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RESEARCH ARTICLE

Application Maintenance Offshoring Using HCI Based Framework and Simple Multi Attribute Rating Technique (SMART)

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ABSTRACT Over the last two decades, the rapid expansion of the Internet has prompted a growing number of enterprises to deploy their work globally. Companies are increasingly reliant on software systems, which need ongoing modification, maintenance, and upgrades. The maintenance phase consumes approximately 80% of the total software budget. Hence, companies have been eagerly looking for offshore outsourcing of these software systems. Choosing the best sourcing model for software maintenance projects remains elusive and challenging due to a variety of technological, social, and political factors. This study aims to analyze application maintenance offshoring related factors and addresses its decision-making process. To achieve the study objectives, factors of two datasets are analyzed based on standard deviation, mean and mean error. The Critical Success Factors (CSFs) are examined thoroughly to explore their impact on decision-making process. Additionally, the study proposes a sourcing framework based on CSFs that uses the Human Computer Interaction (HCI) principles. This framework assists clients and vendors to evaluate the projects prior to offshoring decisions. To enhance decision-making process, a case study is conducted in the Information Technology (IT) industry and the Simple Multi Attribute Rating Technique (SMART) is applied. As the results show, SMART ranks the available options and helps in making effective offshoring decisions.

INDEX TERMS Application maintenance, critical success factors, decision making, HCI, influencing factors, offshore outsourcing, SMART.

I. INTRODUCTION

Over the last two decades, the rapid expansion of the Internet has prompted a growing number of enterprises to deploy their work globally, making it easier for them to outsource the Information Technology (IT) tasks to specialized providers. The countries like Russia, China, and India are projected to become outsourced service centers, especially in software engineering. Companies are increasingly reliant on software systems, which need ongoing modification, maintenance, and upgrades. Businesses are actively seeking to manage expenses associated with software systems that have entered the maintenance phase. Most firms are concerned about software maintenance expenses, which are constantly rising, and many companies spend approximately 80% of their software budget on maintenance. Therefore, these businesses need to

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TABLE 1. Summary of the literature regarding software maintenance cost.

References	Publication date	Software Maintenance cost
Lientz et al. [8]	1978	A significant amount of the entire cost of a system's life cycle is spent on maintenance and improvement. System and programming resource consumption is roughly estimated to be between 75 and 80%.
Banker et al. [9]	1987	The authors presented that maintenance programming, corrections to existing programmes, and enhancements to current programmes take up anywhere between 50% and 80% of the resources used for data processing.
Lehner [10]	1989	The author discussed that the software maintenance cost is 60%.
Alkhatib [11]	1992	The author mentioned that the software maintenance cost is about 49%.
Chang [12]	2001	One of the primary causes of the high costs of large software systems is commonly acknowledged to be software maintenance. It is generally accepted that software maintenance costs 60% to 80% of a system's budget.
Ahn et al. [1]	2003	The authors discussed that many businesses spend about 80% of their software budget on maintenance, and the majority of organisations are concerned about the costs involved. As a result, these organisations must efficiently manage their software maintenance efforts and expenses.
Rao and Sarda [13]	2005	Software life cycle expenses for maintenance range from 40% to 90%, while perfective maintenance, which deals with functional system improvements, is expected to need 55% of total maintenance efforts.
Tan and Mookerjee [14]	2005	The authors analyzed software maintenance activities aimed at improving system functionality. The study indicated that system enhancements are the primary reason for maintenance requests, accounting for more than 75% of the total maintenance effort.
Robillard et al. [15]	2007	A software system's lifecycle expenses can be consumed by software maintenance up to 70%.
Ikram et al. [16]	2021	The authors discussed that it consumes more than 70% of the total budget, allotted for the software development lifecycle.
Rahman et al. [17]	2021	The maintenance phase of the software life cycle is thought to be the longest and uses between 60 and 70% of the overall software budget.

efficiently manage their software maintenance efforts and expenses. Hence companies are eagerly looking for offshore outsourcing of these software systems [1], [2].

Piattini et al. [3] have presented the varying maintenance costs of application reported by different studies from time to time as indicated in Table 1. Since the 1990s, the trend toward offshore software outsourcing has been continuously increasing. The practice of subcontracting all or part of a company's software development in a location other than the company's location and historically outside the place where the product or service will be marketed or consumed is known as offshore software development referred to as offshore outsourcing. Offshore software projects often require domestic vendors offering their services from the same locations and local operations, especially in the developing areas, or foreign offshore vendors who are key players in offshore software development and are mainly headquartered in developing countries [4], [5]. Such initiatives are often time-consuming and reliant on regular, intensive customer and vendor engagements, where the service provider seeks to understand the customer's business processes. An inordinate amount of time is spent selecting suppliers based on stringent technical criteria. Similarly, organizational and managerial skills are required for handling the offshore software outsourcing partnership. This is a frequent problem faced by enterprises new to offshoring. The constraints such as language barrier, legal requirements, and cultural differences are obvious issues that obstruct offshore process management; in addition, the Global Software Development (GSD) has a number of other critical challenges [6], [7].

Despite many studies in the field of Global Software Engineering (GSE), particularly related to offshore outsourcing decisions, selecting the best sourcing model for software maintenance projects remains elusive and difficult. Due to a variety of technological, social, and political factors, adopting an effective sourcing strategy is arduous and time consuming, and also reliant on the interpretation of humans, and therefore, prone to mistakes. This study aims to analyze the influencing factors (two datasets) based on standard deviation, mean and mean error. The Critical Success Factors (CSFs) are analyzed thoroughly to explore their impact on decision-making process. Furthermore, the study proposed a sourcing framework that assists the clients and vendors to evaluate the projects prior to offshoring decisions. In order to improve the decision making this study uses the SMART for ranking the available options and selecting the appropriate sourcing model.

The rest of the article is structured as follows: Section II covers the research background that includes contribution of the study and research context. Section III discusses the research design. Section IV provides results and discussion that includes the process of identifying factors, calculating the standard deviation, mean and mean error of two datasets, proposing a sourcing framework based on critical success factors and using SMART to rank the given options and select the best model. Section V and VI present the study limitations, and the conclusion and future work respectively.

II. STUDY BACKGROUND

In the software business, offshore outsourcing essentially means hiring programmers who reside overseas, generally in nations where labor costs are significantly cheaper than in industrialized countries. Software outsourcing, according to the researchers, is a circumstance in which a customer contracts out all or some part of its application maintenance or development operations to a service-vendor who performs agreed-upon services for a fee. Outsourcing and strategic alliances have increased the use of non-internal technology development [4], [18], [19].

Literature review shows that various studies such as [13], [15], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29], [30], and [31] have focused on GSE, particularly on offshore outsourcing decisions. Bianchi et al. [32] reported the findings of a major application maintenance project that was conducted on one location as well as across the multiple locations of a company. Comparisons were between the two different sections. The results did not show remarkable differences between the scattered and on-site work on two variables namely, cycle time and costs. Sundararajan et al. [33] investigated the maintenance issues in distributed information systems. The maintenance work involved distributed teams with geographic locations that faced challenges such as cultural differences and language barriers. From the standpoint of a vendor, the research study examined the risks along with their resolution techniques. In addition, they identified the implemented best practices in the program as well as the lessons learned. These findings are used in different phases of software such as starting, transitioning and maintenance.

