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Guideline for the Selection of Requirement Prioritization Techniques in Agile Software Development: An Empirical Research

Najia Saher, Fauziah Baharom, Rohaida Romli

Abstract: ***Prioritization is an essential process in any software development. Moreover in Agile, Requirement Prioritization (RP) needs more formal process because it is difficult to maintain priority after requirement change. Changes in the priority list are a continuous process in Agile Software Development (ASD) hence, the ignorance of critical requirements during prioritization will result several problems like unsatisfied client and poor quality of product. Moreover, there is little empirical knowledge on the state of the practice and contemporary problems exist in choosing best prioritization technique after the requirement change in Agile. To achieve this objective a guideline for the selection of RP technique is needed. Hence, the empirical research is used as a methodology for the evaluation of the requirement prioritization techniques practiced in Agile. The aim of this study is to determine RP techniques used in software industry and identify aspect or evaluation criteria to choose the best RP technique according to the environment. This study conducts an empirical study of requirement prioritization after requirement change in Agile, based on the responses from 137 Agile software practitioner representing around 31 organizations in Pakistan. The results reveal the main decision makers in the process of RP, prioritization technique after requirement change in Agile with the evaluation criteria and aspects to perform requirement prioritization. These findings will serve as a foundation to provide a guideline for selecting suitable requirement prioritization techniques in Agile which can help software practitioners to choose appropriate prioritization techniques during the process of requirement change in Agile.***

Keywords: ***Agile software development, Empirical evidence, Requirement change management, Requirements prioritization.***

I. INTRODUCTION

Requirement prioritization has a significant importance in Agile software development. The process of requirement prioritization has been used to determine which candidate requirements should be included in a certain release. Prioritization helps to identify the most valuable requirements by considering the time and cost constraints. The critical and most important requirements are prioritized first to gain maximum benefits [1].

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* Correspondence Author
Najia Saher*, Department of Computer Science & IT, The Islamia University of Bahawalpur Punjab, Pakistan. Email: najiasaher@gmail.com
Fauziah Baharom, School of Computing, Universiti Utara Malaysia, UUM, Kedah, Malaysia. Email: fauziah@uum.edu.my,
Rohaida Romli, School of Computing, Universiti Utara Malaysia, UUM, Kedah, Malaysia. Email: aida@uum.edu.my

Moreover, to accomplish projects on schedule, practitioners usually trade-offs between conflicting requirements. Hence, requirements prioritization is one of the solutions, which could be used by the practitioners to manage these trade-offs [2].

There is a prominent difference in the process of requirement prioritization between traditional and Agile Requirement Engineering (RE). In traditional RE the requirements are typically prioritized once however, requirements are prioritized in each iteration in Agile. Moreover, in Agile RE, prioritization is based on single factor of business value as defined by customer whereas, in traditional RE, many factors e.g. cost, risks, implementation dependencies and business value are considered in the process of requirements prioritization [3]. There are numerous prioritization techniques presented in literature, nevertheless these prioritization techniques still suffering the issues such as scalability, complexity, uncertainty, and time consumption [4].

In Agile software development the process of prioritization is continuous due to the iteration and the welcoming nature of requirement change to gain customer satisfaction. However, this continuous requirements reprioritization can lead the project towards instability if the process of continuous requirement reprioritization has not managed thoughtfully [5]. In Agile, requirements can be changed and prioritized even late in the development due to the high priority of customer satisfaction throughout the lifecycle in ASD [6]. Customers and developers identify new requirements and modify priorities as customer desires, hence requirements are prioritized before each iteration [5].

Therefore, the main purpose of this paper is to highlight the strengths and weaknesses of the existing requirement prioritization techniques commonly used in Agile and provide an empirical evidence to identify aspect or evaluation criteria to choose the best RP technique. The rest of the paper is organised as follows: Section II provides related work and provide an overview of requirements prioritisation techniques with its strengths and weaknesses. Section III defines the research design with study objectives and questioner design. Section IV represents data analysis and findings of the result whereas the discussion is provided in section V. At the end, Section 6 presents the conclusion of the paper.

II. RELATED WORK

Prioritization in Agile is considered as a crucial process that determines the success of the project. Hence, the ignorance of criticality of user-stories can result in several problems like unsatisfied client and poor quality of product [7].

