

REQUIREMENTS PRIORITIZATION ASPECTS QUANTIFICATION FOR VALUE-BASED SOFTWARE DEVELOPMENTS

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ABSTRACT

Requirements prioritization considered as an important activity in requirements engineering, helps in decision making for software development. Requirements prioritization is performed to select the candidate requirements for different software releases. Different prioritization techniques are available in literature to facilitate experts for requirements prioritization in the industry. It is also evident from the literature that different requirements prioritization aspects are considered to support the process of prioritization. Consideration of these aspects is more worth-fuller in the domain of value-based software engineering where the success of the system depends on the success of software. These aspects are reviewed from literature and summarized accordingly to improve the process of requirements prioritization. Moreover, these aspects are classified and quantified as technical aspects and business aspects based on relevance towards prioritization process. Further efforts are made to validate these aspects and their logical grouping from industry experts through survey. Most of the existing techniques in general and value-based software development in specific missing consideration of these aspects. This research contribution is an effort to highlight and summarize identification and quantification of possible aspects to be a part of requirements prioritization process.

Keywords: Requirements Prioritization, Technical Aspects, Business Aspects, Techniques

1. INTRODUCTION

The term “value” is defined in a different way in the literature. According to Ramzan et al., “the degree of fulfilment of stakeholder ‘s requirements in order of their priority while maintaining the agreed upon commitments and constraints of quality” [1, 2]. In the field of value-based software development, major contributions are made by Kauffman and Barry Boehm. According to Boehm “the explicit concern with value concerns in the application of science and mathematics by which properties of computer software are made useful to the people” [3]. As mentioned in literature, value-based software emphasis on meeting needs of stakeholders for prioritization of requirements, providing decision support, determining the cost, the rate of investment and managerial support. Moreover, processes and services are given more consideration in value-based software [1, 2] [3].

Requirements prioritization is very essential for arranging and selecting requirements in some specific order for a software release. According to Babar et al. “the right requirements are considered as the part and parcel of software quality” [4]. A series

of requirements prioritization techniques exist in the literature to help requirements prioritization process. Each technique is examined with special attention to exploring support for technical aspects. Different techniques like Analytic hierarchy process (AHP), extension of AHP (Hierarchy AHP), Minimal spanning tree, Cumulative voting (CV), extended version of CV (Hierarchical cumulative voting (HCV)), Numeral assignment technique, Binary priority list (BPL), Priority groups, Bubble Sort analyzed for aspects [5] [6].

Most of the existing prioritization techniques partially address requirements prioritization aspects. In AHP, pair-wise comparison is performed [7], Zultner (1997) refers AHP based requirements prioritization technique where priorities are settled by customers and stakeholders. Karlson made a contribution and utilized the concept of AHP in the form of cost-value approach for requirements prioritization [8]. SERUM [9] prioritization technique highlights estimation of cost, benefits of prioritization, two types of risk involved in the process of periodization. Value-oriented prioritization (VOP) is supported by a framework for decision making in requirements prioritization [10].

This is not the end and the list of other contributions goes on and on.

Requirements prioritization techniques consider different factors for prioritization. Selection of appropriate prioritization methods depends on certain constraints that must have cared for prioritization of requirement [4]. Different stakeholders have different meaning for prioritization of requirements, based on their own perception. Such as time is more important as compared to cost to complete the project. Determining the importance of requirements is very subjective and varies from one stakeholder to another [5] [6]. Cost and benefit are two major factors closely associated with each requirement. [6] [7] [8] [9] [10].

Research work is divided into three sections. Section II is about different requirements prioritization aspects related to technical group. Section III shows the detail of a survey conducted in the industry and the responses given by the industry experts. Section IV concludes the whole study.

