Int J Syst Assur Eng Manag
https://doi.org/10.1007/s13198-023-02190-x

ORIGINAL ARTICLE

A framework for software vendor selection by applying Inconsistency and Conflict Removal (ICR) method

Anshul Rani[1] · Deepti Mishra[1] · Aida Omerovic[2]

Received: 1 July 2023 / Revised: 6 September 2023 / Accepted: 9 October 2023

Abstract In a software ecosystem, companies' stakeholders make various decisions and perform various tasks to ensure the strategic and architectural goals of the company. Analyzing vendor capabilities and making decisions to select software vendors requires expert professionals. To analyze vendors' capabilities and accessing them according to the company's strategic and architectural goals is presently an ad-hoc and manual process. Presently, there is no systematic process for 'vendor analysis and selection' specifically for the software industry. Therefore, this study introduces a novel framework which elaborates all the tasks required for vendor proposal evaluation. It also includes the automatic detection of inconsistencies and conflicts prevalent during this process. A new method called 'Inconsistency and Conflict Removal (ICR)' is proposed as part of this framework. ICR automates the process of spotting inconsistencies and conflicts by taking scores of vendor capabilities as input reported by different decision-makers. Further, to illustrate this framework, 'a case of Hospital' has been considered. This study provides valuable knowledge that would facilitate organizations in software vendor selection. It will lead to substantial savings in terms of economics, such as actual costs, time, and improved administrative processes.

✉ Deepti Mishra
deepti.mishra@ntnu.no

Anshul Rani
anshul.rani@ntnu.no

Aida Omerovic
aida.omerovic@sintef.no

1 Intelligent Systems and Analytics, Department of Computer Science (IDI), NTNU-Norwegian University of Science and Technology, Gjøvik, Norway

2 Software Engineering, Safety and Security, SINTEF Digital, Oslo, Norway

Keywords Software ecosystem · Decision-making · Vendor analysis · Vendor proposal · Conflict management · Technology management · Knowledge management

1 Introduction

Software industry is one of the most rapidly growing sectors (Mishra and Mishra 2008) and a considerable amount of software is produced world-wide by software organizations with limited resources to assess and improve their processes (Mishra and Mishra 2007). In a software ecosystem, companies' stakeholders make various decisions and perform multiple tasks to accomplish the strategic and architectural goals of the company (Dutta et al. 2011). A software project involving outsourcing can be divided into several chronological stages (Wei and Wang 2004). These stages include the selection of the most suitable software project proposal from a range of proposals submitted by vendors, the effective implementation of the chosen proposal, the management of business processes, and an assessment of the system's practicality (Wei and Wang 2004). Software products delivered by vendors of diverse backgrounds are expected to possess varying strengths and weaknesses (Wei and Wang 2004). However, it should be noted that a weakness in one aspect does not necessarily render a software product unsuitable for consideration, as organizational requirements are typically not absolute (Akinnuwesi and Uzoka 2017). Hence, it is crucial to employ systematic approaches to evaluate and select an appropriate vendor proposal that is cost-effective and aligns with the organization's business process requirements, infrastructure, culture, and technical environment.

Analyzing vendor proposals and selecting one of the potential vendors require highly proficient personnel (Killen et al. 2020; Rani et al. 2021, 2022) as analyzing the

Published online: 07 November 2023

capabilities of each vendor and then evaluating those according to the company's strategic and architectural goals is a subjective task, which requires processing of qualitative data in large quantities (Jadhav and Sonar 2011; Plugge and Bouwman 2018). It can lead to challenges such as how this data can be presented and visualized comprehensibly to facilitate better decision support (Mishra et al. 2008) and to make it comply with the overall architectural/ strategic goals (Herath and Kishore 2009). Which selection criteria are most influential (Jadhav and Sonar 2011; Jansen et al. 2009)? How to relatively rank different selection criteria effectively? Further, due to the presence of various selection criteria, inconsistencies between these criteria may arise when a decision maker (DM) decides on the weightages of these decision criteria (Kilincci and Onal 2011; Lin et al. 2007; Secundo et al. 2017; Saaty and Vargas 1987). Since there are multiple decision-makers having different roles involved in the decision making process (Killen et al. 2020), it may result in conflicts among them while weighing decision criteria and analyzing vendor proposals.

To the best of our knowledge, no such study has been carried out for software vendor proposal analysis, particularly which proposes a systematic way for decision making. It is crucial to note that making an incorrect choice in the decision making process can result in software failure, weakening the overall system and having a negative impact on the company's performance (Rouyendegh and Erkan 2011; Uzoka et al. 2016). Thus, this study fills that gap and presents a framework that can serve as a guideline to decision makers of the companies which put out their software requirements in form of request for proposal (RFP) and in response receive proposals from several potential vendors. Further, the proposed framework addresses the inconsistencies and conflicts by incorporating a 'Inconsistency and Conflict Removal (ICR)' method. ICR method is built on the Analytical Hierarchy Process (AHP) which is widely used in various studies for supplier and software selection (Kilincci and Onal 2011; Lin et al. 2007; Saaty 1987; Saaty and Vargas 1987). However, AHP has limitations such as it does not provide with the actual cause of inconsistency, which is difficult to spot manually by decision makers. Also, with AHP conflicts between the scores provided by different DMs can only be witnessed towards the end (Saaty and Vargas 1987; Tang and Fang 2011). The framework presented in this study cover those aspects by incorporating ICR method. Thus, this research contributes to body of knowledge in software vendor proposal evaluation with automatic detection of inconsistencies and conflicts which may be prevalent during the vendor evaluation and decision-making process. For the same, a new framework is introduced by extending AHP, which spots inconsistencies along with its cause and highlights the conflicts between different DMs early in the decision-making process.

The rest of the paper is organized as follows. In Sect. 2 research questions are set for the study after identifying gaps through literature review. Section 3 describes the proposed framework. Section 4 details the ICR method in detail. Section 5 shows the applicability of the framework with a case study of hospital. Subsequent section 6 provides discussion on the proposed framework and the ICR method with respect to existing literature. Finally, it concludes with limitation, implications along with future research direction in Sect. 7.

