Prioritizing Critical Success Factors of Requirements Engineering using Analytical Hierarchy Process

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Abstract

Requirements engineering is not as straightforward as asking stakeholders what they want the information systems to do. In most cases, their vision tends to be limited by the status quo. Eliciting a complete set of requirements that fulfil every gap and withstand scrutiny during validation is challenging. Hence, it is important to consider various factors influencing the success of requirements engineering. This paper identifies and prioritizes multiple critical success factors of requirements engineering using the Analytical Hierarchy Process. The initial model was developed from a literature review and validated using evidence from an empirical study. Quantitative data was collected through a questionnaire and then analyzed to rank the success criteria and critical success factors. The results show that user satisfaction is the most important success criterion. Meanwhile, clear definition of project scopes and goals is the most critical factor for the success of requirements engineering.

Keywords: Critical Success Factors, Requirements engineering, Analytic Hierarchy Process, software development, ranking.

Introduction

The role of information systems (IS) in an organization is critical. This technology has been proven effective in accelerating bureaucracy, optimizing resources, reducing costs, and improving decision-making (Zeng et al. 2020). Consequently, the need for IS development is increasing. However, developing good IS is complex and resource-intensive, involving cross-functional or cross-organizational groups. Various factors cause the success of IS development.

IS development success or failure factors are common topics discussed in the literature. Various perspectives, methodologies, and research objects have been applied to research this topic, such as IT project failure factors in Hungary (Aranyossy et al. 2017), outsourced IT project failure factors (Verner and Abdullah 2012), and exploratory studies of IT project failures in emerging markets (Ebad 2018). Apriyanto and Putro (2018) conducted a study to investigate the failure rate of IS projects in Indonesia involving various company sizes, project scales, and project complexity. The study showed that out of the 110 projects studied, only 27% were declared successful. The research also concluded that several factors affect the level of project success, namely the complexity of the system, the size of the company,

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and the size of the project. The highest project success rate was found in low complexity small-scale projects in large companies.

Previous studies have categorized the success factors of IS development projects. For example, Yeo (2002) classifies success factors into process-driven, context-driven, and content-driven. In addition, Sudhakar (2016) divided project management failure factors into six categories: environmental, organizational, team, project, and technology. Meanwhile, Khanfar et al. (2018) classified and ranked the factors into the organization, project management, team, planning, and user categories. They also found that planning is the category of factors that has the highest effect on the success of IS development projects. Planning failures include failure to formulate requirements, unrealistic scheduling and budgets, and cost and time estimates errors. Within the planning category, requirements collection and management is the factor that has the most significant effect for project failure (Khanfar et al. 2018).

Requirements are a statement about system capabilities that all stakeholders must agree upon before modelling (Hussain et al. 2016). Requirements are the source of product development's design, implementation, and validation phases. Compiling requirements by systematically studying, analyzing, and refining users' needs is called requirements engineering (RE) (Hofmann 2013). The main result of RE is called system specification, which is a brief statement of the requirements that the system must meet to fulfil a contract or standard (IEEE 1996). Thus, poor requirements collection and management primarily affect IS development project success or failure (Fricker et al. 2015). Khan et al. (2013) assert that RE is a complicated and crucial phase because unclear requirements are the main reason for IS development project failure. Young (2004) stated that IS development project failures are often related to inadequate, unclear or not well documented requirements, or having excessive expectations. Therefore, RE is an essential component and must be considered in every software development project. Nonetheless, this area is given less attention than it needs. Many projects start with a list of basic requirements, which may not accurately capture the users' needs.

RE has several challenges. The main constraints of the RE processes lie in the tools used, documentation, user involvement, traceability, the adaptation of techniques to the processing context, and the number of sources of requirements (Juristo et al. 2002). Moreover, in specific domains such as the online gaming industry, difficulties in RE include fulfilling market demands, involving genuine users, and meeting non-functional requirements (Alves et al. 2007). These problems increase the chances of software development project failure. Therefore, it is important to identify factors that can reduce or overcome these problems to increase the chances of project success. This study defines these factors as critical success factors (CSF).

Several previous studies have discussed CSFs of the RE processes, such as user engagement and feedback, team member expertise, and organizational culture (Kauppinen et al. 2004; Khan et al. 2013; Shafiq et al. 2020). Although previous studies have explored CSF of RE, CSF ranking needs to be done to see which factors are the most crucial and thus can be prioritized by IS development teams. The relevant factors may significantly improve the requirement coverage and decrease requirements-related problems during software development. However, limited attention has been given to this problem.