2. REQUIREMENTS PRIORITIZATION ASPECTS

For software requirements prioritization, key aspects are considered. The requirements prioritization aspects are divided into two major categories of technical aspects and business aspects. Figure 1 show list of aspects related to group of business aspects. These aspects include sales, marketing, competitive, strategic, customer retention, simplicity, innovative, resourceful, client focused and availability. These aspects are highly important and must be given weight for prioritization of requirements [5]. The success of software developed for the domain of value-based software depends on the inclusion of these aspects as a part of the prioritization process. An early effort is made and proposed technique for prioritization of requirements based on multiple aspects. Proposed technique includes aspects which are explored from literature. A list of aspects contains sales, marketing, competitive, strategic, customer retention, simplicity, innovative, dependencies, resourceful, client focused, friendly in term of use, customer success, benefit, value, performance, business growth, security, availability and business risk.



Figure 1. Business Aspects For Requirements Prioritization [5]

1.1. Technical Aspects

The whole prioritization process depends on Different aspects. In the literature, alternative terms are available to denote the notion. Most reported terms are ‘element’ [6], ‘factor’ [7], ‘criteria’ and ‘parameter’. Aspect are defined as a "property" or "attribute" [8]. Aspects explored and reported in the literature are shown in Figure 1 which are to be considered as a part of prioritization techniques.

All these aspects are closely associated with each other and any modification may result in a change in other aspects. Requirements prioritization process performed based on these aspects will improve the quality of results [11].

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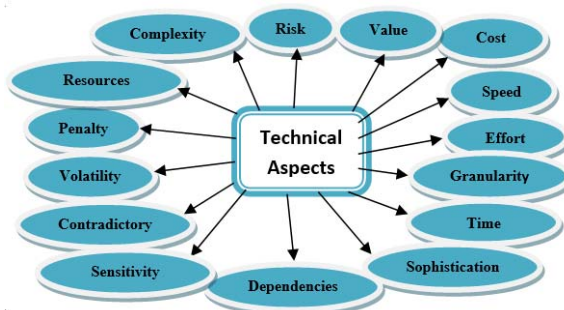


Figure 2. Technical Aspects For Requirements Prioritization [5]

1.1.1. risk

Each project in software development carries different types of risk. These risks are categorized as internal and external and are managed through the risk management process. Internal risk refers technical and market risks and external risks lead to regulatory bodies and external entities associated with projects (suppliers etc.). Many other types of risks exist which causes difficulties for software

development process [9]. These risks include schedule risk, process risk and performance risk. There is a need to calculate project level risk because any given risk usually has an impact on each requirement. Other types of risk that must be considered are a nature requirement as a faulty requirement, the complexity of requirement and unexpected cost of the requirement. Some other reasons for the likelihood of risk in the project are the legal issues, public relation issues and process bottleneck [10, 11].

1.1.2. complexity

The concept of complexity depends on many factors which are responsible for increasing or decreasing the level of complexity in a requirement [12]. A list of factors consists of the amount of time spent on completion of the project, heterogeneity of the organisation, recognition of requirements as functional or non-functional, the skill level of a project team and several stakeholders and their locations. Moreover, project resources play a vital role to handle the complexity of requirements for the success of software development [11, 13].

1.1.3. value

Managing and prioritizing requirements is a difficult process where a value for each process is determined by considering many prioritization aspects [14, 15]. For assigning value to the requirements, different methods are used with different techniques [16]. In a cost-value approach for requirements prioritization, each requirements value is comparable and is assigned on a ratio scale [9]. In AHP requirements prioritization technique, two major perspectives customers and user play a role in assigning a value to the requirements. Cost and value comparison is performed using two dimensions' graph in Cost-value approach for requirement prioritization [9]. In Cumulative-Voting total weights for total requirements remains \$100 and each requirement is assigned a weight to designate its priority [17-19] [15].

1.1.4. cost

Software development organizations measure implementation cost by calculating effort in term of staff hours. Calculation of cost process is influenced by certain measures [20]. These measures include requirements, complexity, code reuse-ability, and the amount of documentation and the volume of testing [21] [22] [13].