Ikram et al. [16] presented a dataset by conducting an empirical investigation. Based on the dataset, they developed a model using machine learning approach. The proposed model can be used in the context of global delivery to assess and analyze the client's proposal. Soliman [34] conducted a research study related to global outsourcing decisions of application services from the perspective of vendor. To address the research objective, they first derived a set of factors. Then a framework based on the factors was developed. The factors are IT experts, product quality, cost, cultural differences, tax incentives and communication technology. Khan et al. [35] conducted the literature review, which was followed by a questionnaire survey that identified a total of six most important challenges and a list of 75 practices. Using the results of the literature review and the empirical investigation they developed a model. The model created is used to provide solutions to the various communication issues in global software development. Fraihat [36] focused on IT outsourcing and investigated the CSFs in the context of the global delivery model. A framework was proposed using critical success factors to help the managers and experts in taking the sourcing decisions of the IT.

Similarly, Väyrynen and Kinnula [37] performed an empirical study. They conducted interviews in the Finnish International Company with the IT experts to study the quasi outsourcing area. The study goal was to identify the key attributes and to compare the attributes of quasi outsourcing with the conventional outsourcing. In particular, they presented three challenges and a list of influencing factors for quasi outsourcing. In general, application maintenance consumes about 60% of an organization's software budget. The company that outsources application maintenance not only reduces cost, but at the same time relieves the maintenance staff and provides them the opportunity to work with new technologies and free up management for core activities. Many companies such as IBM, Accenture, Wipro, Infosys and Tata Consultancy Services deliver application services through their worldwide delivery models, utilizing application expertise from a combination of local, regional and global resources while delivering cost-effective solutions. Similarly, these companies have strong global delivery capabilities that enable effective global delivery. Their global supply networks enabling companies to utilize the right skills and services at the right prices from onshore, nearshore and offshore locations. These companies offer application services by choosing different delivery models according to their needs. The basic models for global service delivery are onshore, nearshore, offshore and blended models [20], [38], [39], [40].

A. CONTRIBUTION OF THE STUDY

The IT professionals and decision makers choose a global delivery model to deliver application maintenance services in the context of offshore outsourcing. The model is often chosen by experts depending on the requirements of the client and the nature of the project. The lack of an adequate decision support system, however, prevents the suppliers and clients from making suitable sourcing decisions. Therefore, the current research proposes a dynamic sourcing model to help IT professionals to choose the best and most appropriate sourcing option. Adopting an effective sourcing strategy would enable the vendor to offer successful global services. The main contributions of this study are as follows:

- Analyses of two datasets' factors based on mean, standard deviation and mean error (step by step calculation (Section IV-B).

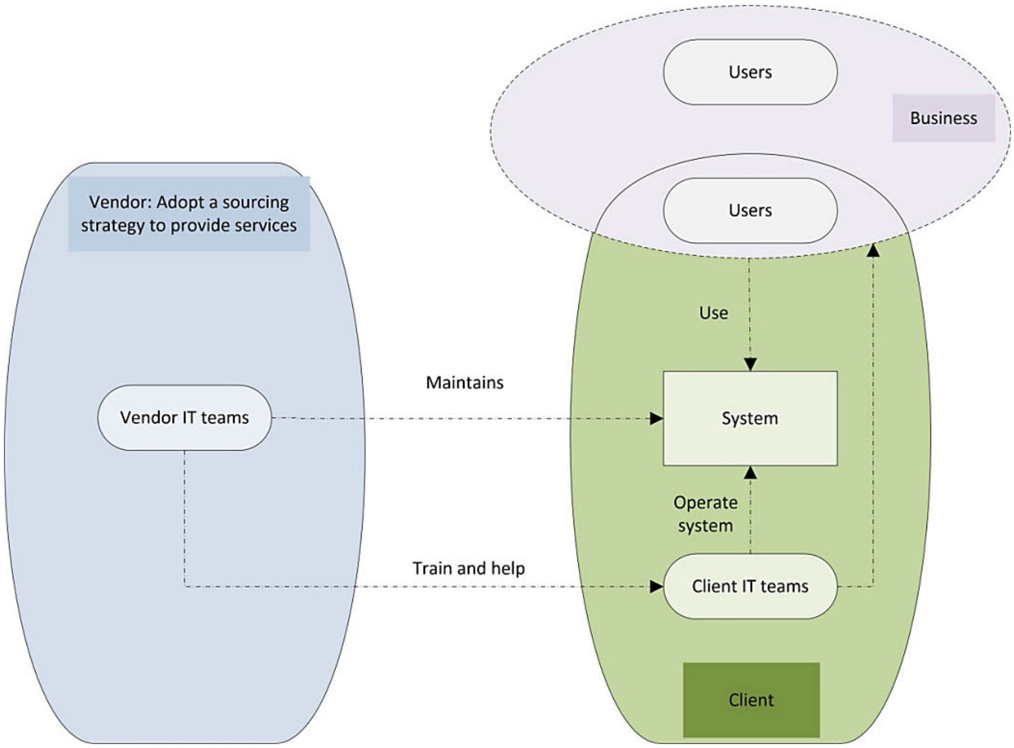

FIGURE 1. **Research context of the current study.**

- Analysis of the CSFs exploring the impact of factors on the decision-making process (Section IV-C).
- Decision making of application maintenance using the proposed sourcing framework (Section IV-D1).
- Decision making using the Simple Multi-Attributes Rating Technique (Section IV-D2).

B. RESEARCH CONTEXT

Our study focuses on the factors that influence software maintenance offshoring decisions. In this context, Fig. 1 shows several entities and their interrelationships. The following text describes the entities involved in this interaction [29].

Customer: in any domain, a customer is an organization that is doing business. The maintenance of the system is funded by this organization.

Business: business is a logical perspective of users who utilize the system to support their business operations, both inside and outside of the customer's company.

Vendor: vendor refers to the company that performs system's outsourced maintenance.

System: a system is a collection of software/applications and documentation that helps the business by automating (partially or totally) the customer's business operations. The system might have been created in-house by the IT team of customer or any group except the maintenance team. Other things like as infrastructure, network, system software, hardware, middleware, and so on have been eliminated from this definition for the purposes of this study. A system achieves a set of goals.

IT team of client: this is a group of people inside customer's company that are in charge of system ownership and maintenance. This group also includes users with expertise in the domain and communicates with system end-users on behalf of the IT staff. The system's objectives are well understood by the IT staff.

IT team of vendor: the maintenance team is a group of people who work for the vendor and are responsible for the system's day-to-day upkeep. This group communicates with the IT department of the customer.

Users: this is a group of people who utilize the system to run their businesses more efficiently. Users might be from within or outside the customer's company. The users communicate with the IT team of customer to submit system maintenance requests and the users also have a clear knowledge of the system's goals.

III. RESEARCH DESIGN

The major goal of the current study is to create a sourcing model to assist clients and vendors in selecting appropriate models for application maintenance offshoring. In order to accomplish the research goal, we adopted a research method that consists of four phases: performing a systematic literature review, performing an empirical investigation, factors analysis and applying the SMART to make ranking of models as depicted in Fig. 2. Literature shows that other studies adopted the same method [41], [42], [43].