The following subsections overview the studies related to the requirement prioritization techniques and models in Agile software development which is followed by the strength and weaknesses of the prominent RP techniques.

A. Overview of Requirements Prioritisation in ASD

In ASD prioritization is success critical and at the same time hard to create and maintain and requires a more formal process. As the priority list changes, there is a lot of changes that leads towards rework [8]. The process of requirement prioritization in Agile is exercised in every iteration due to the nature of welcoming changes in requirement. Moreover, in Agile the only consideration or evaluation criteria to perform prioritization is a business value as mentioned by numerous researchers [9], [10]. The following studies focused on requirement prioritization in Agile that has been depicted in Table I.

Table- I: Studies related to Requirement Prioritization in Agile

Studies	Purpose of Study	Outcome
[11]	Introduced value based SE principles. As diverse stakeholders prioritize differently according to the value of requirement by their own point of view.	Identify several core values of prioritization by increasing overall stakeholder satisfaction and reducing project risk.
[5]	To derive a conceptual model to understand the inter-iteration prioritization from client's perspective.	Identified 15 RP techniques with their basic idea and context of use in Agile.
[12]	Construct a conceptual model to understand the prioritization process in Agile iteration using grounded theory.	Delivered 2 models; one model defines the artefacts of the Agile RP process and second model explains the conceptual categories for making decision in prioritization.
[7]	Described the limitation of existing Agile prioritization techniques and derive the factors for the prioritization of medium and small project.	Derived two factors that impact the prioritization of user-stories e.g. importance and effort.
[13]	Proposed hybrid model consists of several requirements prioritization techniques such as Cumulative voting, Numerical analysis, AHP, Top 10 requirement, MoSCoW for the sprint in case Scrum for Agile software development.	To overcome the lack of influencing factors in Scrum Sprint, requirements were prioritized based on the influencing factors of value, cost, risk, time to market and by considering the effect of non-functional requirements over functional requirements.

According to Hoff, Fruhling, and Ward (2008) [11] there are numerous essential values that should be considered in terms of importance and relevancy to prioritized requirement successfully. Moreover, Racheva, Daneva, and Buglione (2008) discussed 15 techniques used in Agile prioritization with their basic idea and context of use [5]. Later, in 2010 Racheva, Daneva, Herrmann and Wieringa, presented two conceptual models and emphasise on the five aspects such as business value, effort estimation and size measurement, risk, learning experience, and external change should be consider when making decision on requirements prioritization [12]. Furthermore, Popli et al. (2014) presents the drawback of MoSCoW, walking skeleton and validate learning as these methods are not very effective due to the lack of providing importance of user's stories [7]. In 2017 Asghar, Tabassum, Bhatti, and Jadi, proposed a hybrid model by considering the prioritization factors and the effect of non-functional requirements on functional requirements [13].

As summarising the studies in Table I, it has been concluded that there are several frameworks and conceptual models have been proposed in literature without any concrete solution provided and any consensus on a use of prioritisation technique(s).

B. Requirement Prioritization Techniques

This section, summarize and review the various techniques on requirement prioritization. A comprehensive review has been conducted to explore the existing techniques [14]. Although there are several techniques exist and are under practice however these 11 techniques have been extensively practiced in industry for Agile environment. Therefore, for the better understanding about the existing requirement prioritization technique, it has been explored with their respective strengths and weaknesses. Requirement prioritization techniques with their strengths and weaknesses are mentioned in Table II.