1.1.5. speed

While prioritizing requirement, the stakeholder should consider speed as an important aspect. Measures that affect speed include: size of task,

number of persons involved solving the task, and time required to market the product [23].

1.1.6. effort

Another important factor that needs attention is an effort estimation while prioritizing requirements. Usually, the development effort is measured as the amount allocated for staff months to complete the software development process [24]. In software development and maintenance, the process of effort estimation helps to foresee the accurate effort. This issue must be addressed during requirements prioritization process. In the process of effort, estimation difference is calculated between total available effort and effort required for software releases and this job is done by technical and development teams. In AHP, effort estimation is done for all releases of software [15, 17]. The EVOLVE approach is an iterative approach which applies the genetic algorithm in each iteration. This helps in maximizing the overall weighted benefit and estimating efforts for all requirements [18, 19] [25].

Requirements prioritization techniques consider different factors for prioritization. Selection of appropriate prioritization methods depends on certain constraints that must have cared for prioritization of requirement [4]. Different stakeholders have a different meaning for prioritization of requirements based their own perception of importance. For example, sometimes, time is more important as compared to cost with reference to completion of the project. Determining the importance of requirements is very subjective in nature and varies from one stakeholder to another [5] [6]. Cost and benefit are two major factors closely associated with each requirement. [6] [7] [8] [9] [10]. Requirements prioritization takes care of stakeholder viewpoint, as well as implementation and business aspects for the successful development of software.

1.1.7. time

In the software development process cost is calculated by a calculating number of staff hours. Time as an aspect is influenced by many other needs. The scope of these needs covers needs for training, frequency of parallel process in development phase, and development of required supported infrastructure [26] [13, 15].

1.1.8. sophistication

Sophistication is considered as an important aspect for requirement prioritization. Many existing techniques are sophisticated in terms of their use, but how much sophistication is required so far is still difficult to decide. AHP is a requirement

prioritization technique, where a one-on-one comparison is performed against the requirement to determine the priority of each requirement. With the help of this technique, decision makers can easily produce the results and can justify the selection of candidate requirements. Based on its characteristics AHP is considered a complex technique in respect of sophistication [27]. Another technique which is sophisticated in term of sophistication is Numerical assignment [27].

1.1.9. dependencies

Requirements can be prioritized with the help of requirements prioritization techniques and methods. Methods are considered more sophisticated as compare to techniques where aspects are variables are utilized for prioritization process. Requirements dependencies refer to dependencies constraints that should be considered prior to requirements prioritization process. A requirements dependency is one of the aspects which are used for prioritization both by methods and techniques. In the implementation of the requirement, requirements dependencies impact cost and value of requirement [28, 29] [30]. During requirements prioritization process, release planning approaches are helpful to handle requirements dependencies. As a part of release planning, attention must be paid to address critical features and requirements dependencies, otherwise there will be a high risk for increase development time, excess financial burden and loss in market share [31].

Few techniques like SERUM are unable to formally handle dependencies between requirements to support decision making for requirements prioritization. Checking requirements dependencies is the first step before proceeding to requirements prioritization [32]. As a part of release planning, attention must be paid to address critical features and requirements dependencies, otherwise there will be a high risk for increase development time, excess financial burden and loss in market share [31].

1.1.10. sensitivity

Sensitivity analysis is performed by technical teams to establish risk and value for the requirement to include it in a prototype and implementation subsequently [14]. Sensitivity analysis includes scope and impact of changes, managing a portfolio and determining the localization [31]. Different techniques are used in traditional as well business software for evaluation purpose. List of techniques contains Net Present Value (NPV), Internal Rate of Return (IRR), Sensitivity analysis (SA), COCOMO and COCOMO2 [17].