Therefore, this study identifies, categorizes, and ranks CSFs based on the significance of their effect on RE success. The goal is to help IS development teams implement best practices by prioritizing the CSFs with the most potential to increase RE success. Therefore, the research question of this study is "What are the most influential factors in determining the success of RE?"

Literature Review

Software Development Life Cycle

Software development life cycle (SDLC) is a method by which software is developed systematically to increase the likelihood of project completion success that abides by deadlines and budgets and has the right quality (Mishra and Dubey 2013). Although various variations exist, SDLC generally includes the following series of activities (Klopper et al. 2007):

1. Understanding the problem through requirements gathering
2. Planning for a solution (system design)
3. Implementing code
4. Perform testing
5. Launching products
6. Maintaining products

Two of the widely used SDLC are Waterfall and Agile. As one of the earliest methodologies used massively, the waterfall laid the foundation for various succeeding methodologies. Waterfall encourages the definition of requirements before implementation (Ruparelia 2010). Agile also emphasizes the importance of RE (Ochodek and Kopczyńska 2018).

Requirements engineering

Requirements engineering is a branch of software engineering that focuses on a computer system's purpose, functions, and limitations. It reflects accurate specifications of the system being developed as the basis for the requirements analysis and validation process against stakeholder needs (Nuseibeh and Easterbrook 2000). In simpler terms, Sommerville (2010) defines RE as the process of searching, analyzing, documenting, and validating the services and limitations of an IS. The collected requirements can be divided into two types, i.e., user and system requirements. User requirements are statements in natural language and diagrams covering what services the system provides to its users. Meanwhile, system requirements are detailed descriptions of a system's functions, services, and operational limitations. The system requirements document, usually called a functional specification, should define what will be implemented and may be part of the contract between the client and the vendor (Sommerville 2010). RE processes consist of a series of activities that are interconnected to produce a requirements document, such as assessing the usability of the system to the business (feasibility study), tracing requirements (elicitation and analysis), and checking whether the requirements meet user requirements (validation) (Sommerville 2010).

One of the leading measures of the success of IS is the extent to which the system fulfils the purpose of its creation (Nuseibeh and Easterbrook 2000). The success of IS development depends on its suitability for its users' needs and the business environment. Carefully identified requirements is a major issue for project success since the cost of correcting errors after launching the system is higher than the costs of remedying similar errors during the requirements analysis phase (Pfleeger and Atlee 1998). Therefore, the RE processes are very crucial in the IS development process.

Criteria of factors affecting the success of RE

Emam and Madhavji (1995) categorized CSF of RE in IS development into five categories, as follows:

- **Cost-effectiveness.** This dimension addresses whether the resources used in RE processes are reasonable. The top three measures for this dimension are cost comparison with RE processes in similar projects, the ratio of the RE costs to overall system development costs, and the number of changes made to the RE documentation.

- **Architectural quality.** This dimension addresses the quality of the designed architecture of the RE processes, e.g., how the architecture represents system and business process purposes.

- **Quality of cost/benefit analysis.** This dimension reflects the ability to analyze cost and benefit from a business perspective. A cost-benefit analysis is a process that is used to estimate the costs and benefits of decisions to find the most cost-effective alternative. RE results provide a detailed and accurate picture of the advantages of building a system against its costs. One of the goals is to predict whether the designed system will provide greater benefits than the costs incurred.

- **User satisfaction and commitment.** This dimension is directly related to the user's appreciation of the services provided due to the RE processes. For example, the extent to which users understand the capabilities of the system and users' willingness to use the system.

- **Fitness to the organization.** In addition to users' needs, the requirements must also be in accordance with the needs and capabilities of the organization. This aspect can be measured by looking at the organization's ability to implement the IS and the suitability of the IS with the organization's strategic orientation.

Factors affecting the success of RE

The factors that drive the success of an activity are usually called Critical Success Factors (CSF). CSF refers to "a limited number of areas where satisfactory results will ensure successful competitive performance for an individual, department, or organization" (Bullen and Rockart 1981). We identified eleven critical success factors of RE from the literature. The summary is presented in Table 1.