A. PHASE-1: SYSTEMATIC LITERATURE REVIEW

Firstly, a systematic literature review was conducted that presented 15 factors influencing the decisions of application maintenance offshoring as already published [17]. To perform the SLR, different strings were used to search the well-known digital libraries including IEEE Xplore, Springer Link, ACM and Google Scholar for the years 2000 to 2020. Initially, a search string was created by combining the keywords and their alternatives. Upon conducting a trial search using the developed string, we found that IEEE Xplore and ACM yielded extensive lists of publications, while Springer Link did not produce any results using the same string. As each digital library yields different result using the same search string, subsequently the base string was modified and generated distinct search strings for each digital library. The objective was to develop appropriate strings that would help us to identify relevant primary studies. A total of 1050 publications were collected using the developed search words. The collected publications were filtered using three steps, starting with a title reading that produced a list of 368 publications. The second step focused on refining the collected papers by reviewing the summary/abstract, and conclusion of each research article, which narrowed the list down to 154 relevant papers. In the third step, by concentrating on reading the contents of each paper produced a final list of 52 papers. Further information regarding the results obtained using these search strings and the process of study selection can be found in [17].

B. PHASE-2: EMPIRICAL INVESTIGATION

Secondly, the empirical study was performed in the outsourcing industry in order to assess and validate the findings of the systematic literature review as already published [44]. Using an online questionnaire-based survey a total of 96 responses were collected from 30 different countries. The collected data was analyzed based on various variables such as the respondents'' experience, location and position. The data was further analyzed based on the chi-square test. Consequently, the ranking of the identified factors was identified using two different approaches, which led to the derivation of 10 critical factors. The details along with the complete collected data, responses, respondents' countries and their positions are given in the previously published article [44].

The following paragraphs briefly discuss the sub-steps of empirical study. Whereas the previously published paper [44] provides the detailed descriptions of these steps. The questionnaire survey involves two stages, namely the design phase and the sampling phase. In the design phase, questions are formulated that the sample can answer [45]. The sampling can be done using either methodical or non-methodical methods. However, it was not feasible to gather data from experts in various countries through direct means. Therefore, we adopted a non-methodical approach, i.e. an online survey, for collecting data. This approach has also been utilized by other researchers for data collection purposes [46], [47], [48].

The survey includes both closed and open-ended questions. Closed-ended questions aimed at identifying the respondents' ratings of factors previously identified in the study [17]. While the open-ended questions allow experts to add additional factors concerning application maintenance. The questionnaire used in this study has mainly two sections: first section of the questionnaire contains attributes/factors to be assessed and the open-ended questions in the second section of the questionnaire enable respondents to add new criteria. The closed-ended questions were rated on a five-point Likert scale, which was deemed less confusing than a seven-point scale [49], [50], [51], and has been used in previous studies to minimize researcher bias [52], [53], [54].

The open-ended questions were included in the second section of questionnaire, and respondents were asked to rate the factors based on five-points Likert scale such as Very High Influence, High Influence, Moderate Influence, Low Influence, and No Influence. First, pilot testing was carried out with industry experts and two professors from the institutions namely Abdul Wali Khan University Mardan and University of Swabi. Second, the statistical analysis approach was adopted to analyze the collected data that determined the relevance of influencing factors. The factors were ranked based on the ratings given by the respondents. The current paper presents a model based on the 10 critical success factors to make the offshoring decisions.

C. PHASE-3: ANALYSIS OF FACTORS

In this phase the identified critical success factors (10) are analyzed based on standard deviation, mean and mean error. Further, the CSFs are assessed to explore the impact of factors on the decision-making process.

D. PHASE-4: DECISION MAKING USING SIMPLE MULTI-ATTRIBUTE RATING TECHNIQUE

This study uses the Simple Multi-Attribute Rating Technique (SMART) for evaluating the influencing factors and ranking the given sourcing alternatives in order to enhance the decision making process. SMART is a multi-criteria decision method developed by Edward in 1977 [55]. It is a versatile method which is used to evaluate multiple and interrelated factors. SMART helps individuals, researchers, and professionals to make well-informed decisions that are in line with their aims and priorities by facilitating systematic comparisons. SMART offers a simple method to analyze efficiently choices and finding the best solutions in various fields: business, engineering and other industry [56].

The steps involved in multi-criteria decision making are discussed below [55], [56], [57]:

- Determine the number of criteria and alternatives
- Criteria weights are calculated using the formula 1

$$wi = \frac{Wi}{\sum_{j=1}^{m} Wi} \tag{1}$$

where Wj is the score of each criteria and $\sum$Wj is the total weight of all criteria.

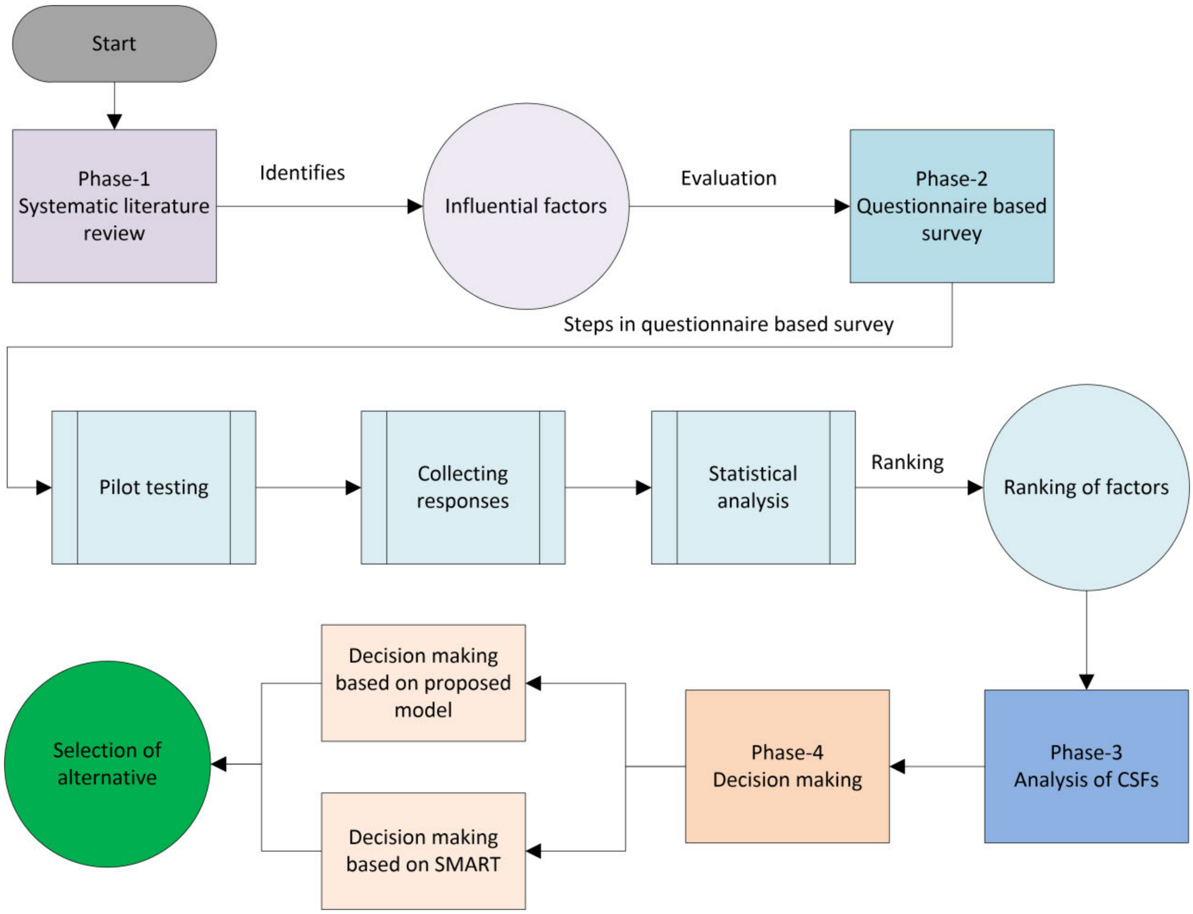

FIGURE 2. Overall research procedure.

