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Analysis of Factors Affecting Decision-Making Process of Offshore Application Maintenance using ISM Approach

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Abstract – Software maintenance has the longest lifespan and requires roughly 60% of the total budget of software development life cycle. Organizations are seeking ways to reduce the software maintenance costs. Therefore, companies use offshore outsourcing to reduce costs by using low-cost countries' cheaper and more skilled labour. This research seeks to analyse the factors impacting the decision-making process and also identifies their structural associations. To fulfil the research objectives, first, the factors are evaluated by the IT specialists using online survey. Second, an ISM approach is implemented creating an ISM model based on factors' interrelationships. Five elements are prioritized in the first level: cost savings, infrastructure, domain expertise, project management, and requirement adjustments. These depend on second-level variables including employee skills, inadequate communication, and language barrier. The third level includes legal requirements and maturity. Further, this study classifies elements into three tiers based on their impact on the decision-making process. The findings of this study help service providers and clients to adopt effective sourcing strategies, increasing project success and saving projects' costs.

Keywords: Application maintenance, factors, structural association, ISM approach, decision making, outsourcing, offshoring

1. Introduction

The rapid adoption of Global Software Development (GSD) has significantly transformed the IT industry by introducing global delivery models that reshape software firms' working environments [1, 2]. The increasing competitiveness for skilled yet cost-effective labour, alongside advancements in IT and communication, has driven the outsourcing of software projects to specialized service providers in countries with lower labour costs, such as India, China, and Vietnam [3, 4]. This approach enables organizations from industrialized nations, including the United States, Japan, Australia, and the United Kingdom, to reduce production costs while enhancing overall performance [5]. IT outsourcing encompasses various subcategories, including software maintenance, business process outsourcing, software development, and infrastructure outsourcing. Software maintenance, which accounts for over 60% of a company's software development budget, is particularly reliant on offshoring strategies to mitigate expenses, achieving cost savings of 20-50% [6, 7, 8, 9].

Offshore outsourcing also offers several strategic benefits, such as reducing development and maintenance expenses, improving productivity, optimizing resources, and accessing the global market, fostering business innovation, and leveraging a highly skilled workforce [10, 11, 12]. Despite its advantages, GSD presents unique challenges not found in traditional software development. These include difficulties in communication, coordination, control, task assignments, legal compliance, and cultural differences among distributed teams [2, 13, 14]. If these challenges are not adequately assessed, they can negatively impact project budgets, schedules, and quality. Additionally, software estimation largely depends on expert judgment, and inadequate understanding of these challenges and their interdependencies may result in inaccurate predictions [15].

This study aims to evaluate key factors influencing offshore service provision in GSD using the Interpretive Structural Model (ISM) technique. By gathering insights from software outsourcing experts via an online survey, the research identifies interdependencies among these factors to enhance decision-making processes. The findings will assist decision-makers, practitioners, suppliers, and clients in selecting appropriate outsourcing models and optimizing offshoring strategies [16, 17].

2. Study background

Software development outsourcing is a business strategy that has been widely adopted over the past twenty years. It can be concisely defined as a collaborative agreement between a client and a vendor to create quality and cost-effective software across international boundaries. Usually, this partnership involves clients from developed nations and vendors from developing countries. In this collaboration the software is developed at the vendor's location and subsequently delivered to the client [18].

The following paragraphs present research studies showing the use of ISM in global software development. Ali et al. [18] conducted an SLR to pinpoint 27 barriers related to software outsourcing partnership. Subsequently, a survey comprising 50 experts from 20 different countries was carried out to examine the connections between these barriers. Further, to uncover the interdependence among these barriers the ISM technique was employed. Khan et al. [19] investigated the most important practices of the requirements engineering within the context of global software development. Through an empirical investigation, they examined 70 practices and classified them into 11 key categories. These dimensions serve as a valuable resource for GSD organizations when defining requirements for secure software development. Kannan et al. [20] introduced a multi-criteria group decision-making framework designed to facilitate the selection of the most suitable Third-Party Reverse Logistics Providers (3PRLP). It examines the interdependencies between various criteria to choose 3PRLP from among 15 alternatives. The study employs ISM and Fuzzy TOPSIS to conduct the analysis. Kumar and Dixit [21] utilized the ISM and Decision-Making Trail and Evaluation Laboratory (DEMATEL) to comprehend the hierarchical and contextual interrelationship structure among the elements of electronic waste management. The innovative model proposed in this research aids decision-makers in identifying the mutual relationships and interconnections among the barriers. In the initial phase of research, conducted by Ali et al. [22] investigated the factors and predictors through SLR and empirical survey for cloud adoption concerning software testing. After that, an Artificial Neural Network (ANN) was employed for the purpose of assessing the non-linear impact of these predictors. Furthermore, in light of the survey results, a group of ten specialists was chosen to examine the intricate connections among these influential factors via the ISM technique. To streamline the comprehension of the findings, the researchers utilized the Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) method for the classification of these factors.

