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A Proposed Requirements Prioritization Model Based on Cost-Value Approach with Collaboration Perspective

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***Abstract*— Criteria analysis in requirement prioritization should always be transparent and holistic to increase the stakeholder's satisfaction. Different stakeholders have their views on the same criteria, making it challenging to agree on a specific set of criterion weights. In software development, collaboration between client and developer is needed for requirements to be achieved. The cost-value approach to determining priority requirements requires a client perspective to determine the value and developer's concept to ascertain costs, then form a cost-value diagram for analysis. Therefore, the research conducted has not been detailed using a cost-value approach involving a client perspective and a developer concept. Usually, the criteria and alternatives weighted by the decision-maker are vague, uncertain, and subjective. Furthermore, using fuzzy numbers help solve different types of uncertainty and conflicting requirements to produce reliable work. This study proposes increasing the weighting of criteria in the requirements prioritization technique, based on cost-value, by doing a collaboration perspective through Fuzzy AHP and TOPSIS using linguistic terms by presenting a proposed model.**

Keywords*— *Requirements Prioritization, Cost-Value, Fuzzy AHP, Fuzzy TOPSIS, Client Perspective, Developer Perspective, MCDM

I. INTRODUCTION

Requirements Prioritization (RP) is a process to determine ranking by assigning priority from one requirement to another. RP is important in any software development methodology including agile [1], [2]. Also, the identified criteria is used to assist the prioritization process. Riegel & Doerr (2015) divides the criteria into six main categories, namely Benefits, Technical Context & Requirement Characteristics, Risks, Costs, Penalties & Its Avoidance, and Business Context [3]. The approach to making prioritization requirements have many criteria being used, usually tailored to the specific situation of software development. Besides using the term, criteria, there are many other terms in the literature, such as Aspect, Element, Factor, and Parameter [4]. Based on Sher et al. (2019), success in value-based software engineering, classifies and measures aspects, to improve process requirements prioritization into two categories, namely technical and business factors. Criteria include in technical categories are: value, cost, risk, effort, speed, time, sophistication, granularity, complexity, dependencies, penalty, resources. sensitivity, volatility, and contradiction. On the other hand, the criteria in the business category are: sales, marketing, strategy, competition, innovation, customer retention, client-focused, availability, simplicity, and resourcefulness [4].

The requirements prioritization process is carried out, by assigning weights to all the requirements, based on several predetermined criteria. All criteria are divided into two categories: beneficial and non-beneficial aspects. Each criterion valued is related to the pre-assigned weightage. The value is considered as positive strength for the beneficial criteria and the negative strength for the non-beneficial [5]. For the beneficial criteria on cost-value, the weightage is interpreted based on the potential candidate requirements' that contributes to the customer satisfaction for the resulting system. The non-beneficial criteria for cost are also implementing successful candidate specifications. The weighting of the criteria is done transparently, and holistically in order to achieve stakeholders' satisfaction [6].

The most basic techniques used for prioritizing requirements based on cost-value criteria are: Analytic Hierarchy Process (AHP) [7], [8]. These techniques are a part of the Multi-Criteria Decision Making (MCDM). There are three major issues in the cost-value approach that are closely related to AHP, which are: scalability, reducing the pairwise comparisons, and stakeholders' bias [9] – [18]. Scalability is defined as the capability to be used by a large set of requirements [19]. Although the requirements increased, scalable techniques are remains as easy to use. Based on the AHP calculations, the reduction of pairwise comparisons will affect the time consumption in the cost-value approach. The stakeholders' bias issue is occurred in the cost-value criteria due to the necessity of involving the stakeholders in the provision of values to the requirements. Stakeholders whose involves in providing values to requirements are advised to exclude any hidden agenda, for values to be accurate.

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Currently, many studies discussed the perspective as an important factor, in the requirements prioritization process [20] – [24]. However, the perspective used is usually generic, including clients, developers, decision-making, value-based, benefit-cost, and technical-business. Specifically, based on cost-value, this research discusses the requirements prioritization, by looking at the perspective of the client and developer. Furthermore, no studies have paid attention to whether collaboration between clients and developers, affects the results obtained, in solving requirements prioritization problems.

In this study, the model proposed is a collaboration between clients that provide weighting and assessment on the value criteria, with developers also providing both on that of the cost. Therefore, fuzzy numbers are used to help solve different types of uncertainty and conflicting requirements.