Utility values are calculated using the following formulas:

$$\text{ui(ai) (benefit criteria)} = \frac{[xij - Min\,(xij)]}{[Max\,(xij) - Min\,(xij)]} \tag{2}$$

$$\text{ui(ai) (cost criteria)} = \frac{[Max\,(xij) - xij]}{[Max\,(xij) - Man(xij)]} \tag{3}$$

where, xij the value of criteria, Min (xij) the minimum value in column, Max (xij) the maximum value in column and Max (xij) – Min (xij) is their difference.

The overall weights of alternatives are calculated using formula:

$$\text{Alternative weights} = \sum\nolimits_{j=1}^{k} Wj.uj\,(ai) \tag{4}$$

where ujai is the utility value i with respect to criteria k and Wj are the weights of criteria.

IV. RESULT AND DISCUSSION

This section presents factors identification process and ranking; factors analysis based on standard deviation and mean error, and exploring the impact of factors; decision making process using the proposed framework and multi criteria decision making using the SMART.

A. FACTORS IDENTIFICATION PROCESS

This section provides a detailed discussion about the factors ranking and CSFs identification process among the identified factors. Table 2 shows the total identified factors as well as factors description, sub factors and their impact on the sourcing decisions. The factors were identified and reported in [17] and [44] by conducting a systematic literature review and an empirical investigation.

In SLR a list of 52 articles were selected for data extraction based on the inclusion/exclusion criteria. A set of 15 factors were extracted from the shortlisted articles. An influencing factor is considered a CSF if it has been mentioned in the literature with a proportion of >=50%. Other researchers [58], [59], [60] also adopted this criterion to identify CSFs. In accordance with this guideline, 10 factors were ranked as CSFs as given in Table 3. These factors are employees skills, poor communication, cost, legal requirements, infrastructure, maturity level, frequent requirements changes, language barrier, domain knowledge and project management. The identified factors in SLR were evaluated using an empirical study. Through the online questionnaire-based survey a total of 96 responses were collected from 30 different countries. The collected data was analyzed based on various variables

TABLE 2. Description of identified factors.

Factors	Description of the factors
Employees Skills (ES)	Employees knowledge, skills and expertise and IT skills
Poor Communication (PC)	Cultural differences, language restrictions, and difference in time zones, all of which hampered communication across the scattered teams
Cost (Cos)	Short projects, long term project, multi-sourcing and project budget
Legal Requirements (LR)	Data protection , privacy and data transfer, intellectual property, labor rights, restrictions such as exports and imports and government approval
Infrastructure (Inf)	Data communication, network, data centers and Internet connectivity
Maturity Level (ML)	Experience in global delivery, team and process maturity
Requirements Changes (RC)	Requirements not clear, volatile requirements, requirements instability and application portfolio changes
Language Barrier (LB)	Impact of "language" on making the sourcing decisions
Domain Knowledge (DK)	Effect of domain knowledge and application expertise
Project Management (PM)	Contract management and relationship management
Service Scope (SC)	Functionality scope and size of engagement
Size Of Engagement (SOE)	Impact of "long term/short term projects" on offshoring strategy
Knowledge Transfer (KT)	Knowledge sharing with teams and in distributed projects and impact of difficulty in information sharing
Cultural Diversity (CD)	Effect of cultural difference on offshoring decisions
Time Zone (TZ)	Effect of TZ on offshore outsourcing decisions

TABLE 3. Final ranking of factors based on SLR and empirical study.

Factors	Percentage in SLR	Factor ranking based on SLR	Percentage in empirical study	Factors ranking based on empirical study	Average ranking of both datasets	Final ranking
ES	77	1	86	2	1.5	1
PC	69	3	78	1	2	2
Cos	69	3	78	3	3	3
LR	69	3	77	4	3.5	4
Inf	61	6	77	5	5.5	5
ML	61	6	71	6	6	6
FRC	61	6	58	8.5	7.25	7
LB	59	8	59	10	9	8
DK	31	13	64	7	10	9
PM	56	9.5	54	11	10.25	10
SS	56	14.5	53	8.5	11.5	11
SOE	13	14.5	59	12	13.25	12
KT	49	9.5	31	13	11.25	13
CD	41	11	26	14	12.5	14
TZ	13	12	52	15	13.5	15

such as the respondents' experience, location and position. The data was further analyzed based on the chi-square test.

Consequently, the ranking of the identified factors was identified that led to the derivation of 10 critical factors. The details along with the complete collected data, responses, respondents' countries and their positions are given in the previously published article [44]. The ranking of factors are given in Table 3 as "factors ranking based on empirical study". The CSFs are further analyzed based on standard deviation, mean and standard mean error (Section IV-B).

Both the set of factors were categorized and ranked. The final ranking of the influencing factors as given in Fig. 3, is achieved by averaging the SLR and the survey rankings. Moreover, a detailed discussion of factors, the ranking and the finalization process of the success factors can be found in [17] and [44].

B. MEAN, STANDARD DEVIATION AND MEAN ERROR OF DATASETS

The sub section presents the calculation of standard deviation and mean error of SLR and survey datasets. Standard

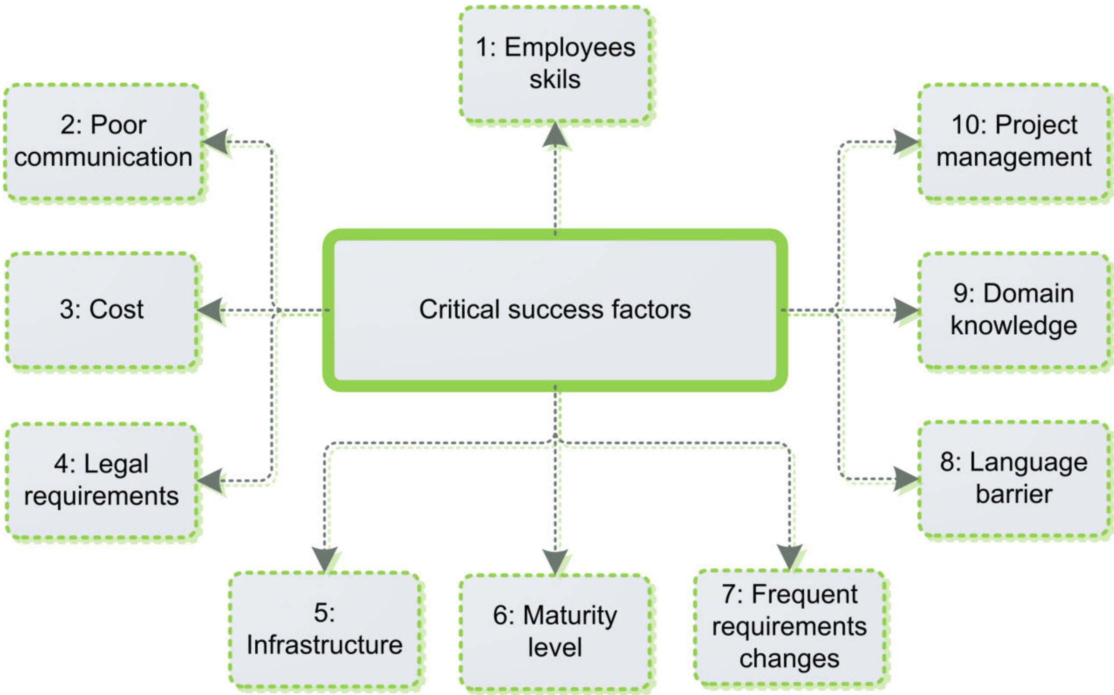

FIGURE 3. Critical success factors among the identified factors.