Rafi et al. [23] classified the test practices based on the pillars of DevOps adoption principles, namely Culture, Automation, Lean, Measurement, and Sharing (CALMS). Subsequently, a survey using a questionnaire was performed to gather insights from professionals about the DevOps test practices and how they align these with the CALMS criteria. Mathiyazhagan et al. [24] performed a research study that comprised of three distinct research phases. First, barriers were identified using the literature review, and from experts' interviews. This phase resulted in the selection of twenty-six barriers. After that, they employed ISM to find out the interrelationships among these twenty-six barriers. Yang et al. [25] developed an integrated fuzzy MCDM method that provides a more effective approach for selecting the best vendor. They combine the Fuzzy AHP and ISM approach for vendor selection. Similarly, Beikkhakhian et al. [26] identified the factor to evaluate the agile suppliers. Using the ISM approach these criteria are ranked and categorized. After that, the fuzzy hierarchical analysis technique is used for finding weights of the criteria, which are used as inputs for the TOPSIS model. Accordingly, six suppliers are evaluated using the fuzzy TOPSIS technique. Hassan and Asghar [27] integrated two methods i.e., ISM with the DEMATEL. These approaches were utilized to identify the interrelationships among the elements and to evaluate their dependencies. To assess these relationships, experts were contacted both in academia and the software development industry.

3. Proposed research method

To achieve the research objectives, a list of critical factors are adopted from the literature. Additionally, the second phase involves an online survey for evaluating the factors in software industry, and implementing the ISM approach. All the steps in the research phases are presented below in detail.

3.1. Identifying factors

The identification of factors was carried out through a two-step process, involving the execution of an SLR and an empirical investigation. Rahman et al. [16] identified 15 factors using systematic literature review. Furthermore, they performed an empirical study [17], highlighting 10 factors as the most important for decision-making.

3.2. Performing Online survey

This survey focuses on receiving the experts' opinions, and for this purpose, a questionnaire is developed and distributed in order to construct contextual relationship among the factors [28]. This data collection strategy was also employed by other researchers [19, 24, 25] in the field of software engineering. The complete details of the online survey are provided in the following sections.

Adopting online questionnaire based surveys for data collection is more effective technique compared to other observational approaches [29, 30, 31, 32]. The questionnaire is designed in Google form and on its top a brief explanation of the survey's purpose is given. The subsequent section, i.e., Section 1 outlines respondent demographics, and Section 2 contains the factors that are included for the assessment by the outsourcing experts. In order to establish connections between the factors, IT experts are requested to provide their insights using four options which are discussed as below [20, 26, 33].

- "V' denotes the relationship where factor i contributes to the achievement of factor j, but factor j does not contribute to the achievement of factor i.
- A' denotes the relationship where factor j contributes to the achievement of factor i, but factor i does not contribute to the achievement of factor j.
- X' shows the relationship where both factors i and j contribute to the achievement of each other.
- O' shows the relationship where both factors i and j have no relationship.

Before distributing the questionnaire, it is tested with the help of IT experts to simplify and improve the questionnaire. IT experts and software engineers are reached through Gmail and social networking sites such as LinkedIn and Research Gate. In addition, specific outsourcing/offshoring groups on LinkedIn are focused for targeting the appropriate population.