Table-II: Requirement Prioritization Techniques in Agile

Prioritization Techniques	Strength	Weakness
Value-Oriented Prioritization (VOP)	• Organization business value is the main concern in VOP [15].	• Not appropriate for larger project. • Ignores requirement dependencies [15].
Quality Functional Deployment (QFD)	• "Voice of the customer". • QFD is a structured methodology which prefers customer needs [4].	• Scalability issue and inconsistencies. • Preferable to be applied in small systems.
Pair Wise Analysis	• Informal criteria for comparing option, thus its judgments based on the participants' experiences [15].	• Complicated, tedious, and provide unreliable results. • Facing limitation in scalability [15].
Planning Game	• PG has an enhanced modification of numerical computation which is very fast and easy to complete the process of prioritization [16].	• Scalability issue, unable to provide the firm result as the number of requirements increases [17].
MoSCoW	• Consistent and very easy to use. • MoSCoW can handle large number of alternative [18]. • MoSCoW is easily scalable [18].	• Lack of grading within categories. • Better suited to product with less customers [19].
Kano Model	• Kano model is the fastest way to prioritize requirements [20]. • Kano is more concerned to the customer "Trustworthiness" and customer preferences.	• It is not for suggesting new product features. • It can only be used for analysing the effects.
Cumulative Voting	• Simplicity of the approach [18].	• Difficult to evaluate the relative priority difference among requirements [15]. • Not scalable [1].
Cost-Value Ranking	• Ability to combine both value and cost of requirements for implementation [21].	• Un-scalable and Time consuming [21]. • Difficult to manage interdependencies as the requirements due to the increase of computational complexity [15].
Binary Search Tree (BST)	• Highly scalable and very fast [22].	• BST comparison is ordinal just shows which requirement is more favourable [22]. • BST is only a simple ranking of requirements that does not assign any priority values [17].
Analytic Hierarchy Process (AHP)	• Provide most reliable result [4]. • Ability to resolve conflicting objectives.	• Scalability issue hence problematic for larger project [21]. • Time consuming when number of requirement increases [17].
Wiegers' Matrix Approach	• Matrix prioritization is easily scalable and based on several criteria (benefit, penalty, cost, and risk). • Spreadsheet auto-calculates the priority values and very easy to conduct.	• It can be easily manipulated by stakeholders to accomplish their objectives [17].

These requirement prioritization techniques are discussed in detail in the study by Saher, Baharom, and Romli (2018) in [23].

III. RESEARCH METHODOLOGY

The overall objective of the effort is to use survey research of the industrial status-quo regarding the use of requirements prioritization in ASD. Despite 49 RP techniques identified in Systematic Literature Review (SLR) conducted by Achimugu et al. (2014) [4], there are still a lack of rigorous empirical research regarding the critical process of requirements prioritization in ASD projects. Therefore, this research provides the guideline to select suitable RP technique, based on the evaluation criteria or aspect related to RP techniques.

The next subsection will present the research objectives of this study. Firstly the research objective is defined that is followed by the instrument designed in the following subsection.

A. Research Objectives

This study aims at understanding the state of practice of requirements prioritization approaches in Agile projects. The overall objective of this study is to select the suitable technique of prioritization after the process of requirement change in Agile. This cannot be exhaustive as there are too many potentially relevant aspects of prioritization in Agile requirements engineering. The objective of this study is formulated and shown in Table III to steer the design of this study.

Table-III: Research Objectives

Research Objectives	
RO1	To determine the decision-makers in the prioritization process.
RO2	To examine the prioritization technique being used to prioritize requirement after requirement change in Agile.
RO3	To investigate the aspect or evaluation criteria used to perform decisions during Agile prioritization.
RO4	To determine the most appropriate requirement prioritization criteria for the selected prioritization techniques.

The first objective aims at understanding who is the decision maker in the process of requirements prioritization in Agile projects. The second research objective, aims to gather knowledge about the choice of requirements prioritization technique(s) by software practitioner in actual situation. Once the technique is formulated then further this study understand the aspect or evaluation criteria practitioners prefer to choose RP technique and finally the mapping or link between the RP technique with aspect or evaluation criteria.

B. Instrument Design

An exploratory study was conducted on the current practices of RP techniques used by Pakistani's software practitioners. More specifically, the objective of the study is to select the suitable technique of prioritization during the process of requirement change in Agile. The exploratory study was conducted using the quantitative approach, which is survey research [24]. The questionnaire was developed in accordance with the study objectives and the construct of the questionnaire is represented in Table IV. The non-probability sampling was used in this study, which is the purposive (judgmental) sampling. The purposive sampling comprises of the selection of unique sample with important features [25]. The purposive sampling is also called judgment sampling, which is the deliberate choice of a participant due to their willingness and the qualities the participant possesses to provide the information [26]. The sample was chosen among the software practitioners in Pakistan with minimum three years of experience working in Agile development backgrounds and culture.