TABLE 4. Dataset (factors) obtained by conducting a systematic literature review.

ES	LR	PC	Cos	ML	Inf	FRC	LB	DK	PM	KT	SS	CD	TZD	SOE
77	69	69	69	61	61	61	59	31	56	56	13	49	41	13

deviation is a key tool in many fields, including finance, physics, psychology, and biology, among others. It is often used in conjunction with other statistical measures, such as the mean and variance, to provide a more comprehensive understanding of the dataset under analysis. Standard deviation and standard error of the mean are two related but distinct concepts in statistics. Standard deviation (SD) is a measure of the amount of variation or dispersion in a set of data. It measures the average distance of individual data points from the mean of the dataset. A higher SD indicates a larger spread of data points, while a lower SD indicates a tighter clustering of data points around the mean. On the other hand, Standard Error of the Mean (SEM) is a measure of the precision of the mean estimate. It measures how much the sample mean varies from the true population mean. The SEM is calculated by dividing the standard deviation by the square root of the sample size [61], [62]. Eq. (5) is the standard deviation formula that can be used to achieve the standard deviation. The dataset obtained conducting the systematic literature review is given in Table 4. The following sub paragraph shows the standard deviation and mean error of the SLR dataset.

$$S = \sqrt{\frac{\sum\left((x-\bar{x})^2\right)}{\mathrm{n}-1}} \tag{5}$$

Mean

$$\begin{aligned}
&= \bar{\mathrm{x}} == \frac{Sum}{N} \\
&= ((77+69+69+69+61+61+61+59+31 \\
&\quad +56+56+13+49+41+13))/15 = 785/15 = 52 \\
&= [(77-52)2+(69-52)2+(69-52)2+(69-52)2 \\
&\quad +(61-52)2+(61-52)2+(61-52)2+(59-52)2 \\
&\quad +(31-52)2+(56-52)2+(56-52)2+(13-52)2 \\
&\quad +(49-52)2+(41-52)2+(13-52)2] \\
&= [(25)2+(17)2+(17)2+(17)2+(9)2+(9)2 \\
&\quad +(9)2+(7)2+(-21)2+(4)2+(4)2+(-39)2 \\
&\quad +(-3)2+(-11)2+(-39)2] \\
&= [625+289+289+289+81+81+81+49 \\
&\quad +441+16+16+1521+9+121+152] = 5429
\end{aligned}$$

Now, we can get standard deviation by putting values in $S = \sqrt{\frac{\sum((\mathrm{x}-\bar{x})^2)}{\mathrm{n}-1}}$

Total number of factors (n) = 15 and n-1 = 15-1 = 14 S $= \frac{1529}{14} = 387.7857$ So, S $= \sqrt{387.7857} = 19.6922$

Similarly, the mean error is calculated by using the Eq. (6).

$$\mathrm{SEM} = \frac{s}{\sqrt{n}} \tag{6}$$

TABLE 5. Dataset (factors) identified by performing an empirical study.

ES	LR	PC	Cos	ML	Inf	FRC	LB	DK	PM	KT	SS	CD	TZD	SOE
86	78	78	77	77	71	58	59	64	54	53	59	31	26	52

TABLE 6. Calculation of mean, standard deviation and standard error mean.

Datasets	Number of factors	Mean	Standard deviation	Standard error mean
SLR	15	52.33333333	19.68925257	5.083743153
Survey	15	61.53333333	17.22898997	4.448506081

Standard error mean = 5.083743153

Table 5 shows the dataset obtained by performing a questionnaire based survey in the outsourcing industry. Eq. (5) is used to calculate the standard deviation of the survey dataset.

$$\bar{x} = \frac{(\sum n1 + n2 + n3 + n3 + n4 + \ldots + n15)}{n}$$
$$= ((86 + 78 + 78 + 77 + 77 + 71 + 58 + 59 + 64 + 54 + 53 + 59 + 31 + 26 + 52))/15 = 61.533$$
$$\bar{x} = \frac{\sum((n1 - \bar{x})^2 + (n2 - \bar{x})^2 + \ldots + (n15 - \bar{x})^2)}{(n-1)}$$
$$= [(86 - 61.533)2 + (78 - 61.533)2 + (78 - 61.533)2 + (77 - 61.533)2 + (77 - 61.533)2 + (71 - 61.533)2 + (58 - 61.533)2 + (59 - 61.533)2 + (64 - 61.533)2 + (54 - 61.533)2 + (53 - 61.533)2 + (59 - 61.533)2 + (31 - 61.533)2 + (26 - 61.533)2 + (52 - 61.533)2/(14)]$$
$$= [(24.5)2 + (16.5)2 + (16.5)2 + (15.5)2 + (15.5)2 + (9.5)2 + (-3.5)2 + (-2.5)2 + (2.5)2 + (-7.5)2 + (-8.5)2 + (-2.5)2 + (-30.5)2 + (-35.5)2 + (-9.5)2/(14)]$$
$$= [(600.25) + (272.25) + (272.25) + (240.25) + (240.25) + (90.25) + (12.25) + (6.25) + (6.25) + (52.56) + (72.25) + (6.25) + (930.25) + (1260.25) + (90.25)/(14)]$$
$$= 4152.06/14 = 296.58 = S = \sqrt{296.58} = 17.22$$

Using Eq. (6), the mean error is calculated: Standard error mean = 4.448506081. Furthermore, Table 6 provides the calculated mean; standard deviation and means error.

There are several reasons why calculating the standard deviation and standard error of the mean of a dataset can be useful [62], [63], [64]:

- Measure of dispersion: The standard deviation is a measure of how spread out the data is around the mean. It helps to understand the variability in the data and how closely the data points cluster around the mean. The standard error of the mean, on the other hand, gives an idea about the precision of the sample mean as an estimate of the population mean.
- Inferential statistics: Standard deviation and standard error of the mean are essential in inferential statistics, where you use sample data to make inferences about the population. For example, you can use the standard error of the mean to calculate a confidence interval for the population mean, or to perform hypothesis testing.
- Comparison of datasets: Standard deviation and standard error of the mean can be used to compare datasets. If two datasets have similar means but different standard deviations, it suggests that they have different levels of variability. Similarly, if the means of two datasets are different, but their standard errors are overlapping, it suggests that the difference between the means is not statistically significant.