1.1.11. contradictory

Requirements contradictions in requirements prioritization are resolved through negotiation stakeholders [33]. Engagement of several clients and representatives lead to high risk of requirements contradictions in agile software development. Negotiation process helps in handling requirements contradictions and disagreements between stakeholders. Contradictory requirements are also considered as defects which should be taken up as an issue and should be resolved through QA activities. Mostly contradictory issues arise in non-functional requirements as compared to functional requirements and considered as an inherited contradiction among different types of non-functional requirements. Some examples of requirements contradiction include security constraints, performance constraints and usability constraints[18] [19] .

1.1.12. volatility

Volatility is the concept that refers to changes in the requirements. Change in the requirements is the most common practice in software development projects. Change process is handled through requirements change management, considered as an important part of project management. Requirements volatility is categorized as low, medium, high and very high volatility. If the change is less than 1% than its very low, change between 1% and 10% is low, change in the range of 10% and 30% is treated as medium, change ranging from 30% to 50% is declared as high and similarly change above 50% is treated as a very high change [34, 35].

1.1.13. penalty

The penalty is the amount of fine or loss that organization must pay if a requirement is missed for software development. Penalty implies on an organization when it does not conform to implement standards and ignore implicit requirements. Mostly importance of these facts does not matter but their ignorance leads to unsuitability for acceptance of the product in the market [31].

1.1.14. importance

Importance is the most common aspect discussed during prioritization of the requirements and gauged by the stakeholders throughout the prioritization process. Many factors and measures play a role in highlighting the importance of the requirement. These factors include the urgency of requirement from an implementation point of view, the strategic importance of the requirement for the company and the priority of requirement for product architecture. Care must be taken to determine priority based on

the importance of requirement by making an allowance for the mentioned factors. Many factors which contribute to the importance of requirements include code re-usability, complexity, testing effort and value of requirement for customer and organization [8]. According to Carlshamre, only 20% requirement remains independent while the rest of the 80 % are interdependent. Such dependencies lead to an increase the level of complexity to a project plan [33] [13].

Figure 3 shows details about different aspects for requirements prioritization. Literature survey is done covering 17 years time span, starting from the year 2002 and ended at the year 2018. The main purpose of this survey is to extract aspects used by different techniques during the process of requirements prioritization techniques. These aspects include business value, complexity, difficulty level, time constraints, penalty, volatility, dependency, scalability, measuring scale type, approach type, risk, cost, value, sensitivity, contradictory, speed and stakeholder expectation. For each aspect, frequency in literature for approximately the last 17 years is recorded.

Figure 4 shows total responses against each aspect in different years, starting from 2002 and ending at 2018. Business values, stakeholder expectations, requirements values, the risk associated with requirements and requirements dependencies are the most cited aspects required for requirements prioritization process. Similarly, some aspects frequency is very high from 2008 to 2018 in terms of their citation in the literature. This reflects the importance of different aspects as a part of the prioritization process for different prioritization techniques. Although each aspect is important and helpful in determining priority of each requirement in a list. However fews aspects high frequecny in a literaure reflects that it has more weight for consideration in the process of requirements prioritization.