3.3. Implementing ISM

The ISM technique is based on graph theory to represent the complex structure of interconnections [34, 35, 36]. It uses an interpretive approach, incorporating insights from both academic and industrial experts, to determine the relative associations among identified barriers. These barriers can be interconnected or independent and may exert either positive or negative influences on a specific problem within the research. Importantly, unlike Fuzzy TOPSIS, AHP, and ANP, the ISM method does not necessitate the establishment of a dominant level of barriers to establish connections between factors. This feature reduces the influence of subjectivity and bias on the part of the experts, thereby facilitating the formation of connections among different predictors and thus enhancing the reliability of the model community [37, 38]. "Fig. 1" shows the steps for implementing the ISM approach to determine the interrelationship among the factors. The steps involves in implementing the ISM approach are Identifying the relevant factors, constructing Structural Self-Interaction Matrix (SSIM), making an initial reachability matrix, obtaining final reachability matrix, partitioning of reachability matrix, creating the conical matrix and diagraph [18, 39].

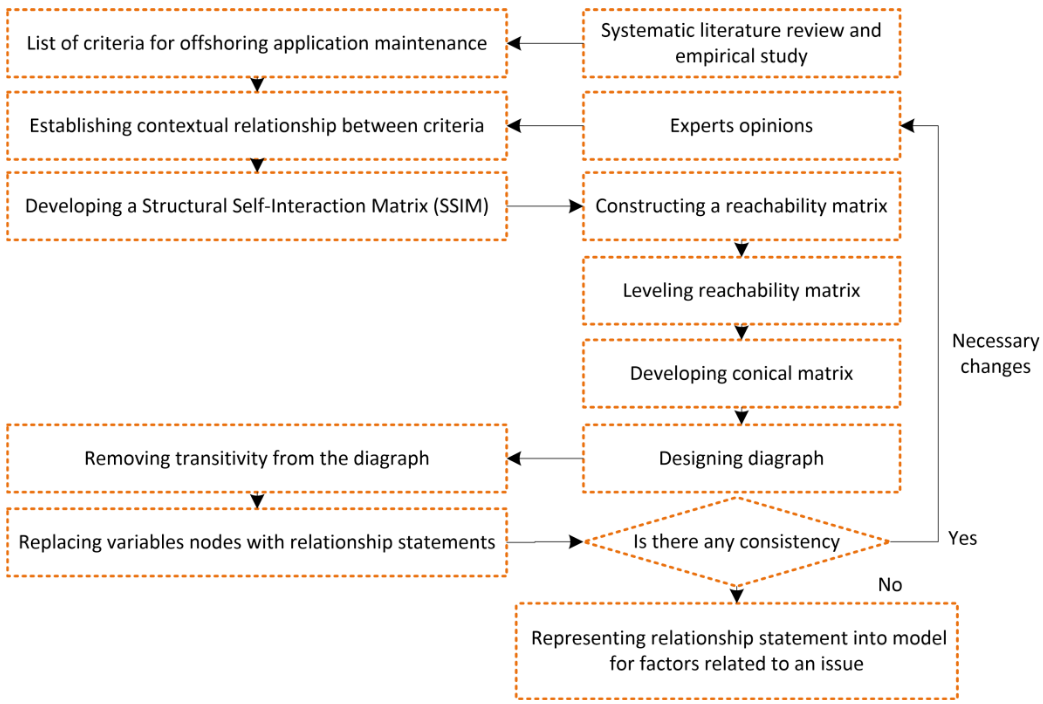

Fig 1. Flow diagram of ISM based model

4. Results and analysis

Conclusions should state concisely the most important propositions of the paper as well as the author's views of the practical implications of the results.

4.1. Influencing factors

The identified critical factors are employee skill, cost savings, poor human communication, infrastructure, legal issues, the degree of employee resource maturity, rapid changes in requirements, language constraints, domain and application knowledge, and project management. The ISM approach is employed to predict the interrelationship among these factors.