2 Related work and motivation

Research studies have identified that the selection of an inappropriate software project proposal for implementation is one of the crucial contributing factors to software failure (Rouyendegh and Erkan 2011; Uzoka et al. 2016). A comprehensive meta-analysis provided by Jadhav and Sonar (2011), involving 70 failed software projects, aimed to identify the causes of such failures. These findings reflect on the need of a systematic framework/guidelines for the entities involved in the software outsourcing (Rani et al. 2021, 2022). The related literature is reviewed in these different directions as following:

2.1 Framework for vendor analysis and selection process

Hunink et al. (2010) presented a framework named ITAXEM (Industry Taxonomy Engineering Method) which enables software vendors, scientists, and government entities to gain valuable insights and identify gaps in information sharing. along with clarifying organizational capacity to create knowledge and artifacts. Van Den Berk et al. (2010) introduced the SECO-SAM (SECO Strategy Assessment Model), a model designed to describe the key characteristics of software ecosystems. This model offers a framework for assessing software ecosystem's strategy and understanding the potential effects of decisions on performance and strategic advantages. Verville and Halingten (2003) presented a six-stage model for the selection of ERP software package that includes continuous planning, conducting an information search to gather relevant data, shortlisting vendors, and technologies during the selection phase evaluating potential candidates through vendor, functional, technical assessments, and finally engaging in business and legal negotiations to make a final choice. However, it lacked the information on what are the necessary activities to be performed to hire software vendors in outsourcing settings.

In comparison, studies (Hunink et al. 2010; Van Den Berk et al. 2010) presented the software ecosystem from different aspects however these studies do not provide the guidelines from a specific entity's perspective such as a company which outsources or a vendor which provides software services to the former. Thus, there is a need for a systematic framework to support decision makers in software vendor analysis and selection process (Rani et al. 2021). Given the significance of vendor selection, finding an appropriate evaluation and selection methodology is a challenging task and is a crucial area for research.

2.2 Vendor proposal analysis

Further, the evaluation and selection of software vendor proposals involve a rigorous process that can span several months and requires the involvement of multiple personnel, as selection criteria need to be meticulously planned and considered within a decision matrix (Kahraman et al. 2003). The decision-making criteria for software adoption can encompass managerial, organizational, technological, environmental, or product-related factors (Van Den Berk et al. 2010). Selection criteria for service suppliers usually fall into four categories: supplier criteria, product performance criteria, service performance criteria, and cost criteria (Kahraman et al. 2003). Service performance criteria, such as follow-up, technical support, lead time, and professionalism, are used to evaluate the benefits provided by the vendor's services (Kilincci and Onal 2011).

The selection of a software provider depends on selection criteria decided by the company outsourcing the requirements and the capabilities of software vendors with enterprise criteria closely related to the quality characteristics of the software product to be implemented (Chin and Fu 2014). Jadhav and Sonar (2011) proposed a comprehensive stage-based methodology for the selection of any software package. They put forward an extensive collection (taxonomy) of software evaluation criteria that are widely applicable and can be utilized to assess any software package. Further, it defined the significance of each evaluation criterion and outlined the corresponding measures associated. Despite the extensive academic studies, effectively evaluating and selecting suppliers for service delivery remains a challenge in many industries including software service industry (dos Santos 2012; Secundo et al. 2017). The literature offers various techniques for selecting the best software vendor by mapping capabilities of different potential vendors against set selection criteria. However, there is no common consensus on the selection criteria guiding the vendor selection process (Chin and Fu 2014).

2.3 Techniques for vendor selection

There exist multiple approaches for evaluating and selecting software project proposal mostly based on Analytic Hierarchy Process (AHP) (Jadhav and Sonar 2009, 2011; Kahraman et al. 2003; Lin et al. 2007). AHP, developed by Thomas Saaty (1983), is a methodology that aims to choose the best alternative among a set of options based on qualitative and quantitative criteria. AHP has been applied in various areas, including workflow management system selection, multimedia authoring system selection, antivirus and content filtering software evaluation, e-commerce software and communication systems evaluation for supply chain, CRM selection, knowledge management tools evaluation, and ERP system selection (Rouyendegh and Erkan 2011; Secundo et al. 2017; Tahriri et al. 2008).

In addition, there exist metaheuristic optimization algorithms like DETDO (Adaptive Hybrid Dandelion Optimizer) (Hu et al. 2023) and the Global Best-guided Firefly Algorithm (Zare et al. 2023) which are commonly used in solving engineering optimization problems. These metaheuristic algorithms are versatile, heuristic-driven techniques for solving complex, non-linear optimization problems. In contrast, AHP provides structured decision support with pairwise comparison method for multi-criteria decision analysis, facilitating systematic prioritization based on subjective judgments.

The strength of the AHP approach lies in its structured and relatively simple solution to complex decision-making problems. It provides a multilevel hierarchical structure of integrated decision criteria that reflects the values, goals, objectives, and desires of the decision makers, offering flexibility (Bruno et al. 2012). However, AHP-based approaches have faced criticism for their limited ability to handle uncertainty, and imprecision when mapping decision-makers' perceptions to precise numbers (Dağdeviren 2008). Further, AHP does not provide any support for spotting the cause of uncertainties in the scores provided by different decision makers. Also, there is no mechanism to deal with the conflicts if there are more than one decision makers.

To make decisions making smooth and more reliable in terms of inconsistencies and conflicts, decision makers (company personal involved in decision making) requires: a) a guideline which includes step to step description of selection process (Killen et al. 2020; Nazim et al. 2022; Nutt 1980; Stodder 2013) b) an automatic measure to cope up with inconsistencies and conflicts. Further, it can be attributed that the framework that decision makers will follow should provide:

(1) *Mechanism to compare different selection criteria:* If selection criteria are to be provided different weight-

ages as per project requirements, then method should be able to accommodate. Manually this practice is cumbersome (Kou et al. 2016; Zlaugotne et al. 2020).

(2) *Ability to process vast data of vendors:* Method should be able to effectively represent and process the vendor's capabilities (Killen et al. 2020; Nazim et al. 2022; Nutt 1980; Stodder 2013; Xu and Yao 2013).

(3) *Measure to reflect on the inconsistencies:* Opted method should be able to reflect and cope up with the uncertainties which decision makers (DMs) might have during evaluating the vendor's capabilities (Killen et al. 2020; Manata et al. 2021; Nutt 1980).

(4) *Mechanism to report underlying conflicts between different DMs:* A conflict can be defined as when a significant difference is observed between the score of two DMs due to their different perspective and understanding of requirements. This conflict may impact the overall ranking of the vendors (Manata et al. 2021; Mbanaso et al. 2009; Nisyak et al. 2020; Stingl and Geraldi 2017; Saaty 1983).