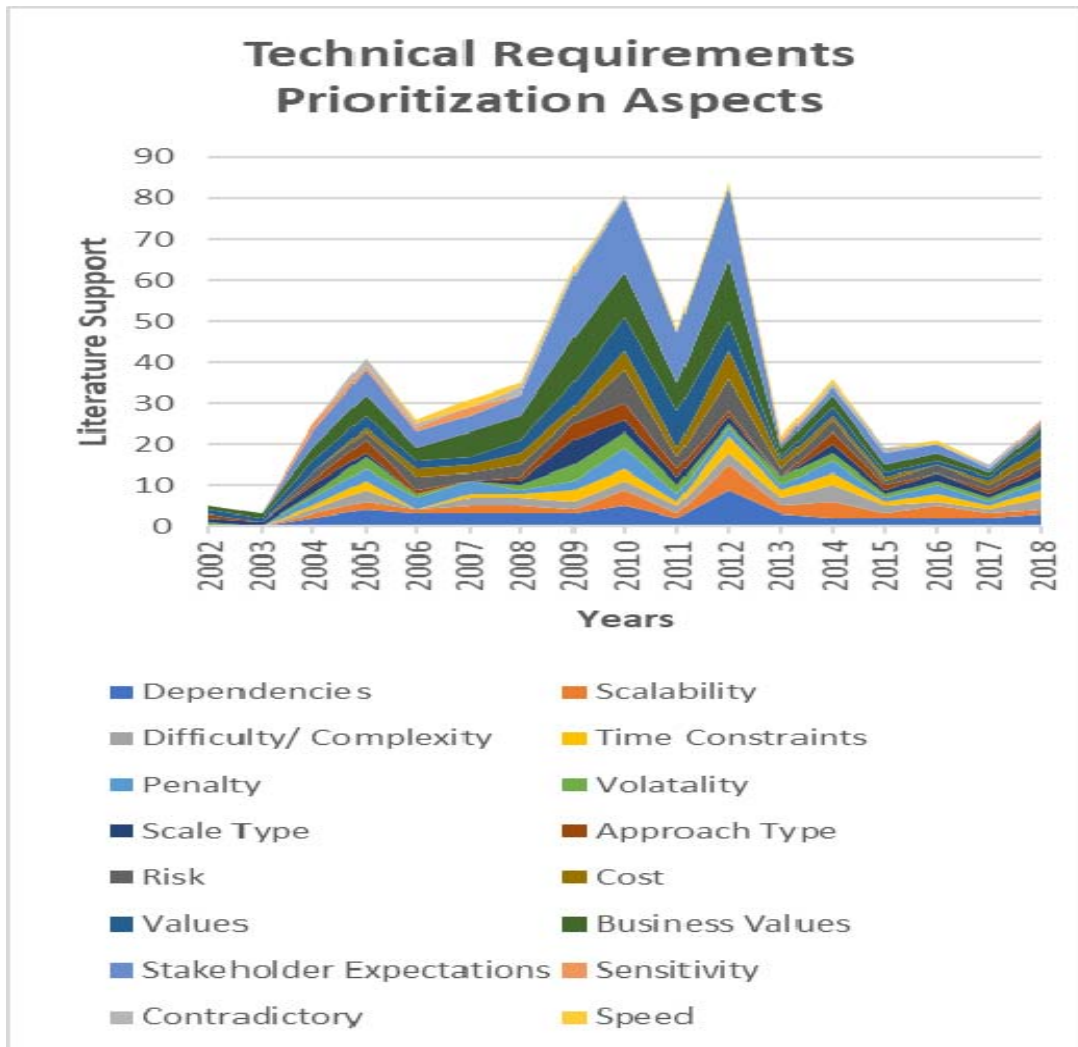


Figure 3. Literature response for aspects for requirements prioritization

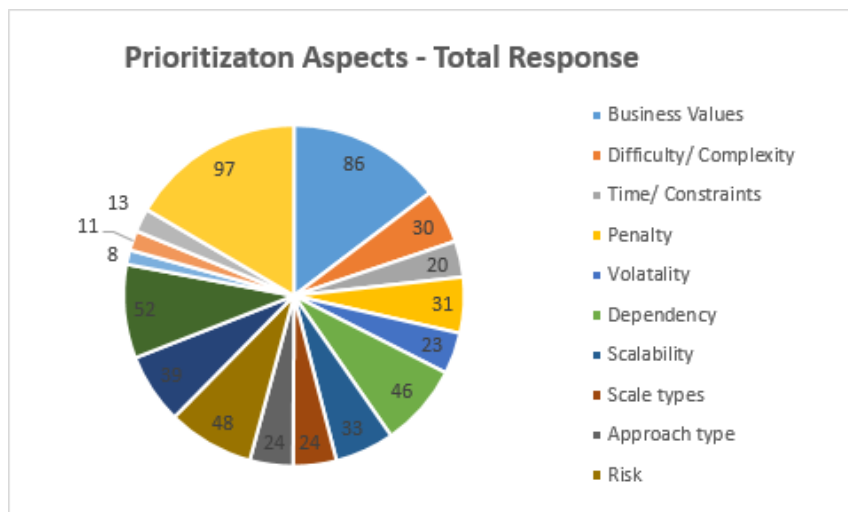


Figure 4. Literature response for aspects for requirements prioritization

3. INDUSTRY RESPONSE - SURVEY

This section contains details about aspects listed in literature and partially considered by existing prioritization techniques in requirements prioritization process. Only extraction of aspects is not enough to justify the use of aspects as a part of the proposed technique. Sampling should be made from industry by conducting a survey to generalize the results. The Pakistan software industry is selected to conduct a survey to validate and generalize the selection of aspects for requirements prioritization. For the completion of the task, three different methods are used which include a questionnaire, interviews and group discussion (meetings). These methods proved helpful and beneficial for getting a reasonable response from the industry experts.

A hard copy of the questionnaire was distributed to different experts in the three major cities of Pakistan. Approaching more than 250 experts, from 80 different software industries, playing different roles in the software industry was a target to pass on the questionnaire. Working experience of all these experts is in the range of 5 to 16 years. Special care was taken in selection of organization based on maturity level in terms of CMM, CMMI and different ISO certification.

Response rate from the respondents for the questionnaire was about 72.40%. Out of 250 distributed questionnaires, 181 experts respond with their views on the asked question.

A semi-structured interview was conducted from 10 different experts from 10 different organizations based on their experience and domain knowledge in the field of requirements engineering and requirements prioritization. The interviews were conducted to know more about aspects, aspects relevance in the prioritization process, and their need for proposed requirements prioritization technique.