4.2. Assessing derived factors using online survey

In order to implement the ISM approach, first the derived factors are assessed using an online questionnaire. The questionnaire is comprised of factors regarding application maintenance and its decision making. To select the suitable experts for the survey, different outsourcing and offshoring groups on LinkedIn were searched out, ResearchGate was used, and also the authors of relevant publications were contacted through their given emails. In the current research study, a total of 15 experts participated including three from academia (researchers/professors), and twelve from industry (freelancers, decision makers, consultants and managers). The experience level of experts is (5-10 years) in offshore outsourcing and decision making. There exists the possibility to generalize the study's findings due to the smaller size of the sample. However, the literature shows that Kannan et al. [20] used five experts' response for choosing the reverse logistic providers. Soni et al. [40] utilized a group of nine relevant experts for investigating the urban rail transit system contributing to its complexity. Similarly, Attri et al. [21] analyzed success factors for productive maintenance using ten experts. Rafi et al. [23] implemented ISM by selecting five experts to analyze the DevOps best practices.

4.3. ISM based analysis

The ISM technique investigates and analyzes the interrelationships among the derived factors affecting the decision making in the GSD context. This method is adopted to examine the contextual interaction of factors. ISM is implemented by adopting the following steps.

4.3.1. Structural self-interaction matrix

Structural Self Interaction Matrix (SSIM) matrix is required to develop the contextual interaction between the criteria [24]. SSIM is constructed on the basis of experts‟ opinions for the purpose of analyzing the extracted factors. Additional feedback rounds were used with experts to validate the basic SSIM. This was accomplished by sending the developed SSIM to specialists via research Gate, LinkedIn, and emails. Then we adjust the changes in light of the input received from the experts. Accordingly, the SSIM matrix was developed and finalized as given in Table 1.

Table 1: SSIM of the extracted factors.

Criteria	10.PM	9.DK	8.LB	7.RC	6.ML	5.Inf	4.LR	3.Cos	2.PC	1.ES
1.Employee Skills (ES)	X	X	V	O	X	O	O	V	O	-
2.Poor Communication (PC)	X	O	A	O	O	A	O	V	-	
3.Cost Saving (Cos)	X	A	A	A	A	X	A	-		
4.Legal Requirements (LR)	V	O	O	O	O	O	-			
5.Infrastructure (Inf)	V	O	O	O	O	-				
6.Maturity Level (ML)	V	X	O	O	-					
7.Requirements Change (RC)	A	O	O	-						
8.Language Barrier (LB)	X	O	-							
9.Domain Knowledge (DK)	A	-								
10.Project Management (PM)	-									

The following paragraph shows some of the factors' relationships. The factors affecting each other are represented by X. Therefore, "ES and PM", "ES and DK", "ES and ML" are showed by X. Similarly, if ith criteria address jth criteria then it is represented by V. So "ES and LB", and "ES and Cos" are showed by V. Likewise, if criteria jth achieves ith then represented by A such as "PC and LB", and "PC and Inf". Finally, if both the criteria do not have relationship, that is represented by O such as "ES and RC", and "ES and LR".

4.3.2. Reachability matrix

The SSIM matrix is changed in this step into reachability matrix by putting the binary values (0‟s and 1‟s) of symbols (V, A, X, and O).

After achieving the initial reachability matrix, the transitivity guidelines are taken into consideration to calculate the final reachability matrix. It states that if an attribute "A" is connected to attribute "B" and further attribute "B" is associated to attribute "C," then attribute "A" is certainly associated with attribute "C". Each factor's dependency and driving power as shown by column and row are listed in Table 2. To determine the factor's driving power, the total numbers of 1‟s are added in each row of the final RM. Whereas, total 1's are counted and added in each column to identify the dependence power of factor. The final reachability matrix is used for factors' level partitioning in order to construct an ISM hierarchical structure.

Table 2: Final reachability matrix.