Table 1. The Extraction of CSFs of RE from the Literature

Factor	Definition	Reference
Environment & Culture	Supportive organizational environment and culture for carrying out the RE processes	(Khan et al. 2013; Saleh et al. 2021)
Management Support	Active support and encouragement from management to perform RE processes	(Kauppinen et al. 2004; Shafiq et al. 2020)
The organization's technical maturity	The level of the organization's technological maturity in implementing RE processes	(Khan et al. 2013; Shafiq et al. 2020)
Relationship among stakeholders	The relationships between stakeholders that can affect the implementation of the RE processes.	(Khan et al. 2013; Saleh et al. 2021; Shafiq et al. 2020)
Understanding & Awareness	Team members' understanding and awareness of each stage in RE	(Kauppinen et al. 2004; Khan et al. 2013; Shafiq et al. 2020)
Skills and Knowledge	Team's ability and expertise in executing each stage in RE	(Kauppinen et al. 2004; Khan et al. 2013; Saleh et al. 2021)
Training	The RE-related training provided by the organization to the relevant teams	(Kauppinen et al. 2004; Saleh et al. 2021; Shafiq et al. 2020)
Best practices	Executing RE according to best methods and practices	(Khan et al. 2013; Shafiq et al. 2020)
Techniques and tools	The use of certain techniques and tools to support the RE processes	(Khan et al. 2013; Shafiq et al. 2020)
Project's scope & goals	Have clear and complete documented objectives and scope before executing RE	(Khan et al. 2013; Shafiq et al. 2020)
User involvement	Involving users or clients to elicit requirements such as through interviews, surveys, or focus groups	(Kauppinen et al. 2004; Saleh et al. 2021; Shafiq et al. 2020)

Analytical Hierarchy Process

There are several Multi-Criteria Decision Analyses (MCDA) that support decision-making with various criteria, such as Analytic Hierarchy Process (AHP), Fuzzy Theory, and Technique for Order Preferences by Similarity to Ideal Solutions (TOPSIS). For example, Chatterjee and Mukherjee (2013) found that decision-making using the AHP method alone or combined with the Fuzzy Theory always produces the same results. Meanwhile, the TOPSIS method has difficulties compiling a ranking because each factor must be compared to the distance with the most ideal and least ideal conditions (Velasquez and Hester 2013). Therefore, using AHP is considered ideal and effective in making complex decisions.

Analytical Hierarchy Process is a multi-criteria decision-making (MCDM) method that describes the multi-factor problems into a hierarchy or a multilevel structure (Saaty 2001). The first level is the objective, followed by criteria, then sub-criteria (if any), and so on, to the last level of alternatives. These alternatives will contribute positively or negatively to the objective through their impact on the criteria. AHP can elicit a subjective assessment of the importance of each criterion and alternative. They are then examined to determine which variable has the highest priority in achieving the expected goal. This approach of breaking down complex problems by transforming an unstructured situation into smaller parts and systematically arranging the elements allows for effective decision-making. AHP has demonstrated its ability as a practical and effective approach to support complex and unstructured decision-making in various application domains. In summary, the steps to prioritize alternatives based on AHP are as follows:

1. Build a hierarchical structure

   a. Define overall goals
   b. Determine the criteria
   c. Determine the actors involved
   d. Determine the goals of the actor
   e. Determine the policy of the actor
   f. Determine the output (alternative) (Saaty 2001).

2. Setting priorities

   At this stage, the alternatives are compared against specific criteria using the pairwise comparison technique displayed in a matrix. This matrix is used to consistently test and obtain information about all possible comparisons and analyze the possibility of priority change.

3. Performing matrix calculations

   This third step aims to get the value of each criterion and alternative. This calculation is based on the eigenvector/eigenvalue principle. How to compute eigenvalues and eigenvectors can be seen in (Strang 2016).