Table-IV: Questionnaire construct and unit of Analysis

Section	Unit of Analysis and Type	Sources
Demographic	a. Position in the company (SC)	[27], [28]
	b. Years of experience in software development (SC)	
	c. Sector of organization (SC)	
Agile Knowledge and Experience	a. Agile experience (SC)	[27]
	b. Agile team member number(SC)	
	c. Agile methodologies used (MC)	
Requirement prioritization	a. Decision makers (MC)	[12], [29], [30], [31]
	b. c. Prioritization techniques (MC)	
	d. Evaluation criteria(MC)	
	e. Evaluation criteria with techniques(MC)	

SC = Single Choice, MC = Multiple Choice.

The instrument was pilot tested to ensure it is not too lengthy. The questionnaire was validated through experienced researchers. Later, the changes were implemented in the questionnaire based on the feedback [32]. Furthermore, the reliability is the ability of an instrument to measure its consistency. To check the reliability of an instrument, Cronbach's alpha, was used to measure of reliability [33].

IV. DATA ANALYSIS AND RESULTS

This section presents the results regarding the general information about the requirement prioritization in terms of decision maker in RP process, commonly used RP techniques in Agile and the aspect of choosing RP techniques. Cronbach alpha can be estimated by statistical analysis using SPSS. Its value can range from 0 to 1, where 0 signify the questionnaire is not reliable and 1 represent absolutely reliable questionnaire. Cronbach's alpha, reliability coefficient ranging from 0.70 to 0.95 is considered acceptable reliability in SPSS [34], [35].

Moreover, the total number of questions or items in the questionnaire was 51 including 11 items related to demographic variables and 40 testing variables. Therefore the Cronbach's Alpha of item 40 is 0.812 as depicted in Table V.

Table-V: Pilot Test Result

Cronbach's Alpha	Cronbach's Alpha based on Standardize Items	No. of Item N
0.812	0.826	40

A. Decision maker in Prioritization in Agile

The first objective aims to highlight the main decision maker in the process of requirements prioritization in Agile projects. Table VI and Fig 1 depicts that product owner (65%), and project manager (56%) are the main decision maker during the process of requirement prioritization followed by clients (48%), and team leaders (32%). The rest are development team (8%), and consultants (5%).

Table-VI: Decision makers in prioritization process

Decision makers in prioritization process	Percentage%
Product Owner	65%
Project Manager	56%
Client	48%
Team Leader	32%
Development Team	8%
Consultant	5%