As highlighted in study conducted by Schwarz (2014), "Organizations are willing to invest in an outsourcing relationship because they perceive its value". Despite being recognized as crucial to the success of an outsourcing alliance, the decision making process is still not fully comprehended (Rouyendegh and Erkan 2011; Uzoka et al. 2016). Therefore, it is imperative to come up with clear list of activities that a company' stakeholder should perform to hire the software vendors. Additionally, spotting inconsistencies and conflicts manually can be tiresome during the process. Despite the considerable efforts made in this direction (Dağdeviren 2008; Mehta and Mehta 2017), there remains unanswered questions. Thus, to propose a framework for reliable decision making which has all the above-mentioned characteristics, the following research questions (RQ) have been set for this study:

RQ1 What are the different activities that should be performed by company personnel in software vendor ecosystem to hire vendors?

RQ2 How to automate the process of locating inconsistencies and conflicts in decision making prevalent during vendor analysis and selection?

3 Framework for vendor proposal analysis and selection

This section describes the framework 'vendor analysis and selection'. Figure 1 shows the different activities performed by company personnel. These activities can be divided into

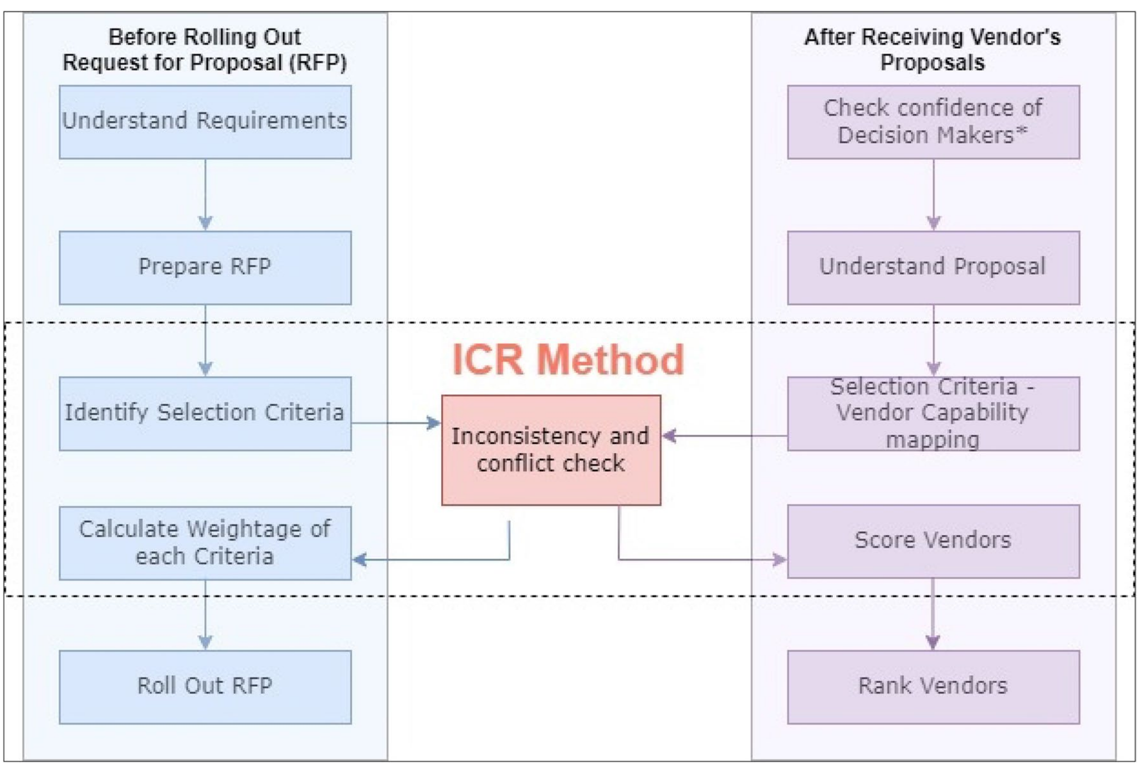

Fig. 1 A framework for vendor proposal analysis and selection in software ecosystem

two categories (a) Activities performed by company personnel before rolling out RFP (b) Activities performed by decision makers after proposals from different potential vendors are received.

As part of the vendor proposal analysis and selection, RFP is formed according to the software requirements in hand. It is necessary that the company personnel responsible for the RFP formation understands the requirements to be outsourced well, along with company's technological and strategical goals. After preparing the RFP, selection criteria are decided based on which software vendors will be evaluated (Jadhav and Sonar 2011; Kramer et al. 2013; Zahedi and Babar 2014; Zhang et al. 2018). It is a usual practice for companies to make those selection criteria and their respective weightages transparent to the interested vendors, so that they can showcase their capabilities accordingly in the proposals (Renault et al. 2009a, b; Tahriri et al. 2008). Thus, a RFP is considered complete if it consists of selection criteria (and weightages) along with the description of the software requirements to be outsourced by the company (Renault et al. 2009a, b). How weightages of different selection criteria are calculated is described in the subsequent section.

Once the RFP is rolled out, interested vendors submit their proposal in response (Liao et al. 2002; Renault et al. 2009a, b). After receiving vendor proposals, decision makers start with understanding the vendor's proposals. It is recommended to have confidence check (accessing level of decision maker' expertise in proposal analysis) of decision makers before they start analyzing the proposals although this step can be optional (Al-Dossari and Shao 2013; Chen and Dai 2021). As part of analyzing the vendor proposals, DMs extract the vendor capabilities (Kobayashi and Osada 2011; Kuehnhausen et al. 2012) from the proposal and map it with selection criteria that was pre decided on the given scale. Thus, DMs score the capabilities of different vendors on various factors (described in subsequent section). At last cumulative scores decides the ranking of the vendors and the top ones in the ranking list are chosen for services (Tang and Fang 2011; UmaDevi et al. 2012).

4 ICR method

Figure 2 describes ICR method in detail. This method supports decision makers in combining the subjective and objective factors while deciding the weightages of selection criteria (before rolling out RFP) and later in the evaluation of vendor proposals to make final decision. To use this hierarchical model of multiple decision making, one must define criteria, sub criteria and alternatives clearly. This method builds upon AHP i.e., building hierarchies, determining weights, and ensuring consistency. Further, a chosen decision method should be able spot the inconsistencies and conflicts as well which is also addressed in ICR method. Additionally, 'inconsistency and conflict check' part of Fig. 1 has been automated by python code and libraries. Pseudocode for the same is provided in Figs. 4 and 5.

Step 1 Define selection criteria: The first step is to clearly define and determine the selection criteria to realize the purpose of software requirements to be outsourced.