Another effective method, group meeting is used to get feedback from a group of software industry experts. Five highly matured organizations were selected to conduct group meetings in three different cities. In each meeting, a group of 5 to 7 experts participated in the discussion and given valuable feedback to support efforts for finalizing aspects of the prioritization process. One more factor kept in mind was the experience of experts and organization in the domain of value-based software development. Most of the projects completed or under development of these organizations were from the domain of value-based software development. Table

1 and figure 5 shows detail of respondents who participated in the survey process. Respondent roles, industry experience and number of respondent detail is necessary to mention here to show the impact of survey response. Another target was to assign weights to each aspect required for prioritization process. Table 2 and table 3 shows details of technical and business aspects identified and quantified for requirement prioritization technique by industry experts. Different data sets are available and used by existing research in the domain of requirements engineering and value-base software system [17, 36, 37]. These datasets contain small, medium and large number of requirements. The ERP system is an enterprise solution package developed to support business activities and business related softwares. Dataset selected for this validation is related to enterprise resource planning (ERP) system, United States based organization providing enterprise solutions [38]. Research scope covers domain of value-based software development; therefore, selection of ERP systems is a reasonable choice for selected data.



Fig. 5 Experts Response For Aspects Required For Prioritization

Table 1. Survey Participants

DEMOGRAPHIC ANALYSIS – SURVEY		
Respondent Roles	Industry Experience	No.
Director	7-15 Years	12
Project Manager	5-15 Years	10
System Analyst	5-15 Years	20
Senior Software Manager	5-10 Years	13
Senior Software Tester	5-12 years	10
Software Quality Assurance	5-10 Years	14
Software Requirements Engineer	5-8 Years	11
Senior Software Architect	5-9 Years	8
Software Auditor	5-7 Years	5
Software Programmer	5-15 Years	12
Software Contents Writer	5-10 Years	5
Manager Development	5-8 Years	9