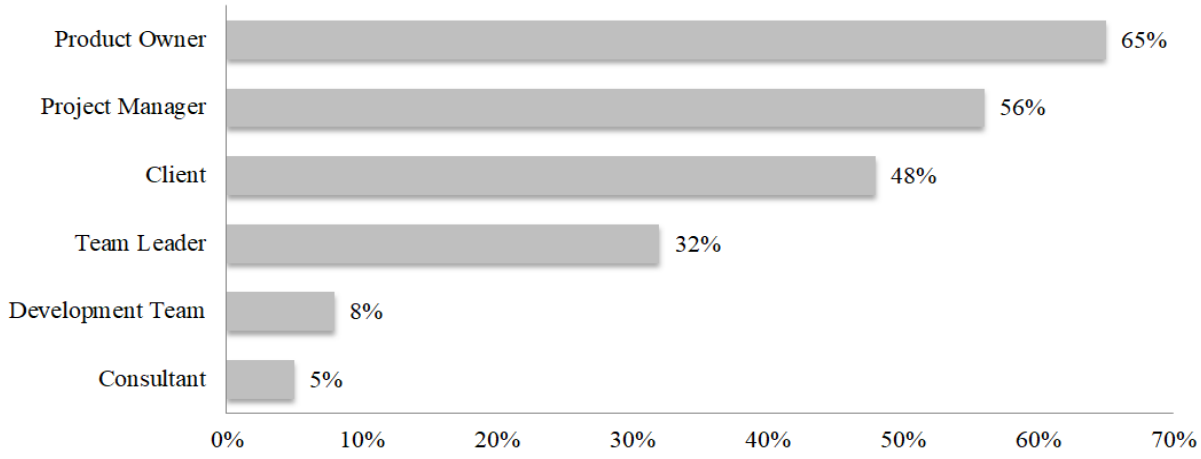

Fig. 1. Decision maker in Requirement Prioritization

B. Prioritization technique(s) used by practitioner in Agile

Furthermore, the respondents were asked about the prioritization technique that is being used by the practitioners after requirement change to re-prioritize the requirements. Multiple answers were allowed in this question. It is apparent in Table VII that most of the practitioner's prefer cost value ranking (51%), followed by Value Oriented Prioritization-VOP (36%), Cumulative Voting (32%), MoSCoW (29%), Planning Game (24%) Analytic Hierarchy Process (AHP) (21%) and Quality Functional Deployment (QFD) (21%). The rest of RP techniques used were Binary Search Tree (BST), Kano Model and Pair wise analysis. In other prioritization technique (3%) stated that they do not use any formal RP techniques also depicted in Fig 2.

Table-VII: Prioritization Technique(s) used by Practitioner

Prioritization technique(s) used by practitioner	Percentage %
Cost-value ranking	51%
Value-oriented prioritization (VOP)	36%
Cumulative Voting	32%
MoSCoW	29%
Planning Game	24%
Analytic hierarchy process (AHP)	21%
Quality Functional Deployment (QFD)	17%
Binary Search Tree (BST)	8%
Wiegers' matrix approach	7%
Kano Model	5%
Pair wise analysis	4%
Other Prioritization Technique	3%

C. Consideration of Prioritization Evaluation Criteria during Agile Prioritization

The respondents were asked about which aspect or evaluation criteria they prefer in selecting PR techniques. The most preferable aspect are customer preference (61%), business value (50%), reliability of result and strategic importance (35%), complexity/ ease of use and voice of the customer (32%), time consumed (30%), cost (26%), benefit (21%), consistency (18%), penalty (12%), technical risk (11%), and judgments on participants experiences (2%). Table VIII and Fig 3 shows the analysis result.

Table-VIII: Prioritization Evaluation Criteria/Aspects

Evaluation Criteria/Aspects	Percentage %
Customer preference	61%
Business value	50%
Reliability of result	35%
Strategic Importance	35%
Complexity/ Ease of Use	32%
Voice of the customer	32%
Time consumed	30%
Cost	26%
Benefit	21%
Consistency	18%
Penalty	12%
Technical risk	11%
Judgments on participants experiences	2%

D. Prioritization Evaluation Criteria w.r.t Prioritization Techniques

According to the respondent's perception, the most appropriate requirement prioritization criteria for the selected prioritization technique are illustrated in Fig 4. It will be further discussed in the next section.