Step 2 (a) Fixate selection criteria: For each selection criteria, sub criteria needs to be defined so that it is easy to understand and quantify those criteria by decision makers.

Step 2 (b) Selection criteria - Vendor' capability mapping: Vendor' capabilities are extracted in accordance with selection criteria by the decision makers from the vendor proposals.

Step 3 Create/Update pairwise matrix: Pair-wise matrix are formed to compare all the alternatives under consideration based on a scale from 1 to 9 (Fig. 3).

Decision makers provide the comparison of each pair of alternatives at different times. Every decision maker creates two types of pairwise matrix that is to:

(a) Calculate the weightage of each selection criteria and
(b) Score the vendor proposals against decided selection criteria.

The details of matrix creation are as follows:

a) Criteria-Criteria pairwise matrix: Provide relative score to each selection criterion with respect to another selection criteria and form a matrix of C_{m*m} where m is number of selection criteria decided in step 1, and each cell of matrix will represent the relative score (S) of one criterion with respect to another. Every decision maker will consider the following to score criteria.

- Project requirements
- Weightages of different criteria categories if mentioned in RFP.

b) Vendor Capability-Criteria matrix: For each criterion (C), score each vendor (V) with respect to another vendor. Form a total m number of matrix of V_{q*q} where q is number of vendors and m is total number of criteria. Following factors can be considered to perform the same.

- Extracted capability of a vendor with respect to criteria under consideration

Step 4 Consistency check: The inconsistencies are created when score provided for different parameters in pair-wise matrix (of both types mentioned in step 3) does not follow the transitivity (Saaty 1983). For example, if criterion A is more important than B, and criterion B is more important than C then criterion A should be marked more important

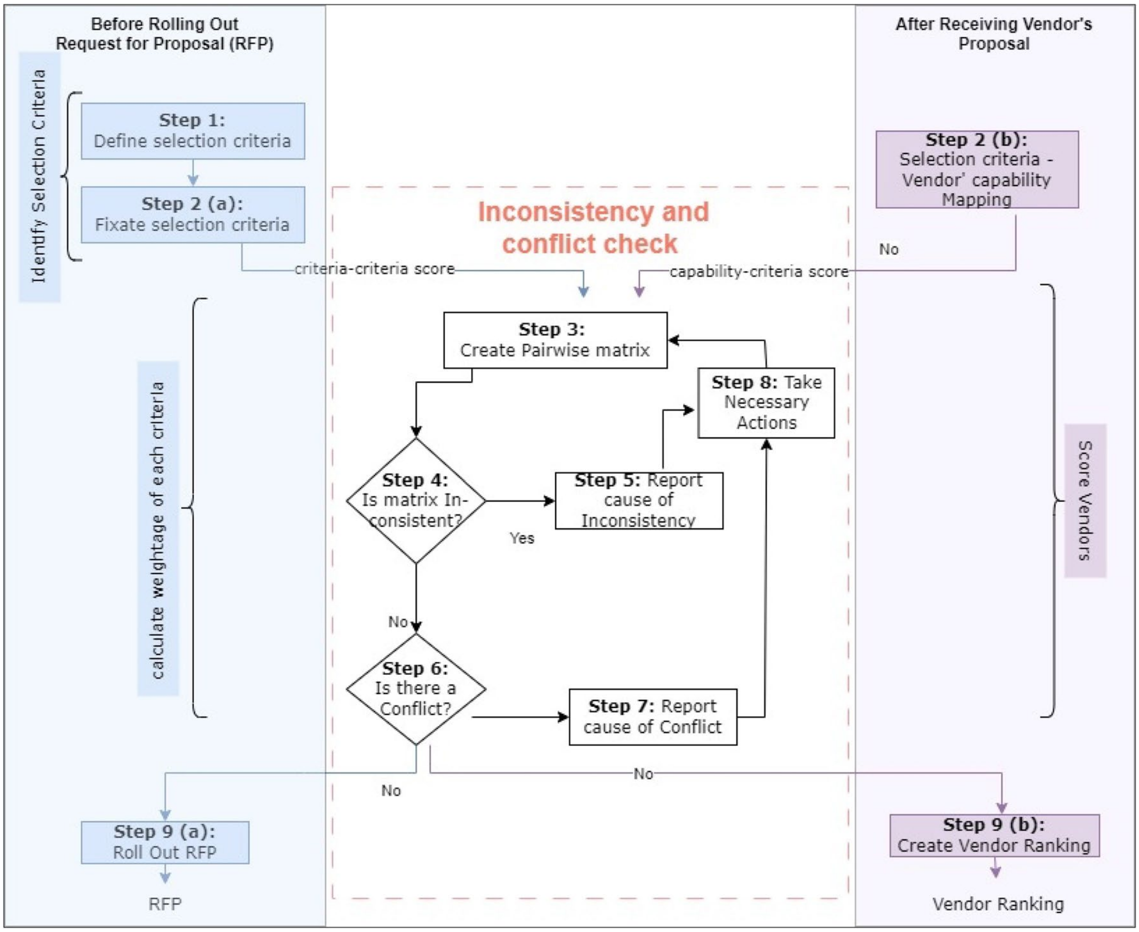

Fig. 2 Inconsistency and Conflict removal (ICR) Method

Fig. 3 AHP scale used (Saaty 1983)

Rating	Description
1—Equal	Both alternatives have **equal importance.**
3—Moderate	One of the alternatives is **slightly more important** than the other one.
5—Strong	One of the alternatives is **strongly more important** than the other one.
7—Very Strong	One of the alternatives is **very strongly important** compared to the other one.
9—Extreme Importance	One of the alternatives is **strictly superior** to the other one.

than *C*, otherwise it will lead to inconsistent matrix. Inconsistent matrix are reported using algorithm given in Fig. 4.

Step 5 Report cause of the inconsistency: Thus, to identify which relative scores between selection parameters led matrix to be inconsistent, algorithm given in Fig. 4 is proposed. The same can be applied for 'vendor capability-criteria' matrix as well.

Step 6 and 7 Conflict check: A conflict can be defined as 'when a significant difference is found between the score of two DMs. A threshold (*T*) can be set to check the conflicts between scores of different decision Makers. If $|S_i - S_j| > (T)$ then a conflict is reported, where *S* denotes the relative score provided by a decision maker for consistent pair wise matrix. Algorithm to check conflicts between different decision makers is given in Fig. 5, which takes pairwise matrix of two decision makers at a time and then reports the cause of conflicts.

