency relation among requirements. • Reducing the effort required by stakeholders and developers to compare the requirements	• The algorithms for this technique, especially those related to dependencies, are specific to the case study in question, and the accuracy and reliability for other cases have yet to be confirmed. • Highly depends on the involvement of stakeholders and developers.
Collaborative Method [35]	Dependency is divided into multiple groups, each of which indicates how the requirements are truly connected to one another, whether entirely, partially, or inferred where the indirect dependency between requirements exists	• Capable of reducing conflicts between stakeholders and developers while deciding on requirement priority values	• User error might occur when the stakeholders involved in the RP process do not fully understand the definition of RP, as well as the flow of the RP process in this technique
DRank [39]	Dependency graph based on contribution dependency and business dependency	• PEAT was elected as a ranking criterion to make the process simpler and more fully operational. • RankBoost was used to calculate the SubjRP based on stakeholder preference was to alleviate the difficulties of evaluating the requirements. • The PageRank algorithm was developed to assess requirement dependencies, allowing objective dependencies to be automatically converted into partial order relations.	• Does not work well with other types of dependencies aside from contribution dependencies and business dependencies

		• An integrated RP method was developed to reconcile the subjective preferences of stakeholders with the objective requirements dependencies to make the RP process more reasonable and relevant.	
Improved Highly configurable system (HCS) [40]	Dependence become a comparison factor in prioritising requirements.	• The RP process done by separate the requirements into different categories and complete the evaluation by specific criteria such as Time, Cost, Complexity, Criticality, and Dependency.	• Not flexible since the result obtained from one case study only
Interactive Requirements Prioritization [41]	Dependency (Dep) graph based on the dependency hierarchy for both IGA and SMT	• Increase optimization during RP process which lead to result accuracy. • Reduced the number of elicited pairs, which resulted in improved handling of the scalability issue.	• Totally rely on expertise during the ranking process, which only considers user knowledge if there are ties in disagreement value.
Intuitionistic Fuzzy Approach (IFS) [42]	Dependency graph	• Consider both stakeholders and developer input without ignore dependency element	• Biased problems may arise because of stakeholders' lack of competence in this area.
Majority Voting Goal-Based Approach (MVGB) with Vertical Binary Search [49]	Dependency used in terms of level values for each requirement for the priority values equation	• The RP process can be completed in short of time and suitable for large number of requirements • Very efficient and systematic when comes to calculating the priority values of requirements.	• The judgment throughout the RP process is heavily dependent on stakeholders, which can introduce biases and uncertainties. This is due to the limitations in stakeholder knowledge regarding the RP process.
Mathematical Programming Technique [43], [55]	Dependency ratio	• Has restriction that only allow the be selected and released unless its predecessor has been selected first.	• Too complex to implement
Multi-Aspects Based Requirement Prioritization Technique [44]	Dependency is classified as either directly or indirectly dependent on each other based on the Technical Aspect and the Business Aspect.	• Improves the decision-making quality for the application of the business and technical aspects for RP process	• The existing techniques have been evaluated, and the findings demonstrate that a few techniques are parallel in functionality but complex in the application
Novel Collaborative Requirement Prioritization Approach [45]	Dependency flow graph	• Capable of providing the best support issues of collaboration, dependence, and the role of initial preferences of both stakeholders and developers	• User error may occur if stakeholders are not well-versed in RP, as the ranking process is entirely dependent on stakeholders. • Not suitable for projects with fewer requirements dependency.
Quantitative study of RP criteria using model ordinal data [50]	Dependency classified as one of criterion by represent it as “Yes” or “No” option	• Suitable for project with large number of requirements • The criteria used are not fixed and can be adjusted according to the specific development phase.	• The content is lacking for other case studies which cause the validity to be uncertain. •
Software-Supported Requirements Prioritization in Distributed Scrum Projects [46]	A graphical representation of requirements in terms of dependency and the hierarchy of requirements	• Recognising interdependence between requirements on overall features or epics, as well as release date deadlines, allows users to stay on track with the release plan and product roadmap.	• Time-consuming

Software Requirements Prioritization Method Based on Qualitative Assessment and Cost-Benefit Prediction (OurRank) [47]	Employ appropriate elements based on the discovered relationship between requirements during decision-making process.	• Permits for the prioritisation of elements with more similar criteria and can be utilised for contrasts between elements with the same priority.	• Experts' social contact might lead to the sunken costs fallacy or confirmation bias. • There is no assurance that the results will be the equivalent if executed by other teams.
Value-Based Requirements Prioritization Technique (VBRP)[48]	Calculate the distance between requirements that are linked to each other.	• Able to provide a clear picture of priorities in remarkably less time by performing multiple- criteria decision analysis (MCDA) and suitable for large number of requirements.	• Introduce irrelevant requirements/test case during rank reversals which cause the priorities of the existing items to change and may lead to a different prioritization ordering altogether

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