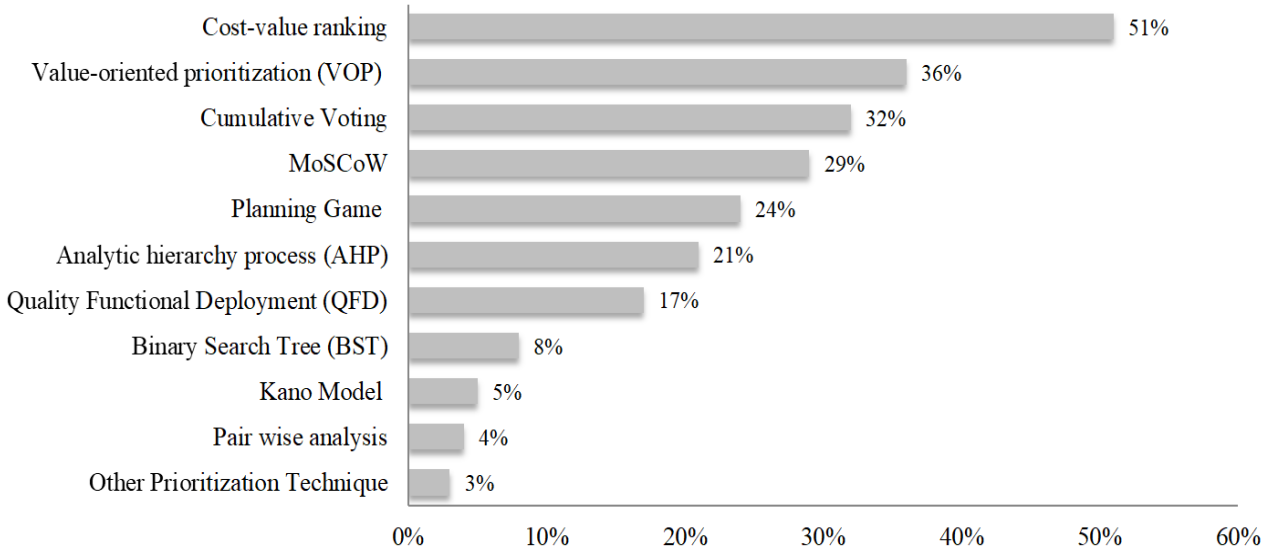

Fig. 2. Requirement Prioritization Techniques used in Agile Software Development

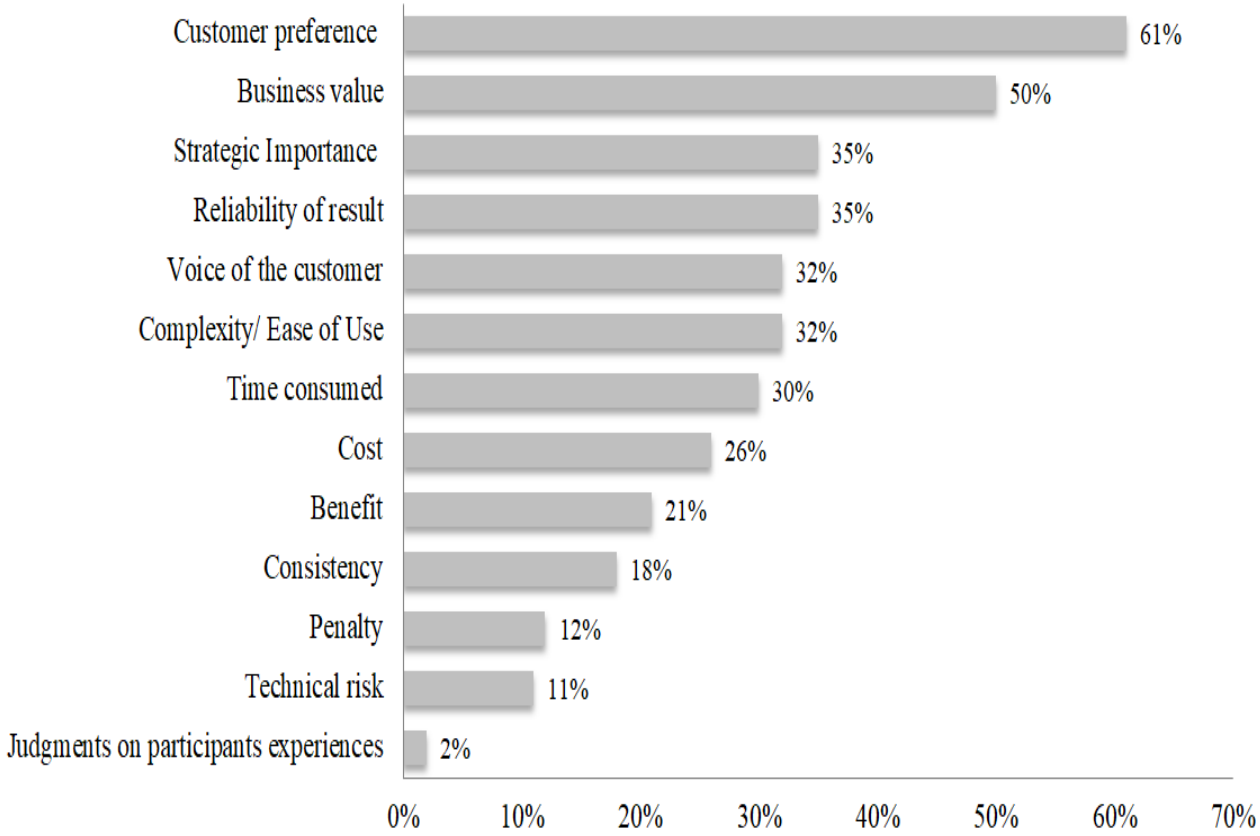

Fig. 3. Prioritization Evaluation Criteria in Agile

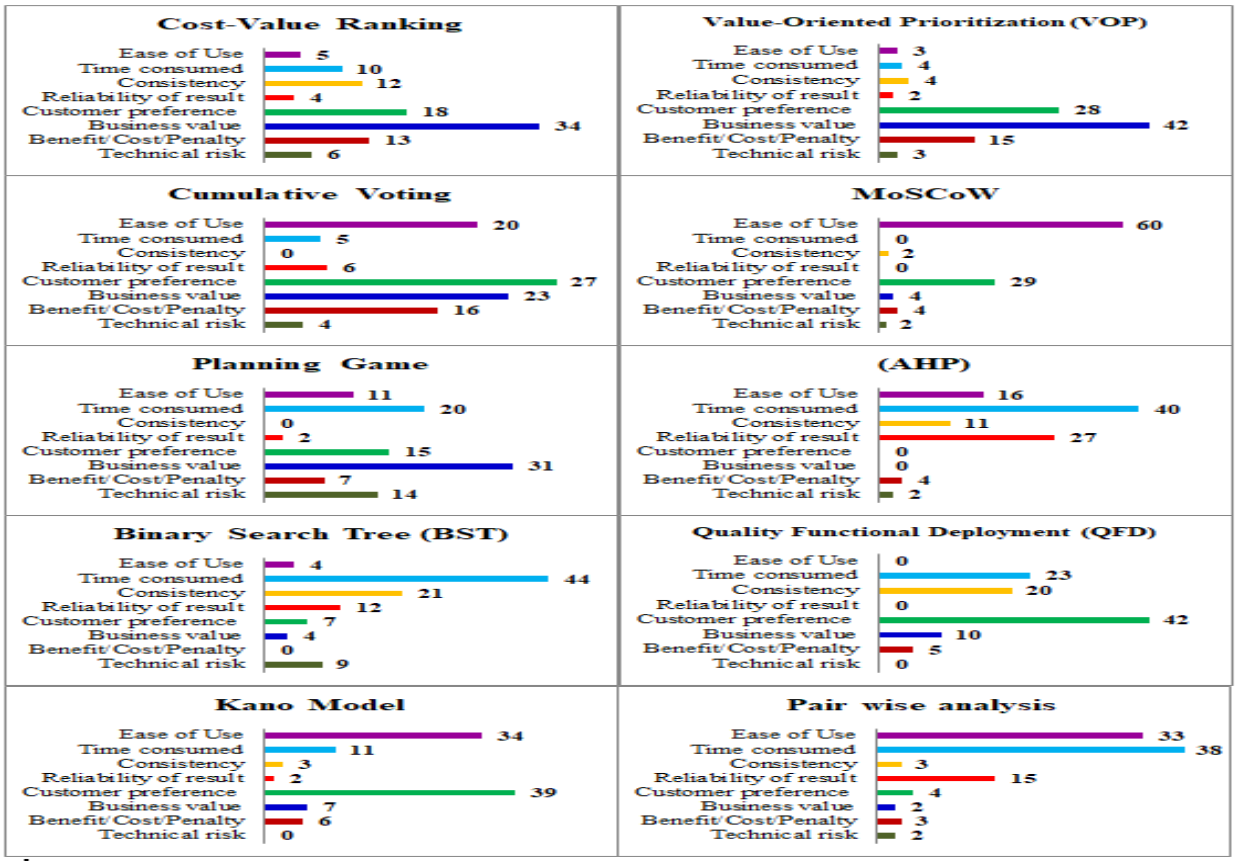

Fig. 4. Prioritization Evaluation Criteria for selected Prioritization techniques

V. DISCUSSION

The overall objective of the effort of this exploratory study is to gain the insight of the industrial status regarding the use of requirements prioritization in ASD. Generally, this paper reviewed about the strength and weaknesses of several prioritization techniques.

The first objective reveals that the product owner and project manager plays an important role in the process of requirement prioritization. Nonetheless, the development team and developers opinion should be considered in the process of making decision about requirement prioritization as developers possess knowledge both in development and in the respective subject domain.