Fig. 4 Algorithm to check inconsistency in ICR method

Step 5: Algorithm to report cause of inconsistency

```
P: represents every pair wise matrix
A,B,C,D.. : parameters
Flag: Temporary variable, initially flag=0
Report Inconsistency (P)
{
   Repeat for every possible set* of parameters (A, B,C,D) of size 3
  {
          if (P[A,B]>1 && P[B,C]>1)
          {
                    if (P[A,C] >=avg (P[A,B], P[B,C])):
                              Print ("matrix is consistent");
                    else:
                              flag=1;
                              Print (A, B, C: relative scores for A, B,C parameters are
                                    creating inconsistency);
          }
          if (P[A,B]<1 && P[B,C]<1)
          {
                    if (P[A,C] <=avg (P[A,B], P[B,C])):

                    else:
                              Print (A, B, C: relative scores for A, B, C parameters are
                                    creating inconsistency);
          }
          If (flag==0):
            Print (matrix is consistent);
  }
}
* like (A, B, C) (B, C, D), (C,B,A), (C,D,A)…….
```

Fig. 5 Algorithm to check conflicts in ICR method

Step 6: Algorithm for conflict check

```
P1 : Pair wise matrix from DM1
P2 : Pair wise matrix from DM2
T: Threshold
Conflict check (P1, P2, T)
{
Repeat for every pairwise matrix provided by different decision makers

          For every pairwise parameters in P
           D=P1[A,B]- P2[A,B]
          If mod (D)>T
          Print (conflict at A,B)
}
```

Step 8 Take necessary action: If there are any uncertainties or conflicts, then necessary actions should be taken. These necessary actions could include:

- Going through RFP and proposals again to better understand the requirements.
- Practices to get better understanding of the selection criteria which may include training from experienced personnel.
- One to one meeting with expert where every decision maker justifies the scores to mitigate inconsistencies in the scores provided.

- Conducting discussion meetings of decision makers to reflect on different score provided to know underlying reasons of conflicts in scores to resolve them.
- Other discussion platform with higher authorities to deal with anomalies.

Step 9 (a) Prepare RFP: RFP is prepared with clear requirements and the set selection criteria.

Step 9 (b) Vendor ranking: Ranking of vendors is created following the similar procedure as AHP (Saaty 1983), which involves calculation of normalized matrix followed by weight calculation of each criteria and then vendor ranking is generated based on final weights of available of alternatives.

$$\text{Final Weights of } A_i = \sum \left[\left(\textit{local weights of } A_i \textit{ with respect to criterion } C_j \right) * \left(\textit{Local weights of Criterion } C_j \right) \right]$$

5 Case study

To show the applicability of the framework the case study method is chosen. Case studies enable researchers to evaluate the framework's suitability for real-world scenarios and determine if it can be effectively applied in practice (Piekkari and Welch 2018). Also, case studies present practical instances of the framework's application, facilitating comprehension and adoption of the framework by other researchers and practitioners. Further, it has been observed that the previous studies conducted in the same context opted for the case study method to prove applicability of their proposed approaches. For example, Akinnuwesi and Uzoka (2017) presented a case study of ERP to explain the applicability of their suggested framework about which/how software package should be acquired for the best interest of the organization. Similarly, in (Secundo et al. 2017) usability of their developed method is described by using a case study in an aerospace company.

For this study, a case of hospital has been considered to explain the proposed method. The hospital is looking for additional functionalities of 'e-appointment and report sending automation' to be added in their existing software system (snippet in Fig. 6). Therefore, hospital has rolled out the RFP in public for willing vendors to apply for and send proposals for the same.

5.1 Problem definition

Suppose there are two potential vendors Vendor X and vendor Y from which hospital has received the proposals and two decision makers are responsible for determining the selection criteria and analyzing vendor' proposals. Brief

E-Appointment and report sending' is an extension to existing Hospital software system, which enables doctors and patients to interact if needed without intervention of administration staff of hospital. The doctors should be able to view booking requests made by the patients and if doctor confirms the appointment, it should notify the patient who made request. Also, after appointment doctor should be able to share test/consultation reports with patients if requested. There will be three main users a) Doctor, b) Patient, and c) Admin, of the system described below along with their requirements of usage. Doctor can view the patient requests of appointment, can confirm the requests, suggest alternative schedule, view the feedback given by patients and exchange messages with patients if needed. Doctor can also share test/consultation results with patients. The patient can view available schedule of doctors and based on the doctor' availability the patient can put request for appointment, receive confirmation from doctor, and their health reports as well. Administration staff should be able to view the registered doctors and patients along with the upper mentioned ***functionalities system should comply with***

- *Existing Hospital system which is already used for maintaining doctor and patient record and AWS cloud storage services*
- *Comply with existing login with BankId*
- *Comply with government health guidelines*
- *Should be able to comply with* ***EU legal code of conduct***

Additionally, the system should ***be easy to use*** *as this will be used by citizens of all age groups and all levels of education background.*

Fig. 6 Snippet of a sample RFP from Hospital

Fig. 7 Sample of vendor proposal received

Proposal from Vendor X	Proposal from Vendor Y
Name: Vendor X *Company Size: 100-150 employees* *Budget Proposed: 10k-20K£* *Time Proposed: 9-12 months* *Location: Non-EU* *Following technical specification are proposed for implementation.* *Front End: HTML, React* *Back End: Django, MySQL server* *GDPR compliance will be taken care by getting consent from every used when they register in the system. We have experience in 5 similar projects. Further, we tend to interview stakeholders (admin, doctors and patients) for more in-depth discovery of functional requirements and to know the skill level of customers.*	*Name: Vendor Y* *Company Size: 1000-1500 employees* *Budget Proposed: 15k-25K£* *Time Proposed: 12-15 months* *Location: Germany* *Following technical specification are proposed for implementation.* *Front End: Java, HTML, React* *Back End: Django, MySQL server* *Our company is ISO certified and follows 'common security guidelines' for all the levels of the security. Thus, we can ensure GDPR complaints for the project. Company uses its own cloud framework to store data, details for same can be provided on demand. We are new to such kind of projects, yet we ensure quality work.*

of the proposals submitted by the vendors are as shown in Fig. 7.

5.2 Application of ICR method for the given case

The different steps of ICR method are divided in two parts; a) Before RFP formation b) After receiving vendor proposals as described below:

5.2.1 Before RFP formation

Step 1 This step involves the identification of selection criteria (Table 1) through requirements given in RFP against which capabilities of vendors will be analyzed. The chosen selection criteria for the given case are vendor credibility, compatibility of product, security of product, usability of products. These criteria are extracted by decision makers from crucial requirements (bold text in the Fig. 6).