Furthermore, this study is to be structured into different sections, namely Related work, Proposed model, Result & Evaluation, and Conclusion, with further research work.

II. Related Work

Each requirement has a vital priority weight in calculating values, to produce a priority list [4], [25]. In this case, the requirements prioritization is part of the implementations in requirements analysis. The analysis is observed to be part of the activities in requirements engineering (RE)[26], which is carried out, based on stakeholder preferences [25], [27]. Furthermore, weighting criteria transparently and holistically is a guarantee that stakeholder satisfaction is higher [6]. Therefore, different stakeholders have their views on the same criteria, making it difficult to agree on a specific set of criterion weights.

The criterion weighting problem refers to generating an array of weights from the different varieties, arising from stakeholders. Such issues arise when the decision-maker assigns value to the criteria and then calculates the average. This approach does not have any evidence that the decision-maker knows the need to give particular weight, therefore resulting in subjectivity being a problem [28] – [30].

Based on the cost-value approach, many studies focused on improving the results of weighting criteria, carried out by decision-makers, for requirements prioritization techniques. Therefore, there are several literature studies, related to criteria weighting, in multi-criteria decision making (MCDM).

Khan et al. (2016) is considering multiple stakeholders' points of view and business goals. These views are analyzed by the requirements engineer. This approach is considered as multi-perspective requirements prioritization.

However, it does not explicitly differentiate from the client and developer point of view, regarding the cost-value approach. In Khan et al.'s study, historical data were stored, for selecting the most appropriate and effective prioritization technique, to prioritize a set of requirements, on another similar released system [11].

Hannan et al. (2015), modified the traditional Kano Model, by involving expert opinion, each requirement's weighting, and fuzziness. Stakeholder opinion and specialist judgment of each requirement, became an input for the fuzzy inference system, in calculating the requirements, to become a bias-free classification. The approach being processed is to negate human behaviour, and produce unbiased & neutral results [12]. However, in this study, stakeholders' and experts' involvement are still quite dominant, apart from not differentiating the positions of clients and developers.

Bakhtiar et al. (2015), used AHP and Fuzzy Kano models, to prioritize value-based software requirements. This study's model is divided into three levels, namely Stakeholder, Expert, and Fuzzy logic. In level 1, stakeholders carry out two main tasks, which includes performing the traditional Kano classification of the requirements needed, and giving essential factor for each requirement, using a seven leaked scale. At level 2, experts are involved, by providing an assessment of the Kano classification of stakeholders. The next task is for experts to assign weights of each requirement, using AHP. In this case, the experts should have expertise in the product domain, and be neutral in decision-making. At level 3, experts' assessment, stakeholders' essential factors, and weight-based on AHP are processed by the Fuzzy inference system. This process finally calculates the prioritization requirements, including stakeholder satisfaction, while eliminating human biases, and uncertainty. In this case, the requirement classification is displayed in the form of a fuzzy rule, defined in the Mandani method. Therefore, the set values are fuzzified, using the trapezoidal membership function [9].

Babar et al. (2015) research is introducing Priority Handler (PHandler) that combines three different approaches for prioritizing requirements. They are combining the AHP to neural networks and VIRP (value-based intelligent requirement prioritization) technique. AHP is used to prioritized requirement groups, and to increase the prioritization efficiency [10]. To predict the values of requirement is used the back-propagation neural network. It also reduces PHandler expert biases. The VIRP technique includes three main steps, which are: Requirement elicitation & decision maker's level, Professional level, and Fuzzy logic-based requirement prioritization.

T.C. Wang & Lee (2009) approach is involving the end-users in the decision-making process. This approach is using the modified TOPSIS fuzzy method that is based on Shannon's Entropy theory for weighting the subjective and objective criteria. Moreover, the procedure in TOPSIS is modified where the decision-maker is using linguistic variables. This research provides more information to the decision-makers in order to make wiser decisions [31].

I. M. Ramirez et al. (2017) are developing a tool to make-used of users' feedback. In this study, the process involves a group of expert decision-makers. Then, selected criteria (such as development cost and impact on existing customers) are adjusted based on the preferences of the decision-maker. Two phases involve, which are: (1) Identify the correlation between user feedback and requirements, (2) Driven the requirements prioritization based on the feedback. In the first phase, extract data related to the requirements based on the user feedback analysis. In the second phase, the requirements were prioritized, by explaining the suitability of the aggregated properties based on the users' feedback. The main reason for this process is to:

(1) encourage a profitable interaction with the decision-maker, and (2) combine knowledge from two sources simultaneously [32]. The two sources are preferences from decision-makers and the system functions derived from the requirements.