4. Calculating the consistency ratio (CR) value using the formula shown in equation 1-7. The CR value must be equal to or less than 10% (Saaty 2001). Otherwise, there is an error in the assessment, which requires correction. The consistency ratio value close to zero shows the consistency of the comparison matrix. The formula for the consistency test (Saaty 2001) is as follows:

$$\mathrm{CR} = \frac{CI\ (Consistency\ Index)}{RI\ (Random\ Index)} \quad [1]$$

$$\mathrm{CI} = \frac{\lambda max - n}{n-1} \quad [2]$$

$$\lambda\ max = \frac{\sum VB}{n} \quad [3]$$

$$VB\ (Eigenvalue) = \frac{VA}{VP} \quad [4]$$

$$VA\ (\text{Intermediate vector}) = a_{ij} \times VP \quad [5]$$

$$VP(priority\ vector) = \frac{VE}{\sum \sqrt[n]{\prod_{i=1}^{n} a_{ij}}} \quad [6]$$

$$VE(Eigen\ Vector) = \sqrt[n]{\prod_{i=1}^{n} a_{ij}} \quad [7]$$

Note: $\lambda\ max$ is the maximum eigenvalue and n is the number of compared alternatives

a_{ij}: matrix of pairwise comparisons

RI is a random index (Random index) issued by the Oak Ridge Laboratory, as seen in Table 2.

Table 2. Random Index (Alonso and Lamata 2006)

N	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41
N	**9**	**10**	**11**	**12**	**13**	**14**	**15**	
RI	1.45	1.49	1.51	1.48	1.56	1.57	1.59	

Proposed Theoretical Framework of CSF of Requirements engineering based on AHP

This study adopts the hierarchical model of AHP described in the previous subsection to describe the relationship between RE success goal, RE success criteria, and RE CSF resulting in a theoretical framework shown in Figure 1. The first level of the framework is the goal, i.e., the success of RE. The second level is the criteria for the success of RE, i.e., cost-effectiveness, quality of architecture, quality of cost/benefit analysis, client satisfaction, and fitness to organization adapted from (Emam and Madhavji 1995) as explained in the previous subsection. These criteria are a comparison indicator of the alternatives. Finally, the third level is the alternative factors affecting RE's success, as discussed before. These factors are computed and ranked based on their significance to support RE's success.

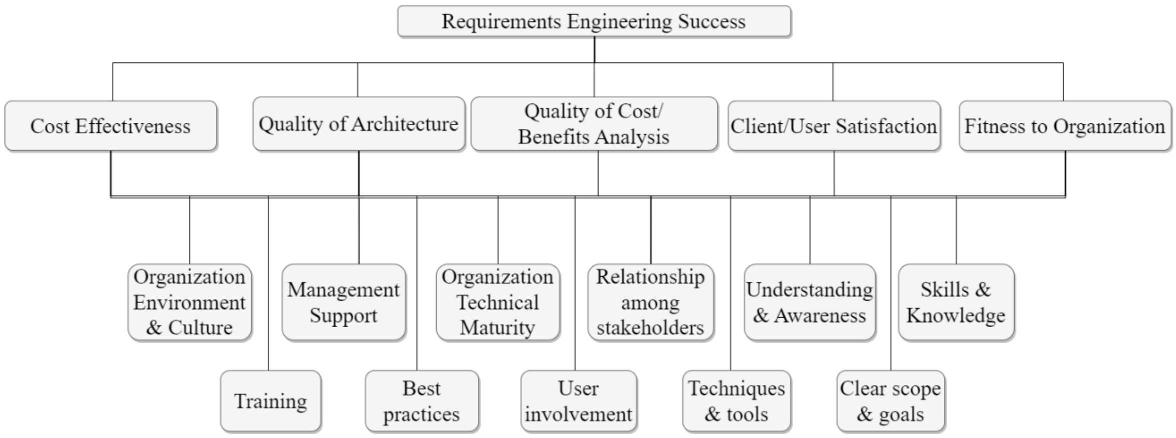

Figure 1. The Theoretical Framework of This Study

Research Methodology

This study uses a quantitative approach to get a broader range of responses in the pairwise comparison model. Data were collected using a questionnaire distributed to respondents working in software development teams and involved in RE processes. The questionnaire is a strategy to collect structured data from a measurable population (Saunders et al. 2016). The selection of the questionnaire was based on the need for pairwise comparison data to validate the proposed theoretical framework.

Previous studies found that the planning stage is the most crucial phase in IS development process (Khanfar et al. 2018) since it requires a lot of analysis and evaluation, determines the resource used and directly affects the end product. Within planning, RE is also resource-intensive (Khanfar et al. 2018). It involves a certain degree of uncertainty since stakeholders may not be able to clearly describe their needs, which may affect the IS development process. This analysis provides a solid foundation for this research's following four stages, as depicted in Figure 2.