Criteria	1.ES	2.PC	3.Cos S	4.LR	5.Inf	6.ML	7.RC	8.LB	9.DK	10.PM	DP
1.ES	1	1*	1	0	1*	1	1*	1	1	1	9
2.PC	1*	1	1	0	1*	0	1*	1*	1*	1	8
3.Cos S	1*	1*	1	0	1	0	1*	1*	1*	1	8
4.LR	1*	1*	1	1	1*	0	1*	1*	1*	1	9
5.Inf	1*	1	1	0	1	0	1*	1*	1*	1	8
6.ML	1	1*	1	0	1*	1	1*	1*	1	1	9
7.RC	0	0	1	0	1*	0	1	0	0	1*	4
8.Lb	1*	1	1	0	1*	0	1*	1	1*	1	8
9.DK	1	0	1	0	1*	1	0	1*	1	1*	7
10.PM	1	1	1	0	1*	1*	1	1	1	1	9
Dependence (DP)	9	8	10	1	10	4	9	9	9	10	

4.3.3. Levels' partition of the factors

Both the reachability set and antecedent set for every element are calculated from the final reachability matrix in accordance with the recommendations of Farris and Sage [41] and Warfield [42]. The factor (i) itself and other factors that can be reached from that specific factor (i) make the reachability set. It includes the factor that each column represents if it has a score 1 in the row of the considered factor (i). In a similar way, the factor (i) and other attributes that could reach it make the antecedent set. The factor that a row represents is part of the antecedent set for each row that has a value of 1 in the column of the considered factor (i). The intersection is derived after deriving the reachability set and antecedent set of each attribute, and accordingly the levels of various elements are determined.

The factors that are on the top of the hierarchy cannot reach the factors above their level. Therefore, the reachability set of factor i at the top including that factor (i), and any other factor of the same level to which factor I can reach. Likewise, antecedent set is comprised of factor i which is the top level factor; and any other factor reaching it from the levels below it, and any other factor of a strongly connected subset including the factor (i) in top level. Consequently, the intersection of reachability and antecedent sets will be similar to reachability set [41, 43].

After finding the top level factor, it is eliminated from the list of factors to be considered, and new top level factors belong to the remaining list are identified. This process is continued until all levels of required hierarchy are found. The identified factors' levels help to develop digraph and also used to make final ISM model. The factor at the top level is placed at the top of the digraph and this process is continued until the complete diagraph is achieved. In the current case, Tables 4 shows the selected 10 factors along with their calculated reachability set, identified antecedent set, intersection set and their levels.

This table shows the levels' partition summary i.e., factors 3, 5, 7, 9 and 10 have similar reachability and intersection sets. Therefore, these attributes are separated and positioned in Level 1. Thus, according to the principles of ISM approach, factors in level 1 are removed from the table. This partition process is further continued using the remaining factors till all factors' levels are identified. In this way, level 2 factors are derived based on reachability set, antecedent set, and intersection set which is followed by the identification of level 3 factors namely, factors are 7 and 8.

Table 3: Level partition's summary.

Factors	Reachability set	Antecedent set	Intersection set	Level

3. Cost saving	1,2,3,5,7,8,9,10	1,2,3,4,5,6,7,8,9,10	1,2,3,5,7,8,9,10	1
5. Infrastructure	1,2,3,5,7,8,9,10	1,2,3,4,5,6,7,8,9,10	1,2,3,5,7,8,9,10	
7.Requirements change	3,5,7,10	1,2,3,4,5,6,7,8,10	3,5,7,10	
9. Domain knowledge	1,3,5,6,8,9,10	1,2,3,4,5,6,8,9,10	1,3,5,6,8,9,10	
10. Project management	1,2,3,5,6,7,8,9,10	1,2,3,4,5,6,7,8,9,10	1,2,3,5,6,7,8,9,10	
1. Employees skills	1,2,6, 8	1,2, 4,6,8	1,2, 6,8	2
2. Poor communication	1,2, 8,	1,2, 4,6,8	1,2, 8	
8.Language barrier	1,2, 8	1,2, 4, 6,8	1,2, 8,	
4. Legal requirements	4	4	4	3
6. Maturity level	6	6	6	

4.3.4. Developing conical matrix

Conical matrix is established by grouping the factors of the same level across the rows and columns of final reachability matrix [28, 44] as depicted in Table 4. Similarly, the driving power is obtained by adding all the 1's in rows and the dependence power is identified by adding all 1's in columns.