Step 2 (a) After deciding on the main selection criteria, sub criteria are decided for each criterion (Table 2). These sub criteria support in providing details of criteria selected in depth making it easier for decision makers to understand their subjectiveness.

Step 3 At this step, criteria-criteria pairwise matrix is created by each decision maker by accessing the RFP requirements as shown in Table 3.

Step 4 and 5 For each criteria-criteria matrix, consistency is checked, and cause of inconsistency is also reported if there is any, using the algorithm shown in Fig. 4 (Sect. 3). Criteria-criteria matrix provided by both the decision makers are checked for inconsistencies one by one by using this algorithm.

After running the algorithm for matrix provided by DM1, the result reported was *'usability, security, compatibility: relative scores for usability, security, compatibility parameters are creating inconsistency'*. (Refer Table 3: step 3 cells highlighted yellow). That means it holds *usability > security* and *security > compatibility* in terms of the relative importance but it does not follow the relative transitive importance between *usability* and *compatibility*.

After running the algorithm for matrix provided by DM2, the result reported was *'security, usability, compatibility: relative scores for security, usability, compatibility parameters are creating inconsistency'*. That means it holds *security > usability* and *usability > compatibility* in terms of the relative importance but it does not follow the relative transitive importance between *security* and *compatibility*. (refer Table 3: step 3, cells highlighted yellow).

Table 1 Chosen selection criteria for the given case

Selection criteria (Estdale and Georgiadou 2018)	Explanation
Vendor credibility	It considers the background information of the vendor for example, experience in similar projects etc
Compatibility	It considers to which level does vendor deliverables will comply with mentioned dependencies of the project
Security	The extent to which vendor can handle confidential health data
Usability	It refers to how vendor propose to make product easy to use for all users

Table 2 Chosen sub-criteria for the given case

Selection criteria (Estdale and Georgiadou 2018)	Sub-criteria	Explanation
Vendor credibility	Experience in similar projects	How much experience does vendor holds in the similar projects as given requirements in the RFP
	Cost/time	Provided quotation for cost and time
	Managerial aspects	Cultural differences, location
Compatibility	Interoperability	Degree to which two or more components can exchange information and use exchanged information
	Co-existence	Degree to which a product can perform its required functions efficiently while sharing a common environment and resources with other products
Security	Integrity	Degree to which a system, product or component prevents unauthorized access to, or modification of, computer programs or data
	Confidentiality	Degree to which a product or system ensures that data are accessible only to those authorized to have access
	Authenticity	Degree to which the identity of a subject or resource can be proved to be the one claimed
Usability	User interface aesthetics	Degree to which a user interface enables pleasing and satisfying interaction for the user
	Accessibility	Degree to which a product or system can be used by people with the widest range of characteristics

Table 3 Creation and updation of criteria-criteria matrix after inconsistency and conflict removal

Decision Maker 1 (DM1) | Decision Maker 2 (DM2)

Step 3: Initial Pair-wise (Criteria-Criteria) matrix provided by Decision Makers (DMs)

DM1:

	Vendor Credibility	Compatibility	Security	Usability
Vendor Credibility	1	0.33	0.20	0.14
Compatibility	3	1	0.20	0.33
Security	5	5	1	0.20
Usability	7	3	5	1

DM2:

	Vendor Credibility	Compatibility	Security	Usability
Vendor Credibility	1	0.33	0.14	0.14
Compatibility	3	1	0.33	0.11
Security	7	3	1	5
Usability	7	9	0.20	1

Step 4 &5: Pair-wise (Criteria-Criteria) matrix after inconsistency removal

DM1:

	Vendor Credibility	Compatibility	Security	Usability
Vendor Credibility	1	0.33	0.20	0.14
Compatibility	3	1	0.20	0.20
Security	5	5	1	0.20
Usability	7	5	5	1

DM2:

	Vendor Credibility	Compatibility	Security	Usability
Vendor Credibility	1	0.33	0.14	0.14
Compatibility	3	1	0.14	0.11
Security	7	7	1	5
Usability	7	9	0.20	1

Step 6 & 7 : Pair-wise (Criteria-Criteria) matrix after conflict removal

DM1:

	Vendor Credibility	Compatibility	Security	Usability
Vendor Credibility	1	0.33	0.20	0.14
Compatibility	3	1	0.20	0.20
Security	5	5	1	0.20
Usability	7	5	5	1

DM2:

	Vendor Credibility	Compatibility	Security	Usability
Vendor Credibility	1	0.33	0.14	0.14
Compatibility	3	1	0.14	0.11
Security	7	7	1	0.33
Usability	7	9	3	1

Afterwards, matrices are updated by taking necessary actions as mentioned in step 8 (Sect. 3). Updated entries are highlighted in green (refer Table 3: step 4 and 5, highlighted green).

Step 6 and 7 After inconsistency removal, updated matrices are checked for conflict between scores provided by different DMs. For the same, algorithm given in Fig. 5 is used. For the given case, $T = 4$ is assumed. After running the algorithm, the conflicted cell having $T > 4$ are highlighted yellow is shown in Table 4. Subsequently necessary actions are taken to address the conflicts and updated cells are highlighted in green (Table 3: step 6 and 7).

Step 9 (a) Weightage of each selection criteria is calculated and is put along with the requirements in the RFP and then RFP is rolled out.

Table 4 The results after running algorithm

	Vendor Credibility	Compatibility	Security	Usability
Vendor Credibility	0	0	-0.06	0
Compatibility	0	0	-0.06	-0.09
Security	2	2	0	4.8
Usability	0	4	-4.8	0

5.2.2 *After receiving proposal*

Step 2 (b) At this step decision makers analyze the vendor proposals, and extract the capabilities of each vendor from proposals, which are used for forming the capability-criteria pair-wise matrix in next step.

Step 3 At this step, capability-criteria pair-wise matrices are formed as shown in Table 5. These pair-wise matrices are formed by decision makers by extracting the various capabilities of vendors from vendor proposals according to decided selection criteria.

Step 4 and 5 For pair-wise (Capability-Criteria) matrix, there were only two vendors to compare, we do not need to check for consistency of matrices, as no transitive inconsistency can prevail.