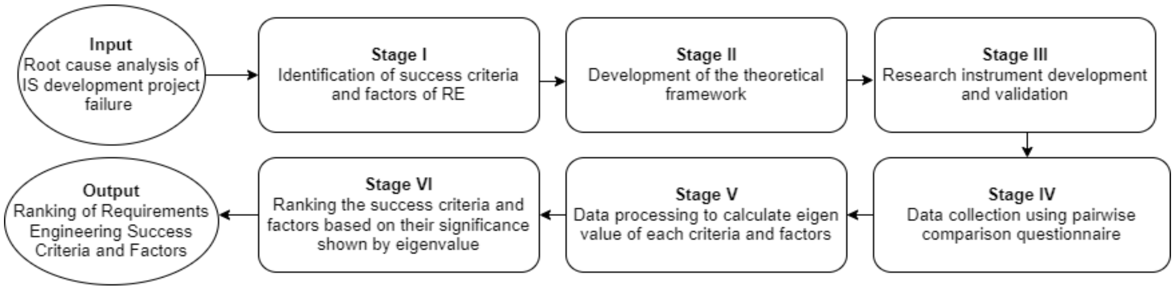

Figure 2. Research Stages

1. Identification of success criteria and CSF of RE from the literature

   This study identifies CSFs from the literature using the Systematic Literature Review (SLR) approach. After formulating the research question, a search strategy was started by first identifying the relevant literature sources based on the platform's suitability for the research topic. This study obtained search results from four sources: IEEE Explore, ACM Digital Library, Science Direct, and Proquest. The keywords used were combinations and synonyms of "Success Factors" and "Requirements Engineering". Papers that fulfilled the following inclusion criteria were included in this study: (1) Discuss the factors that influence the success of RE, (2) Focus on IS development projects, (3) Published in international journals or conference proceeding over the last 20 years, and (5) Written in English.

2. Development of a theoretical framework

   A theoretical framework was developed based on the criteria and factors in the literature review stage. The resulting theoretical framework describes the relationship between criteria and factors by adopting AHP.

3. Research instrument development and validation

   The questionnaire used in this study applied the pairwise comparison method recommended by (Saaty 2001). First, five criteria were compared against each other to determine their significance toward RE success. Similarly, a pairwise comparison was conducted among factors within each criterion. Then, before distribution, a readability test was conducted to ensure that the questionnaire could be understood and completed by respondents. The test was performed by a potential respondent who is a Chief Technology Officer at a start-up company, who was selected due to the respondent's experience and work relevance to the RE processes. Then, the questionnaire was improved based on the results of the readability test.

4. Data collection

   The questionnaire was distributed online to respondents. The purposive sampling approach was taken to select respondents who could provide in-depth and detailed information regarding the phenomenon. Respondents must work in a software development team and be involved in the RE processes. The respondents compared one criterion against another to determine its significance by assigning a value of 1 to 9, as described in Table 3. The output of this stage is data regarding the importance of the criteria and factors to the success of RE.

5. Data processing

   The pairwise comparison data for success criteria and factors were then analyzed using the AHP matrix calculation, explained in the previous section. The weighting is done using Expert Choice 11[2] software as a data processing tool. The output is eigenvalues for success criteria and factors.

[2] https://www.expertchoice.com/2021

The weight of each criterion and alternative was checked for consistency by comparing it with Saaty (2001). The calculation of the consistency ratio (CR) was also carried out using Expert Choice 11 software.

Table 3. Values for Pairwise Comparison Matrix

Value	Definition	Explanation
1	Equally important	Both alternatives have the same contribution to achieving the goal
3	Slightly more important	One alternative is slightly more important than the other
5	More important	One alternative is clearly more important than the other
7	Very important	One alternative dominates or is very important than the over
9	Absolute importance	One alternative has the highest level of importance compared to the other

6. Ranking the success criteria and factors

   The success criteria and factors were ranked based on their eigenvalues that have been declared consistent. The higher the eigenvalue of a criterion or factor, the higher its rank. The researchers also observed the RE practice in the field to validate the results and make notes. Finally, conclusions were made from the findings and suggestions were drawn for further research.

Results and Discussion

Out of 120 respondents, only 28 filled out the questionnaire completely. Nevertheless, the number of respondents obtained satisfied the research requirements with the AHP method because it did not have a minimum data limit (Darko et al. 2018). For instance, Fadli (2013) used AHP and only collected 12 responses. The CR calculation yielded values ≤ 10%, which means that the weight has been consistent so that it can be used as input for the next stage.