Table 4: Conical matrix

Criteria	3.Cos	5.Inf	7.RC	9.DK	10.PM	1.ES	2.PC	8.LB	4.LR	6.ML	D.P
3.Cos S	1	1	1	1	1	1	1	1	0	0	8
5.Inf	1	1	1	1	1	1	1	1	0	0	8
7.RC	1	1	1	0	1	0	0	0	0	0	4
9.DK	1	1	0	1	1	1	0	1	0	1	7
10.PM	1	1	1	1	1	1	1	1	0	1	9
1.ES	1	1	1	1	1	1	1	1	0	1	9
2.PC	1	1	1	1	1	1	1	1	0	0	8
8.LB	1	1	1	1	1	1	1	1	0	0	8
4.LR	1	1	1	1	1	1	1	1	1	0	9
6.ML	1	1	1	1	1	1	1	1	0	1	9
Dependence	10	10	9	9	10	9	8	9	1	4	

4.3.5. Developing ISM based model

An initial digraph is generated on the basis of conical matrix that includes transitivity links. This diagraph is developed by the number of edges and nodes [45, 46]. "Fig. 2" depicts the ISM model which is developed after eliminating the indirect links showing relationship among the factors. It shows that the given factors are arranged in three levels in the hierarchical form.

In this model, the top level factor is included at the top and second level factors are added at second position and this process is continued unless the bottom level factors are placed at the lowest position in the ISM model. Five factors, namely, cost saving, infrastructure, domain knowledge, project management and requirement changes are placed on top level of the hierarchical system depending directly on the second level's factors: employees skills, poor communication and language barrier. Level 3 has two factors, namely legal requirements and maturity level. Similarly, the factors on level 2 are achieved by the lower level III which are legal requirements and ML.

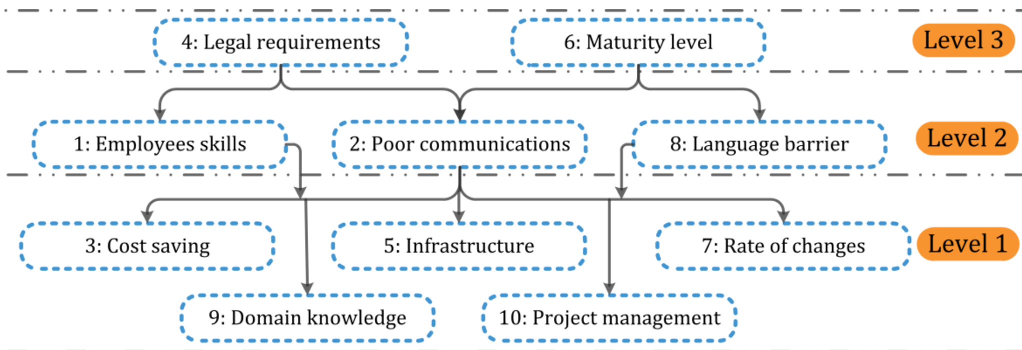

Fig. 2: ISM based criteria model.

4.3.6. MICMAC analysis

It was performed to assess the driving as well as the dependence power of the extracted factors [47, 48]. It shows the categorization of factors into four clusters: autonomous, dependent, independent and linkage criteria.

6. Conclusion and future work

The main objective of this study is to understand the complex interrelationships among the factors for decision making. In this study, a list of 10 critical factors that have impact on application maintenance and its decision making were evaluated using the ISM approach. Using the online questionnaire survey, the experts' judgments were received on the given factors. As a result, 15 responses were received and accordingly the structural self-interaction matrix was developed which was converted into the reachability matrix. It was followed by the identification of factors' levels showing their impact on decision making. Finally, an ISM based criteria model was developed that categorized the factors into three hierarchical levels. Level 1 factors are cost savings, infrastructure, domain knowledge, project management, and requirement changes which are directly influenced by level-2 factors, namely employee skills, poor communication, and language barriers. The third level consists of legal requirements and maturity level. This categorization helps the decision makers in selecting suitable models for software projects. It provides clear insights into which influencing factors serve as the key drivers and which are more influenced by other attributes. The ISM approach revealed the categorization and prioritization of the given factors, offering an effective framework for decision-makers to select suitable strategies for projects. Similarly, it is intended to enhance the developed ISM based model by combining tow multi criteria decision making techniques AHP and TOPSIOS. In addition, we are planning to propose a hybrid decision support model for application maintenance that combines the ISM approach and ANN.

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