Step 6 and 7 After inconsistency removal, updated matrices are checked for conflict between scores provided by different DMs. For the same algorithm given in Fig. 5 is used. For the given case assumed $T = 4$. After running the algorithm, identified conflicts are shown in Table 5 highlighted yellow. Afterwards conflicts are removed by taking necessary actions given in step 8 (Sect. 3). Cells highlighted green shows the updated cells in Table 5, after conflict removal.

Step 9 (b) Table 6 shows the cumulative weight calculated for each criterion, and then afterwards weight for alternatives

Table 5 Creation and updation of Capability-Criteria matrix after inconsistency and conflict removal

Decision Maker 1 (DM1)			Decision Maker 2 (DM2)		
Step 3: Initial Pair-wise (Capability-Criteria) matrix provided by Decision Makers (DMs)					
Vendor Credibility	Vendor X	Vendor Y	**Vendor Credibility**	Vendor X	Vendor Y
Vendor X	1	0.33	Vendor X	1	0.11
Vendor Y	3	1	Vendor Y	9	1
Compability	Vendor X	Vendor Y	**Compability**	Vendor X	Vendor Y
Vendor X	1	5	Vendor X	1	5
Vendor Y	0.20	1	Vendor Y	0.20	1
Security	Vendor X	Vendor Y	**Security**	Vendor X	Vendor Y
Vendor X	1	0.20	Vendor X	1	0.14
Vendor Y	5	1	Vendor Y	7	1
Usability	Vendor X	Vendor Y	**Usability**	Vendor X	Vendor Y
Vendor X	1	3	Vendor X	1	5
Vendor Y	0.33	1	Vendor Y	0.20	1
Step 4 and 5: Pair-wise (Capability-Criteria) matrix after inconsistency removal As there were only two vendors to compare, so no transitive inconsistency can prevail.					
Step 6 & 7: Pair-wise (Capability-Criteria) matrix after conflict r emoval The matrices which were updated after conflict removal are shown below, rest are same					
Vendor Credibility	Vendor X	Vendor Y	**Vendor Credibility**	Vendor X	Vendor Y
Vendor X	1	0.20	Vendor X	1	0.14
Vendor Y	5	1	Vendor Y	7	1

Table 6 Cumulative weights of each criterion

	DM1	DM2	Cumulative wt
Vendor credibility	0.05	0.05	0.05
Compatibility	0.11	0.08	0.10
Security	0.26	0.31	0.28
Usability	0.58	0.56	0.57

Table 7 Ranking of vendors

Alternative	Weights	Rank
Vendor X	0.58	I
Vendor Y	0.42	II

is calculated as per equation given in Section 3 and thus vendor *X* is ranked first in priority accordingly (Table 7).

6 Discussion

Since decision making is one of the crucial activities for an outsourcing project to be successful, the proposed framework provides the guidelines for the decision makers in a company outsourcing their software requirements (dos Santos 2012). In contrast to the various frameworks presented in the previous studies for the software ecosystem in various contexts (Hunink et al. 2010; Jadhav and Sonar 2011; Kilincci and Onal 2011; Liao et al. 2002; Lin et al. 2007; Secundo et al. 2017; Wei and Wang 2004), the proposed framework in this research enlists the activities that are to be performed by the company stakeholders in the role of a decision-maker. Table 8 presents the comparison of these existing frameworks.

Hunink et al. (2010) proposed a framework for information technology outsourcing which mostly focused on vendor client relationship, and the factors affecting it. The decision making was considered as an integral part of it but not described in detail. These details are necessary for the practitioners in the role of decision making in order to apply it in a real setting. On the other hand, the framework by Wei and Wang (2004) was scoped down to only ERP selection for companies and does not provide description on how it can be adopted to other outsourcing settings. In comparison, the present research provides a framework which can be adopted by any organization outsourcing their software requirements.

Further, Jadhav and Sonar (2011) provided guidelines for software selection, and compared different approaches. Their research put forward an extensive collection (taxonomy) of software evaluation criteria that are widely applicable and can be utilized to assess any software package, which resonates with the activity 'select decision criteria' of the proposed framework (Fig. 1). Similarly, the framework presented by Liao et al. (2002) is focused only on the process of electronic tendering which resonates with the activity 'Prepare RFP' of the framework in this research. Although these two studies (Jadhav and Sonar 2011; Liao et al. 2002) provide detailed information regarding these specific activities of the proposed framework however they do not cover the entire process of software vendor selection.

Additionally, the presented framework utilises ICR method built as an extension of AHP, which enhances the usability and accuracy of the whole framework. AHP has been integrated with other techniques, such as Fuzzy Set Theory (Kilincci and Onal 2011; Lin et al. 2007; Secundo et al. 2017) to increase the usability of decision-making method for different case studies. The study conducted by Kilincci and Onal (2011) used the extended AHP method for supplier selection of raw materials and components in a washing machine company and Lin et al. (2007) utilized fuzzy AHP for selecting the best possible storage in data warehouse system whereas Secundo et al. (2017) applied fuzzy AHP for software selection in an aerospace company. These studies reflect the importance of integrating fuzzy set theory with AHP. The proposed framework can also be easily integrated with fuzzy set theory by embedding it in step 'select decision criteria' (Fig. 1) and weightage of selection criteria along with the alternatives can be calculated using fuzzy set theory which will further increase the usability of the proposed framework.

AHP-based approaches have faced criticism for their limited ability to handle uncertainty and imprecision when mapping decision-makers' perceptions to precise numbers (Dağdeviren 2008) and it has been addressed to some extent in the presented framework by incorporating ICR method. ICR method (built on AHP) handles the uncertainties and conflicts that may prevail during the decision process. Decision making is an important task for companies as it has direct impact on performance and strategic goals of companies (Van Den Berk et al. 2010). The proposed framework with ICR method supports decision makers by adding automatic removal of inconsistencies and conflicts thereby improving usability and transparency of decision-making process.

7 Conclusion, limitations, implications and future work

Software outsourcing comes with additional responsibilities such as vendor selection and management in light of company's strategical and technological goals. This paper presents a framework entailing all activities of 'vendor proposal analysis and selection' process. It also includes a novel ICR method to deal with the inconsistencies and conflicts that decision makers might face during the process of rating the capabilities of the vendors. Further, Hospital case study is provided to show the application of the framework.