C. IMPACT OF CRITICAL SUCCESS FACTORS ON SOURCING DECISIONS

The current subsection discusses the impact of critical success factors on decision making. The factors are used to evaluate the projects to make effective offshoring decisions of application maintenance. The CSFs are explained in the following subparagraphs, which show their impact on the sourcing decisions.

Employees Skills: It is the most important element among the derived criteria. It encompasses the knowledge, skills, IT skills and expertise of the employee. For example inexperienced people may contribute to a higher failure rate in outsourced projects since they are unable to handle problems fast and appropriately without sufficient help. Vendors with experienced staff and a broad skill set can supply high-quality products on time. Similarly, client-side resources with significant knowledge of the clients and processes along with the IT skills enable the customer to get services smoothly [65], [66], [67].

Poor Communication: Communication between the systems developers and other distributed resources at different stages of the software and also in the maintenance process is critical to the project's quality and timeliness. Global sourcing, on the other hand, brought difficulties such as cultural differences, language restrictions, and difference in time zones, all of which hampered communication between the scattered teams. In the GSD context, sometime questions remain unanswered due to missing frequent contacts or bad communication. As the programmers teams are distributed on sits make improper assumptions. Further, changes in the requirements are not transferred to the working teams in a timely manner, which presents issues in global software development. Due to the insufficient communication, the distributed project shows low productivity and faces significant difficulties [68], [69], [70], [71], [72], [73].

Cost: It is one of the primary drivers of offshore outsourcing, since it allows companies to reduce the overall cost of their projects. Organizations may save 30-50% on their costs by implementing an offshore strategy. While, on-site workers consume a significant amount of resources, increasing both production and transaction costs [24], [74].

Legal Requirements: GSD presents a number of obstacles; among them the legal restrictions are one of the most critical factors influencing outsourcing decisions. Data protection, Intellectual Property (IP) protection, confidentiality, employment and labor rights, export and import limits, privacy and data transfer restrictions, government approval for offshore, taxes, and currency exchange are just a few of the legal problems to consider. However, the most important concern is the intellectual property protection, which must be thoroughly examined and carefully considered before making the outsourcing choices [75].

Infrastructure: The service delivery process can be hampered by an unreliable communication infrastructure. Poor communication infrastructure in some nations might be a major disadvantage particularly in offshored projects that negatively impacts service quality as well as delivery. 'Internet connectivity', 'network', 'data communication', 'servers', 'data centers' and, 'application management' are all examples of infrastructure. The findings show that client with a stronger IT infrastructure and established processes are more likely to engage in offshore outsourcing [76], [77].

Maturity Level: Client maturity, past global experience, vendor maturity, and process maturity are all the sub-factors of maturity level. Both the client and the supplier must have worldwide experience in global outsourcing [44]. Similarly, robust processes allow the vendors to work in shifts and around the clock to complete the job quickly. Mature organizations are more capable to deal with global difficulties and maintain global services smoothly. Whereas, a vendor's lack of worldwide delivery knowledge can lead to service delays during the contract's initial stages [78], [79].

Frequent Requirements Changes: This factor consists of volatile requirements, unstable requirements, application portfolio changes, and the requirements that are imprecise [76]. Any change in the business process during the project's execution leads to changes in requirements. As a result, changing requirements necessitate periodic meetings with the customer to modify the changes. Similarly, language and cultural barriers can make the requirements collection step more difficult and time consuming. Likewise, modifications in the project scope may have a negative impact on service delivery [6], [78], [80].

Language Barrier: The service quality and ease of communication between scattered teams are affected by a language barrier. The employees of vendor must be native speakers providing remote helpdesk services and should be able to speak the client's language clearly; otherwise a communication gap would occur. Language differences may pose problems during the requirements collecting process, resulting in requirements that do not match the demands of the consumers [81], [82], [83].

Domain Knowledge: The customer believes that the vendor often lacks sufficient expertise and knowledge of the customer's business and application. As a result, a lack of understanding and experience related to the client application generates a range of issues, including delays in service delivery and a negative influence on product quality [84], [85].

Project Management: It plays a key role in the distributed projects as managing scattered teams around the world is a challenging task. Some of the primary challenges of worldwide software development are rapid changes in requirements, weak communication, and the synchronization that make more difficult the tasks allocation as well as scheduling [18], [86].

D. DECISION MAKING OF APPLICATION MAINTENANCE OFFSHORING

This section focuses on sourcing decision-making based on proposed conceptual framework and multi criteria decision making approach based on SMART.

1) DECISION MAKING USING PROPOSED FRAMEWORK

This section presents the selection of suitable model using the proposed conceptual framework based on 10 critical success factors. The proposed framework as given in Fig. 4, is an effective and user-friendly model based on Human Computer Interaction (HCI) principles that can be used by clients and vendors to make effective decisions. Recently, software engineering and HCI have significantly improved to meet the expectations and requirements of customers. User requirements and usability should be taken into account while creating an effective source frameworks and models. Usability is one of the important features of Human Computer Interaction. It is an HCI concept that helps people to utilize the developed systems, models and frameworks easily and guarantees that they have the required features and functions [87], [88].

Table 7, shows the decision making process of application maintenance as well as it helps to identify the appropriate sourcing model. The decision is based on the impact of factors (Low/Medium/High) which are discussed as follows:

In order to deal with IT offshoring, the service providers need to have a certain set of skills. IT projects in outsourcing context are Knowledge intensive.

The employees skills includes customer requirements, functional domain, technical expertise, and project knowledge. The knowledge of the vendor and the client is distinct

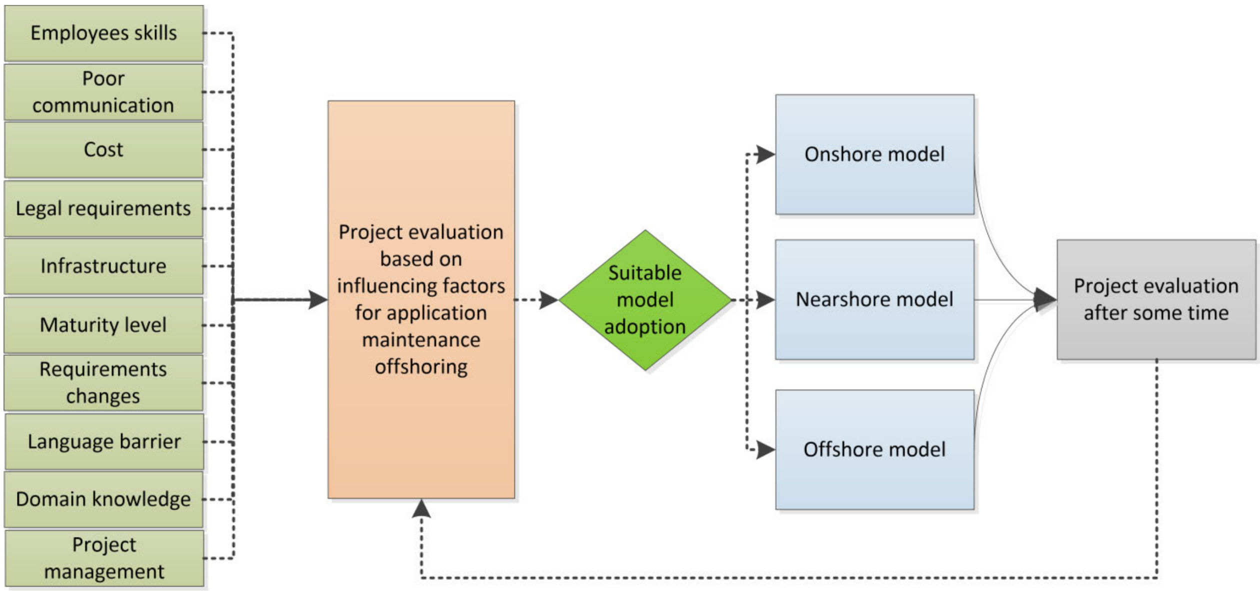

FIGURE 4. Sourcing model based on the 10 CSFs.