The second objective intended to find out the prioritization techniques being used by the software practitioners. Hence, from the survey the RP techniques like cost value ranking (CVR), value oriented prioritization-VOP, cumulative voting, and MoSCoW were the most desirable and eminent RP techniques used to determine requirements prioritization with greater value to business successes. The cost value ranking technique is most suitable in Agile due to the consideration of cost and value. Moreover, according to Thakurta (2013), it is favourable for the less number of requirement because the computational complexity increases in managing interdependencies as the number of requirements increases [15]. Similarly, the value-oriented prioritization technique was proposed by Azar, Smith, and Cordes (2007) [36] in which requirements are prioritized based on their business value to the organization or stakeholders. Moreover, cumulative voting is a ratio-scale RP technique to determine the main requirements according to the degree of importance by distributing 100 points. Cumulative voting is best in Agile as it is not suitable for large number of requirements [1].

The third objective sought to determine a set of key factors or aspects of requirement prioritization. The key aspect or evaluation criteria in Agile software development from the survey result were customer preference, business value, reliability of result, ease of use, time consumed, consistency, cost, benefit, penalty, technical risk and judgments on participants experiences.

The fourth objective intended to determine the most appropriate requirement prioritization criteria for the selected prioritization technique as referred in Fig 4. For instance cost value ranking is favourable in case of business value, customer preference and time consumed. Similarly, for VOP is the choice in case of business value, customer preference. In conclusion the RP techniques such as cost value ranking, VOP, cumulative voting, and planning game, are the favourable choices of practitioners due to its business value and customer preferences. However, QFD and kano model is considerable in case of customer preference alone. Moreover, cumulative voting, MoSCoW, kano model, and pairwise analysis are the choice due to its ease of use. However, AHP, Planning Game, QFD and pair wise analysis are reported as the most time consuming RP techniques.

VI. CONCLUSION

Requirement prioritization is very important and influential factor in software development and hence, it becomes more critical during the process of requirement change in Agile. This paper reviewed the current requirement prioritization techniques practiced in Agile software development with the empirical evidence. Moreover, the strengths, weaknesses of well-known prioritization techniques for Agile are identified. The findings from this study are intended to extend abilities of software practitioners to choose the suitable requirement prioritization techniques on the basis of its evaluation criteria during the inter-iteration process of Agile. Thus, companies in the software industry practicing Agile, sought to improve on requirement re-prioritization after the requirement change in ASD. The significance of this study comes from the level of detail with regard to the issue of requirement prioritization on a single dimension of business value as reported by many researchers and due to the lack of empirical evidence in the adoption of RP techniques in Agile [9], [10], [37]. However, the evaluation criteria will be helpful for the practitioners to make a right decision in the selection of prioritization techniques in Agile software development. Hence, better decisions related to prioritization will increase the chance of project success.

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AUTHORS PROFILE

Najia Saher, She is an Assistant Professor in Islamia University Bahawalpur, Pakistan. She gained her first degree in Software Project Management from the NU FAST- National University of Computer and Emerging Science, Pakistan in 2012 and currently doing her Ph.D. from School of Computing, Universiti Utara Malaysia, Her research interest includes Software project Management, Software Engineering, Agile Software Development, Requirement Change Management, and Software Quality.

Associate Prof. Dr. Fauziah Bt Baharom, She is Associate Professor at School of Computing, Universiti Utara Malaysia and holds a PhD in Computer Science. She is actively doing researches in Software Engineering and lead several research grants awarded by Ministry of Education which are
FRGS, ERGS and LRGS. Her area of interest is Software Quality, Software Evaluation and Certification, Service Oriented Architecture, Multi Criteria Evaluation, Agile Requirement Engineering. She has experience in teaching Object Oriented Programming, Software Engineering and Research Methodology in Computing.

Associate Prof. Dr. Rohaida Binti Romli, Rohaida Romli holds a PhD degree in Software Engineering. She is a Associate Professor at the School of Computing, Universiti Utara Malaysia (UUM). Her research interests include automated programming assessments as a part of software verification and testing research area, software engineering, software quality and metrics, programming languages and implementation, and teaching and learning programming methods/strategies (SE/CS education).