Table 8 Comparison with existing frameworks

	Summary of study	Limitations	Addressed in the present study	Lessons taken for future work
Liao et al. (2002)	• Emphasize on why digital tendering is important • Compares paper based tendering and digital tendering • Provides a roadmap on how digital tendering can be incorporated in the existing infrastructure of public sector	• Interpretations are limited to public sector of a specific region • No details on vendor selection or decision criteria establishment are provided	• Presented framework details the activities that are to be performed as part of 'decision-making' in software ecosystem along with ICR method to cope up with inconsistencies and conflicts	• Automation and digitalisation are important for 'RFP' preparation and roll out
Wei and Wang (2004)	• Framework for selection of suitable ERP project • Framework designed to integrate both objective data sourced from external professional reports and subjective data gathered from internal vendor interviews • Fuzzy set theory is employed to amalgamate linguistic evaluation descriptions and their corresponding weights	• Framework is specific to ERP systems only • No details provided on how conflicts and uncertainties will be handled that are prevalent during the selection process	• Presented framework can be adapted to any software intensive ecosystems • ICR method presented in Sect. 3 deals with inconsistencies and conflicts	• Fuzzy set theory can be embedded with presented method to improve the usability and adaptability of the presented framework
Lin et al. (2007)	• Presented a case of optimal data warehouse selection • Utilised fuzzy AHP • Concluded that computerizing the decision process can support usability of the method	• Suggested decision criteria and sub-criteria are specific to data warehouse • No details provided on how conflicts and uncertainties will be handled that are prevalent during the selection process	• Presented framework can be adapted to any software intensive ecosystems • ICR method presented in Sect. 3 handles inconsistencies and conflicts	• Fuzzy set theory can be incorporated to improve the usability and adaptability of vendor selection process • Automating the process can support usability of the selection process for beneficiaries
Hunink et al. (2010)	• Generic taxonomy for ontology selection • Taxonomy about how the vendor- client relationship should be engineered and can be adopted to different domains	• The taxonomy focuses on what to do for ontology selection in a software ecosystem rather than providing details on 'how' it can be done • No details provided on how to compile vendor's information • No vendor evaluation method is suggested	• The present study provides in detail how vendors' information can be handled and analyzed	• How presented method can be adopted different domains?
Jadhav and Sonar (2011)	• Generic methodology for software selection • Introduction of a Hybrid Knowledge-Based System (HKBS) approach to aid decision-makers in software package evaluation and selection • Evaluation and comparison of the HKBS approach with Hierarchy Process (AHP) and Weighted Scoring Method (WSM)	• Process of decision-making is not detailed • No details provided on how conflicts and uncertainties will be handled that are prevalent during the selection process	• Presented framework elaborates the general decision-making process in detail • ICR method presented in Sect. 3 deals with inconsistencies and conflicts	• Methods to Evaluate and compare with existing techniques

Table 8 (continued)

	Summary of study	Limitations	Addressed in the present study	Lessons taken for future work
Kilinci and Onal (2011)	• The suggested process involves considering both qualitative and quantitative factors to identify suppliers capable of consistently meeting a firm's requirements at an acceptable cost • Fuzzy AHP is used to calculate the weights of these attributes and alternatives	• Specific to washing machine supplier selection • Process of decision- making is not elaborated • No details provided on how conflicts and uncertanities will be handled that are prevalent during the selection process	• Presented framework elaborates the general decision-making process in detail • ICR method presented in Sect. 3 deals with inconsistencies and conflicts	• Fuzzy set theory can be embedded with presented method to improve the usability and adaptability of the presented framework
Secundo et al. (2017)	• Address the service supplier selection challenge crucial for high-tech manufacturing firms' competitiveness (Aerospace company) • Introduce the fuzzy extended analytic hierarchy process (FEAHP) for service supplier evaluation	• No details provided on how conflicts and uncertanities will be handled that are prevalent during the selection process	• ICR method presented in Sect. 3 deals with inconsistencies and conflicts	• Fuzzy set theory can be embedded with presented method to improve the usability and adaptability of the presented framework

The proposed framework can act as a guideline for software practitioners in the role of decision maker by.

(1) making the decision process smoother and easier to follow for the decision makers in the organization for software vendor selection.
(2) facilitating decision makers with automatic detection of inconsistencies and conflicts which may prevail during the decision-making process due to different understanding of outsourced requirements, selection criteria, or vendor capabilities.

The proposed ICR method considers every decision maker is equally proficient in vendor selection and experienced in specific domain. Hence the rating and scores provided by each decision maker is given equal weightage. However, in a real scenario expertise of decision makers may vary or certain decision makers might have higher confidence level in the decision making because of their experience or hierarchical structure of employees in company. Thus, the result of the framework will differ if varied expertise of the decision makers is taken into consideration. Further to show the applicability of the method, only two decision makers are considered for the case study to show the calculations in a simplified manner.

In future, authors intend to improve and extend the proposed ICR method by incorporating 'confidence level' (varying expertise) of decision makers and reflect on how it can further support the conflict and inconsistency removal process. Additionally, decision makers will be categorized based on their expertise, role and focus areas, for example, administration, technology and business-oriented stakeholders will have varying weightage associated to their category and different criteria for evaluation.

The framework presented in the study can act as basis for the future research and can be validated with various case studies. Furthermore, the proposed framework can be adopted to different domains where inconsistencies and conflicts are prevalent in decision making process. For example, it can be adapted to software vendor acquisition in other sectors such as energy, education, e-commerce etc. For those cases, decision criteria, and sub-criteria will differ from the case presented here but the selection process will remain the same afterwards for deciding weightage of criteria as well as for inconsistencies and conflict removal. However, in practice, beneficiary of the framework may show resistance towards adoption and acceptability of presented novel framework. We believe that special training sessions along with making them aware about the benefits of framework will omit that resistance. Additionally, a tool or web interface of this framework will add-on to the ease of its adaption and also towards its integration to their existing process. In future, we plan to do the same after it has been validated with practitioners. We have already started with the process of framework validation and improvement by exposing this framework to industry practitioners and gathering their feedback through interviews and workshops.

Further, the research conducted in this study is constrained by a limited sample size of two decision makers, which restricts our ability to capture a comprehensive perspective from a wide range of individuals. It is important to recognize that the adoption of an ill-suited decision-making process by the organization's management can contribute to the failure of an outsourced software solution. Therefore, future research should focus on developing an implementation framework that explores the cause-and-effect relationship between the activities involved in the software vendor selection and subsequent implementation process. This will provide valuable insights in improving the effectiveness of presented framework and implementation in real scenarios.

Funding Open access funding provided by NTNU Norwegian University of Science and Technology (incl St. Olavs Hospital - Trondheim University Hospital).

Data availability The code for ICR method can be made available upon request to the practitioners and research community.

Declarations

Conflict of interest Authors declare no conflict of interest.

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