TABLE 7. Project evaluation based on factors' impact level.

Factors	Sub-factors	Influence level
ES	Availability of experienced human resources, employees' knowledge, skills, expertise and IT skills.	Low/Medium/High
PC	The impact of PC is analyzed based on factors and sub-factors such as cultural differences, language restrictions, and difference in time zones.	Low/Medium/High
Cos	sub-factors of cost are short project, long term project, multi-sourcing and project budget etc.	Low/Medium/High
LR	Data protection, privacy and data transfer, intellectual property, labor rights, confidentiality, restrictions such as exports and imports, government approval regarding sourcing and taxes on businesses, exchange of currency.	Low/Medium/High
Inf	Infrastructure includes data communication, network, data centers, servers, and internet connectivity.	Low/Medium/High
ML	Employees experience in global delivery, client maturity, maturity level of team and maturity in various processes.	Low/Medium/High
FRC	Requirements not clear, volatile requirements, requirements instability and application portfolio changes.	Low/Medium/High
LB	The impact of language is analyzed as using the global delivery models, distributed teams work from various countries to provide services.	Low/Medium/High
DK	It includes employees, knowledge and their application expertise.	Low/Medium/High
PM	Managing the scattered teams and rapid changes in requirements, contract and relationship management, weak communication, tasks allocation and scheduling.	Low/Medium/High

but complimentary. While the client has understanding of the requirements and the business area, the vendor has technical and project knowledge [89]. Similarly, Doney and Cannon [90] discussed that well-trained vendor workers can satisfy the customers. When a company's employees are competent and capable of keeping their promises, customers have higher faith in that company. According to Gunasekaran [91] the success of outsourcing depends on interactions between vendors and clients, such as the sharing of information and resources as well as collaboration and cooperation.

In GSD context the distance between a vendor and a client can cause communication issues. Holmstrom et al. [92]

TABLE 8. Criteria scores and calculating their weights.

Criteria	Rating	Standard weights= (rating/sum)100
Employees Skills	90	(90/540)100=16.7
Poor Communication	50	(50/540)100=9.3
Cost	100	(100/540)100=18.5
Legal Requirements	30	(30/540)100=5.6
Infrastructure	50	(50/540)100=9.3
Maturity Level	40	(40/540)100=7.4
Frequent Requirements Changes	60	(60/540)100=11.1
Language Barrier	20	(20/540)100=3.7
Domain Knowledge	40	(40/540)100=7.4
Project Management	60	(60/540)100=11.1
Sum= $\sum_{j=1}^{m} Wj$ =	540	

discussed that cultural, temporal, and geographic distances have an impact on communication and coordination. Similar to this, Leischnig et al. [93] indicates that interaction improves the success of inter-organizational relationships. Therefore, the success of outsourcing is positively impacted by interaction skills and it motivates the selection of offshore model. On the other hand, poor communication motivates to select the onshore model.

According to Gunasekaran et al. [91] the commitment to offshoring could affect interaction between the provider and customer. Lee and Kim's [94] study supports this claim by showing that partnerships are impacted by top management support. The partnership may be impacted by a company's capacity for supplying, hiring, and maintaining qualified workers for the outsourced project. Therefore, it may be said that management ability has a positive effect on sourcing decision and it motivates for offshoring.

The factors such as lack of detailed specifications, ambiguous requirements, and project specificity all have a significant impact on global IT development. Both the vendor and the client must establish collaboration when working on an IT project [95]. Similar to this Beulen et al. [6] have discussed that any change in the business process at the time of project's execution, leads to changes in requirements. As a result, changing requirements necessitate periodic meetings of customer and vendor.

Bhatt et al. [24] discussed that cost is one of the main drivers of global sourcing, since it allows the companies to reduce the overall cost of their projects. Organizations may save 30-50% by implementing an offshore strategy [74].

The selection of a suitable model is affected highly by data protection, privacy and data transfer, intellectual property, labour rights, confidentiality, restrictions such as exports and imports, government approval regarding sourcing and taxes on businesses, exchange of currency. The project with high legal issues is suitable to be delivered using onshore model. Whereas, it could be delivered from the nearshore location by overcoming the legal issues [75]. Rahman et al. [17] presented that infrastructure such as data centers, networks and internet connectivity are important at GSD. These factors should be considered during the decision making process of application maintenance. The distributed teams across countries speak different languages that create confusion in requirements understanding and resolving issues. Language hurdles can impede progress and result in miscommunication [20].

2) MULTI CRITERIA DECISION MAKING USING SIMPLE MULTI-ATTRIBUTES RATING TECHNIQUE

To simplify the decision making of application maintenance as shown in Table 7, and to increase the understanding and usability of the proposed model, multi attribute decision making method is adopted. For this purpose a case study is performed in the software industry from the vendor's perspective. The multi attribute method, SMART is adopted to rank the sourcing alternatives. The IT expert with 15 years of software industry experience assigned values to the criteria and alternatives on the scale of 0-100. Where 0 is the lowest and 100 is highest score. The various steps of SMART are discussed as follows:

Calculating the Criteria Weights: The ratings of criteria along with their respective weights are given in Table 8. The normalized weighting is calculated using Eq. 1 i.e., dividing each criterion score by the total weight.

Ranking of Alternatives: Similarly, the decision-maker assigns ratings to the available alternatives based on scale 0-100, against each factor. Table 9 shows ratings of alternatives along with maximum, minimum and maximum-minimum values in each column.

Using Eq. (2) and (3) the utility values (cost criteria and benefit criteria) i.e., are calculated (Table 10). Among the 10 criteria only 4 are cost factors: PC, LB, LR and FRC. Whereas, the remaining criteria are considered as the benefit factors.