H. Bendjenna & P. Charre (2012), used the model of Mitchell et al., to classify stakeholders. The use of Fuzzy Choquet integral increases the effectiveness for subjective human evaluation. MCDA is used to provide the priority values for a group of stakeholders. The process is based on the model of Mitchell et al. where the stakeholders used to determine the evaluated criteria. The Choquet integral is used as an aggregation operator. Mitchell et al. model is classifying the stakeholders based on three attributes, which are: the power of the stakeholder has, legitimacy of the stakeholder involvement, and urgency of the project. The case study in this research used four stages in prioritizing stakeholders, (1) The Decision-maker determines the weight of each criterion, (2) The weight of each group is determined, using the λ-fuzzy measure, (3) Assessment of clients based on the criteria, (4) Calculating the overall score, using the Choquet integral [33].

V. Shukla & G. Auriol (2013) presented a methodology for criterion weighting in the context of system engineering projects based on Fishburn et al. This research provides a holistic measure to assimilate diverse criteria weights that coming from distinguished stakeholders. The assimilation is done in order to produce a single criterion using classical preference modeling and to show that all clients are satisfied with the proposed prioritization result. This approach has four steps: Categorization, Preference modeling, Simulation solution, and Generating scores [6].

P. Wang, Z. Zhu & Y. Wang (2016) proposed method is combining the Simple Additive Weighting (SAW) model, Techniques for Order Preference by Similarity to an Ideal Solution (TOPSIS), and Gray Relational Analysis (GRA). It has four basic stages: (1) Experimental design, (2) MCDM evaluation, (3) RSM regression, (4) Decision-making. Then, six detailed steps for the systematic problem-solving process are: (1) Determining the alternatives and criterion level, (2) Experimental design of attribute weights, (3) Experimental design of criterion factors, (4) MCDM evaluation, (5) Construction of response surface regression model, and (6) Ranking the alternatives. This method is using experimental design techniques in decision-making for minimizing the influence of human preferences. The mathematical models were created to assist decision-makers while selecting the conflict criteria. In order to gain the extracted features, diverse MCDM evaluation methods are combined [34].

Based on the research problem in weighting the criteria for requirements prioritization process that involves the prioritization technique used, stakeholder preferences, and the score calculation. We found the limitations of weighting the criteria using a cost-value approach. Thus, this study proposes a new model for weighting the cost-value on conducting requirement prioritization.

III. PROPOSED MODEL

Figure 1. displays the model proposed in the requirements prioritization, called the ReproColla (Requirements Prioritization Collaboration) technique. The purpose of this model is to weight criteria and prioritize requirements, by collaborating between clients and developers.

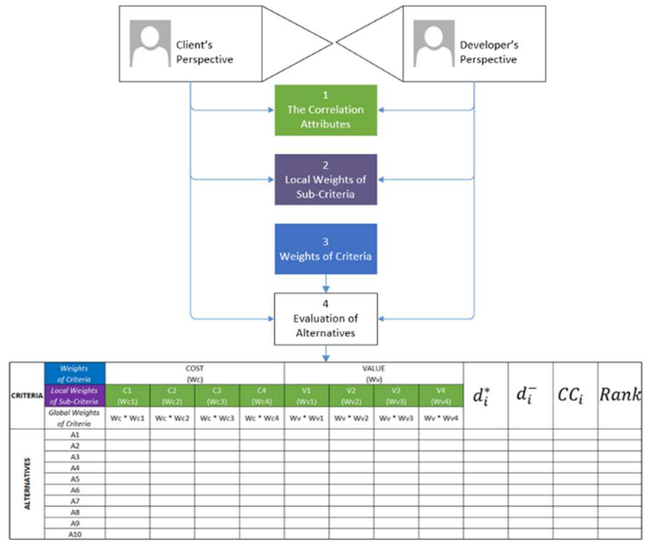

Fig. 1. The model of ReproColla

The ReproColla model consists of four main phases, the details of which are described below.