Implementation Engineer	5-12 years	6	Configurative Management Engineer	5-12 years	5
Functional / Domain Consultant	5-8 Years	4	System Engineer	5-16 years	4
Technical Support Engineer	5-12 years	7	Portfolio Manager	5-8 Years	6
Technical Sales Engineer	5-10 Years	6	Business Analyst	5-12 years	5
Team Leader	5-15 Years	9			

Table 2. Technical Aspects

Requirements	Risk	Cost	Speed	Effort	Granularity	Time	Sophistication	Sensitivity	Contradictory	Validity	Penalty	Resources	Complexity	Total of all Aspects	Technical risk	Net Score	Net Result in points
Weights	8	7	6	8	7	8	6	7	6	7	8	8	6		-8		
R1	7	6	5	7	6	8	5	7	5	7	8	8	6	612	5	652	0.652
R2	8	7	6	8	6	8	6	6	6	7	7	7	5	624	5	664	0.664
R3	7	7	6	7	7	7	6	6	5	6	7	7	5	594	6	642	0.642
R4	8	6	5	7	7	8	5	7	6	6	8	8	6	626	5	666	0.666
R5	8	7	6	8	6	7	6	7	5	7	7	7	6	623	6	671	0.671
R6	8	7	6	8	7	8	5	7	6	6	8	8	5	641	4	673	0.673
R7	7	6	5	8	6	7	6	6	5	6	7	7	5	582	4	614	0.614
R8	7	7	6	7	7	7	5	7	6	7	7	6	6	606	5	646	0.646
R9	8	7	6	8	7	6	6	6	5	6	6	7	5	594	7	650	0.650
R10	8	6	5	8	7	7	5	7	6	7	8	7	6	625	6	673	0.673
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Table 3. Business Aspects

Requirements	Sales	Marketing	Competitive	Strategic	Customer retention	Simplicity	Innovative	Depend	Resourceful	Client focused	Friendly	Customer Success	Benefit	Value	Performance	Business Growth	Security	Availability	Total of all Factors	Business risk	Net Score	Net Result in points
Weights	7	6	8	9	7	8	7	6	7	9	9	7	7	8	9	7	9	8		-5		
R1	5	5	6	7	5	6	5	4	5	5	5	4	5	6	6	5	1	5	692	3	707	0.707
R2	5	6	5	5	5	7	4	4	5	7	6	5	5	6	7	6	2	6	740	4	760	0.760
R3	5	4	3	6	5	6	5	3	5	5	6	5	4	6	6	5	3	4	666	4	686	0.686
R4	6	5	6	7	5	6	4	4	4	5	6	5	5	7	6	5	2	6	726	4	746	0.746
R5	5	5	6	6	6	6	6	5	5	7	6	6	6	6	7	6	6	4	804	3	819	0.819



R6	5	4	4	6	5	7	4	4	3	6	5	4	5	6	5	6	3	7	689	3	704	0.704
R7	6	5	7	7	5	6	5	5	6	7	7	5	6	7	8	6	5	7	855	4	875	0.875
R8	6	5	6	6	6	7	6	4	5	6	7	5	6	7	6	6	5	7	820	4	840	0.840
R9	5	4	3	6	4	6	5	3	5	5	6	6	5	6	5	6	2	7	686	3	701	0.701
R10	6	4	3	5	5	5	4	4	4	6	5	5	4	5	5	5	2	6	638	3	653	0.653
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4. CONCLUSION

To achieve better results for value-based software development, attention must be paid to aspects required for requirements prioritization. Existing requirements prioritization techniques are re-evaluated, and different aspects are compiled. According to the industry experts, selection and classification of large number of aspects will improve the quality of decision making for requirements prioritization. Specially consideration of business aspects is more beneficial for value-based software development. Initial results for identification and quantification of aspects are very encouraging for requirements prioritization process. This research contribution added a list of technical and business aspects. Weight allocated to each aspect and priority weight assigned to each requirement is vital to calculate requirement value to produce priority list. Further efforts are required to generalize the survey by extending its scope to cover multiple countries and different software industries.

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