Using Eq. 4, the overall weight of each alternative is obtained by multiplying the weights of criteria with the partial

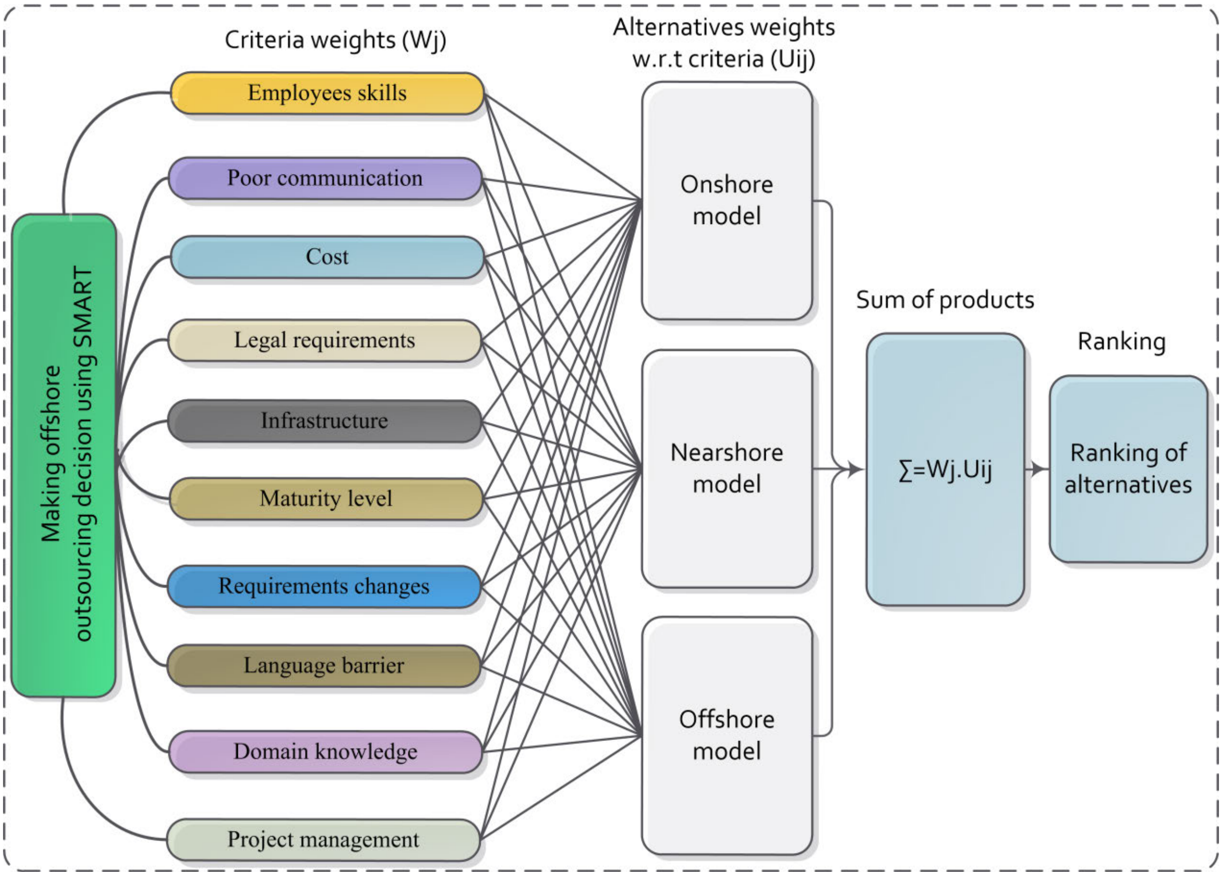

FIGURE 5. Adoption of sourcing strategy.

TABLE 9. Ratings of alternatives w.r.t criteria.

Alternatives	ES	PC	Cos	LR	Inf	ML	FRC	LB	DK	PM
Onshore model	50	40	50	20	50	60	40	10	50	70
Nearshore model	60	40	70	20	50	70	50	20	60	70
Offshore model	80	50	100	30	40	80	50	20	80	80
Maximum	80	50	100	30	50	80	50	20	80	80
Minimum	50	40	50	20	40	60	40	10	50	70
Maximum-Minimum	30	10	50	10	10	20	10	10	30	10

TABLE 10. Calculating utility values.

Alternatives	ES	PC	Cos	LR	Inf	ML	FRC	LB	DK	PM
Onshore model	0.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	0.00
Nearshore model	0.33	1.00	0.40	1.00	1.00	0.50	0.00	0.00	0.33	0.00
Offshore model	1.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00

weights of alternative (utility weights) with respect to criteria and then all the values are added (Table 11).

The result indicated that offshore model is 61.11, the nearshore model is 43.21, and the onshore model is 38.89. Thus, the offshore model has been ranked highly, followed by nearshore model, and onshore model. As a result, the offshore model is the most appropriate option for application maintenance among the available alternatives.

V. STUDY LIMIATIONS

This study presented a dynamic sourcing model based on 10 critical success factors. The proposed model shows the decision making of application maintenance in the context

TABLE 11. Weights of alternatives.

	Criteria weights										
	16.7	9.3	18.5	5.6	9.3	7.4	11.1	3.7	7.4	11.1	
Alternatives	ES	PC	Cos	LR	Inf	ML	FRC	LB	DK	PM	Alternative ranking $\sum_{j=1}^{k} Wj.\text{Uij}$
OM	0.00*16.7	1.00*9.3	0.00*18.5	1.00*5.6	1.00*9.3	0.00*7.4	1.00*11.1	1.00*3.7	0.00*7.4	0.00*11.1	38.89
NM	0.33*16.7	1.00*9.3	0.40*18.5	1.00*5.6	1.00*9.3	0.50*7.4	0.00*11.1	0.00*3.7	0.33*7.4	0.00*11.1	43.21
OfM	1.00*16.7	0.00*9.3	1.00*18.5	0.00*5.6	0.00*9.3	1.00*7.4	0.00*11.1	0.00*3.7	1.00*7.4	1.00*11.1	61.11

of offshore outsourcing. The CSFs were identified in two phases: firstly, a systematic literature review was conducted [17] that identified a list of 15 factors. The influencing factors were derived from 52 selected papers. Then, an empirical study was conducted [44] to evaluate the factors and find their impact on sourcing decisions. Accordingly, an online questionnaire based survey was conducted based on the results of SLR. The two phases: systematic literature review and empirical investigation ensures the contents validity. Threats to validity concerning the identification of influencing factors using SLR are given in [17].

Similarly, study limitations regarding the questionnaire based survey and sample size are presented in [44]. The scope of this study is to propose a dynamic sourcing model and to address the decision making process of application maintenance offshoring. The proposed conceptual model based on the CSFs, showing the decision making process. However, making sourcing decision based on the proposed model requires expertise and prior experience in the offshore outsourcing. The proposed model does not have automation and need to be automated in the future to make effective and automated sourcing decisions. Similarly, the SMART has been applied to evaluate the alternatives and select the appropriate option for the application maintenance. However, the result obtained using the SMART needs to be compared with other available multi criteria decision making approaches.

VI. CONCLUSION AND FUTURE WORK

Companies are increasingly reliant on software systems, which need ongoing modification, maintenance, and upgrades. On the other hand, businesses are actively seeking to manage expenses associated with software systems that have entered the maintenance phase. The current study analyzed the application maintenance offshoring related factors based on standard deviation, mean and standard mean error. The factors were further evaluated showing their impact on offshoring decisions. In addition, we proposed an effective and user-friendly model based on the CSFs. It assists the clients and vendors to evaluate the projects prior to offshoring decisions. To enhance the decision-making process a case study was conducted in the IT industry. The multi attribute decision making method, SMART was applied for ranking the available options of the application maintenance services. The result indicated that the offshore model has been ranked highly (61.11), followed by nearshore model (43.21), and onshore model (38.89). As a result, the offshore model is the most appropriate option for application maintenance among the available alternatives. The proposed framework and multi criteria model assist the vendors and clients in adopting a suitable delivery model for global IT services. The proposed framework and SMART based model are used to adopt effective sourcing strategy. In the future, Decision Making Trial and Evaluation Laboratory (DEMATEL) approach will be used to evaluate the identified factors and find their interrelationship. Further, it would be interesting to develop a sourcing decision model using fuzzy logic. It will automate and simplify the complex decision-making process of application maintenance.

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