A. *Phase 1 (The Correlation Attributes)*

The list of attributes in the cost and value category is obtained from the literature review. The client and developer are to choose 8 (eight) attributes from the list provided, which are then used as sub-criteria, in the prioritization process. Table I below, shows the attributes used, based on Riegel & Doerr[3].

TABLE I. THE ATTRIBUTES OF COST CATEGORY AND VALUE CATEGORY

Costs Category	Value Category
Development cost/ effort	Organizational Effectiveness
Documentation cost	Organizational Efficiency/ Productivity Improvement
Functional implementation cost	Operational Risk Reduction
Technical implementation cost	Customer Relations
Testing Cost	Business Innovation
Cost for Fixing Defects Detected During Testing	Marketing Support
Quality (attribute) Implementation Effort	Decision Making
Risk Mitigation Effort / Cost	Communication

B. *Phase 2 (Local Weights of Sub-Criteria)*

The attributes that have been selected in phase 1 will be carried out in a calculation process to determine their weight using FAHP. With pairwise comparisons, clients and developers are comparing each attribute's importance with another using fuzzy linguistic terms. The result of this phase is the local weight for each sub-criterion.

B.1. The overview of fuzzy set theories

When a study requires an uncertain quantitative value, it could use fuzzy numbers. It is used to determine a single value number, where each possible value has its weight between 0 and 1. Thus, fuzzy numbers are expressed as fuzzy sets that define fuzzy intervals in absolute numbers. Fuzzy truth of membership in a vaguely defined set and reject absolute membership (yes or no) [35].

The use of fuzzy numbers is to reduce the types of uncertainty and conflicting requirements during a bid. It is done in order to produce reliable work [36]. The fuzzy rules are used within fuzzy logic systems. The rule is to produce an inference output based on the input variables. This approach is used to count based on "degree of truth", rather than "true or false". This is the conceptual framework that serves to address the uncertainties in knowledge representations.

The initialization of the fuzzy logic system requires the definition of linguistic variables. The definition applies to the words or sentences in artificial language or natural language. The definition is used to describe the level of each value. Linguistic variables are used to associate each criterion to the language in a fuzzy environment. Table II & III shows two sets of linguistic terms are used to assess the criteria for weighting and rank each of the qualitative criteria [31].

TABLE II. THE CRITERIA OF FUZZY LINGUISTIC TERMS

Importance	Abbreviation	Fuzzy Number
Very Low	VL	(0, 0, 0.2)
Low	L	(0.05, 0.2, 0.35)
Medium Low	ML	(0.2, 0.35, 0.5)
Medium	ML	(0.35, 0.5, 0.65)
Medium High	MH	(0.5, 0.65, 0.8)
High	H	(0.65, 0.8, 0.95)
Very High	VH	(0.8, 1, 1)

TABLE III. THE ALTERNATIVE OF FUZZY LINGUISTIC TERMS

Importance	Abbreviation	Fuzzy Number
Very Poor	VP	(0, 0, 0.2)
Poor	P	(0.05, 0.2, 0.35)
Medium Poor	MP	(0.2, 0.35, 0.5)
Fair	F	(0.35, 0.5, 0.65)
Medium Good	MG	(0.5, 0.65, 0.8)
Good	G	(0.65, 0.8, 0.95)
Very Good	VG	(0.8, 1, 1)

Therefore, the weighting provided by the client and developer is calculated, using fuzzy AHP, resulting in weight for each criterion.

B.2. Fuzzy AHP

The AHP technique has been developed using fuzzy numbers in its calculations. It is used when decision-makers are considering uncertainty. Human experiences and judgments are represented by linguistic and vague patterns are used in complex systems. As a result, better linguistic representations are developed as quantitative data. Then, the collection of decisions is refined by the fuzzy set theory [37].

Fuzzy AHP technique is carried out, using the following steps1.

1. Construction of the fuzzy pairwise comparison matrix
2. Calculate the degree of possibility
3. Calculate the weight vector
4. Check the consistency ratio

C. Phase 3 (Weights of Criteria)

The weighting of the cost and value category is carried out, based on the percentage provided by the client and developer, using FAHP.

D. Phase 4 (Evaluation of Alternatives)

In this last phase, the calculation process is carried out using FTOPSIS, where the client and developer compare alternatives with sub-criteria, using fuzzy linguistic terms. Therefore, the final results obtained, are the priority order of all alternatives.