Demographic

In terms of industry, most of the respondents worked in the information technology industry, followed by banking and government. In terms of position, the majority of the respondents work as software developers and product managers. Half of them have been working for 2-4 years. More detailed demographic data can be seen in Table 4.

Ranking Requirements engineering Success Criteria

The eigenvalues were calculated for each criterion based on the pairwise comparison matrix. The ranking is then done by sorting them from the largest eigenvalue. As can be seen in Table 5, the criterion with the largest eigenvalue is user satisfaction, followed by fitness to organization, quality of cost/benefit analysis, quality of architecture, and lastly, cost-effectiveness.

Based on the results above, user satisfaction is the criterion with the largest eigenvalue. This finding indicates that user satisfaction with the results of RE is considered the most crucial in determining the success or failure of the RE processes. Basically, requirements in software development are formulated to solve problems faced by users (Sommerville 2010). Therefore, the high ranking of this criterion further emphasizes how crucial user satisfaction is in gathering and defining requirements.

The following most crucial criterion is fitness to the organization, which explains how the results of the RE match the needs and capabilities of the organization. In addition to conformity with user needs, requirements are also considered essential to fit the organization (Emam and Madhavji 1995). Without suitability, the IS developed may not reach its intended use since the organization lack the capability to utilize it. Additionally, IS adoption may meet resistance from within the organization if there is a misfit between the system and the organizational context.

Table 4. Demographic Data

Respondents' Demographic		**Amount**	**Percentage**
Industry	IT Consultant	8	28.5%
	Marketplace	7	25%
	IT Services	7	25%
	Telecommunication	2	7.1%
	Logistics	2	7.1%
	Banks	1	3.5%
	Government	1	3.5%
Position	*Software Developer*	12	42.8%
	Product Manager	10	35.7%
	Business/System Analyst	2	7.1%
	Lead/Manager	2	7.1%
	Project Management Office	1	3.5%
	UX *researcher*	1	3.5%
Years of Experience	<2 years	4	14.2%
	2-4 years	14	50%
	4-6 years	8	28.5%
	>6 years	2	7.1%

Table 5. Ranking of Success Criteria

Criteria	**Eigenvalue**	**Rank**
User Satisfaction	0.328	1
Fitness to Organization	0.244	2
Quality of Cost/Benefit Analysis	0.186	3
Quality of Architecture	0.130	4
Cost Effectiveness	0.111	5

Furthermore, the quality of the cost/benefit analysis criteria is ranked third. In performing cost/benefit analysis, the software development teams must analyze the functionalities to release at a certain version and the costs. Software functionalities compete with limited resources (Svensson et al. 2010). Therefore, it is required to balance the need for user satisfaction and fitness to the organization with quality of cost/benefit analysis. Hence, it may explain the neutral preference toward Quality of Cost/Benefit Analysis compared to other criteria.

Next, the quality of architecture is ranked fourth. This criterion measures the quality of RE products. Quality of architecture represents how precise the system architecture modelling is as the results of RE. The criterion placed in the second to last position may be because the quality of architecture may not solely reflect the quality of RE. Other factors affect the quality of architecture, other than RE processes, such as the language and architectural framework used and the architect's expertise (Almari and Boughton 2014).

Finally, cost-effectiveness is placed last. This criterion indicates how effectively the development team uses available resources during the RE processes. According to the questionnaire respondents, this criterion is not more important than the other criteria. The goal of achieving cost-effectiveness may hinder the quality of RE (Reddi 1984). For instance, eliciting a complete requirement may require a long time and higher costs. Hence, cost-effectiveness is a competing goal of RE success. Thus, it is considered not significantly important for RE success. This statement is in accordance with the results of research by Emam and Madhavji (1995), who suggest that this criterion is considered the least frequently as a measure of the success of RE compared to the other four criteria.

Ranking Requirements Engineering Success Factors

Table 6 shows the eigenvalues and ranks of all factors for all criteria. First, within **cost-effectiveness** criteria, the three most significant factors affecting RE success are project scope & goals, user involvement, and skills & knowledge. Meanwhile, the three least significant factors are the relationships among stakeholders, training, and organizational environment & culture. Clear project scope and goals are essential to achieve cost-effectiveness, as creeping scope increases costs. Thus, it is crucial to define precise scope during RE. Meanwhile, the least significant factor is the organizational environment and culture, which indicates that the environment does not help create cost-effective RE processes.