D.1. Fuzzy TOPSIS

Fuzzy TOPSIS finds the best alternative of the shortest distance from the Fuzzy Positive Ideal Solution (FPIS) and the longest from the Fuzzy Negative Ideal Solution (FNIS). FPIS obtains the best performance values of each alternative but FNIS obtains the worst performance values. Typically, decision-makers having difficulties assigning an appropriate performance rating for each criterion under consideration. The benefit of using the fuzzy approach is easier to determine the relative importance of criteria rather than the precision of using fuzzy numbers [38].

The TOPSIS Fuzzy technique is carried out using steps,

1. Constructing weighted normalized for the fuzzy decision matrix
2. Calculating Distance FPIS and FNIS
3. Calculating closeness coefficient
4. Ranking the preference order

IV. Result and Evaluation

Furthermore, the proposed model in this research is compared with other similar studies, by observing several factors which are: the basis for the prioritization process; the cost-value approach, perspective, weighting; and the use of fuzzy tools.

Table IV, shows a comparative analysis, between the proposed models and ten other studies.

TABLE IV. COMPARATIVE ANALYSIS OF PRIORITIZATION APPROACH, COST-VALUE APPROACH, PERSPECTIVE AND WEIGHT

No	Source	Prioritization Approach	Cost Value Approach	Perspective	Global Weight	Local Weight	Using Fuzzy	Using Tool
1	Kukreja (2013) [39]	TOPSIS	Cost, Benefit	Business, Technical	No	No	No	Yes, Winbook
2	Kouhdaragh et al. (2017) [40]	Numerical Value	Cost Function	-	Yes	Yes	No	Yes, MATLAB
3	Mohamed et al. (2008) [41]	HCV, VOP, VOHCV	Cost, Value, Risk, Impact, Aspect	Business	Yes, (1 to 10)	Yes, (1 to 10)	No	No
4	Alawneh (2018) [42]	Hierarchical Dependencies	Use Case, Non-Functional Requirements	-	No	No	No	No
5	Babar et al. (2015) [10]	VIRP, Neural network, AHP	The value of Requirement (RV) using equations.	Business, Experts	No	No	Yes	Yes, PHandler
6	McZara et al. (2015) [16]	SMT, NPL based SNIPR	Cost factor	Systems Engineers	Yes	No	No	Yes, Sharp-NLP, Yices
7	Shao et al. (2017) [21]	Preferences and Dependencies	Benefits, Costs, Penalties, Risks, Others (ISO 25010)	Stakeholders	No	No	No	Yes, Drank
8	Kukreja et al. (2013) [43]	VBRP based on TOPSIS	The most valuable items	Business	Yes	No	No	Yes, Excel
9	Achimugu et al. (2016) [18]	The preferential requirements of stakeholders	Weights Scale	Stakeholders	Yes	No	Yes	Yes, ReproTizer
10	Khan et al. (2016) [11]	Historical data from a requirements repository	Implementation cost, value to users, risk, and time	Stakeholders, Requirements Engineers	No	No	No	Yes, Repizer
11	Proposed Model	FAHP and FTOPSIS	cost-value approach with client and developer collaboration	Product Owner, Developer Team	Yes	Yes, with FAHP	Yes	Yes, ReproColla

V. CONCLUSIONS AND FUTURE WORK

This research work aims to identify the limitations of existing requirement prioritization models, in order to help improve them. In this research, the problem of weighting the criteria in the prioritization requirements, proposed a new RP model, based on the cost-value approach, with a collaboration perspective. Furthermore, fuzzy numbers were used, to help solve the types of uncertainty and conflicting requirements. The proposed model had four main phases, namely, (1) The Correlation Attributes, (2) Local Weights of Sub-Criteria, (3) Weights of Criteria, (4) Evaluation of Alternatives.

Furthermore, the client and developer perspectives provided weighting to the criteria and were calculated, using Fuzzy AHP. The results obtained, then provided an assessment of alternatives, and were calculated, using Fuzzy TOPSIS.

The proposed model is aimed to (1) improve three major issues in terms of scalability, reduce pairwise comparisons, and stakeholders bias; (2) adding the cost-value approach to the requirements prioritization process; (3) increase the accuracy of the prioritization results. Therefore, our future work in this research is to test the proposed model with sample case studies based on real-world scenarios.

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