Second, for the **quality of architecture** criterion, the three factors considered the most significant are project scope & goals, skills & knowledge, and best practices. Meanwhile, the three factors with the lowest significance are management support, the relationship among stakeholders, and the organizational environment & culture. Like the previous criterion, the project scope and goals factor has the highest eigenvalue among all factors, followed by the skills and knowledge factor. This finding shows how crucial the team's skills and knowledge are in producing good architecture as a result of RE processes. On the other hand, organizational environment and culture factor is the least significant factors. Based on these results, it can be inferred that the environment and organizational culture do not significantly affect the quality of the system architecture from the results of RE.

Third, for the **quality of cost/benefit** analysis criterion, the three factors considered the most significant are project scope & goals, skills & knowledge, and user involvement. Meanwhile, the three factors with the lowest significance are management support, training, and organizational environment & culture. Just like the previous criteria, the project scope and goals and skills and knowledge factors are at the first and second places. The difference with the previous criteria is that the user involvement factor plays a more important role than other factors mentioned above.

Next, for the **user satisfaction** criterion, the three factors considered the most significant are user involvement, project scope & goals, and understanding & knowledge. Meanwhile, the three factors with the lowest significance are management support, organizational environment and culture, and the organization's technical maturity. Contrary to the previous criteria, user involvement is the most significant factor. This finding shows how important user involvement is in creating satisfying RE results for users.

Finally, for the **fitness to organization** criterion, the three factors considered the most significant are project scope & goals, organizational environment and culture, and understanding & knowledge. Meanwhile, the three factors with the lowest significance are user involvement, best practices, and training techniques & tools. However, the significant difference is that the organizational environment and culture factor is in second place with the same eigenvalues as understanding and awareness. This result shows that a supportive environment and culture support RE processes that produce results that match the needs and capabilities of the organization.

Table 6. Summary of Eigenvalues and Ranks for All Criteria

Factor	Cost-effectiveness		Quality of Architecture		Quality of Cost/Benefit Analysis		User Satisfaction		Fitness to Organization		Global	
	Eigenvalue	Rank	Eigenvalue	Rank	Eigenvalue	Rank	Eigenvalue	Rank	Eigenvalue	Rank	Eigenvalue	Rank
Project's scope and goals	0.179	1	0.167	1	0.177	1	0.118	2	0.109	1	0.138	1
User involvement	0.136	2	0.088	6	0.104	3	0.249	1	0.089	9	0.132	2
Skills and knowledge	0.102	3	0.146	2	0.121	2	0.091	4	0.089	8	0.104	3
Understanding and awareness	0.088	5	0.091	5	0.096	4	0.115	3	0.106	3	0.102	4
Best practices	0.085	6	0.114	3	0.095	5	0.087	5	0.073	10	0.087	5
Organization's technical maturity	0.098	4	0.086	7	0.081	7	0.044	11	0.089	6	0.078	6
Relationship among stakeholders	0.064	9	0.048	10	0.07	8	0.081	6	0.089	7	0.076	7
Techniques and tools	0.071	7	0.111	4	0.083	6	0.062	7	0.064	11	0.074	8
Management support	0.067	8	0.049	9	0.064	9	0.052	9	0.096	4	0.072	9
Organizational environment and culture	0.059	11	0.041	11	0.052	11	0.047	10	0.106	2	0.07	10
Training	0.061	10	0.058	8	0.056	10	0.054	8	0.09	5	0.069	11

For all criteria, the top two factors affecting the success of RE processes are (1) project scope and goals and (2) user involvement. A clear definition of the scope and project objectives is the most significant factor determining the success of RE. After that, the project team can also focus on engaging users. Involving users in RE can minimize defects in design, reduce unnecessary costs, and acquire users' buy-in for the system (Alvertis et al. 2016). This result aligns with (Fricker et al. 2015), who stated that there is a strong positive correlation between the precise definition of project scope and the success of RE. The definition of scope and goals also helps mitigate risk (Islam and Houmb 2010), which may affect the high ranking of the factor, especially in the cost-effectiveness and quality of cost/benefit analysis criteria.

Meanwhile, the high ranking of user involvement is in line with the results of (Kujala 2003), which states a positive correlation between user involvement and user satisfaction in software development. The study concluded that early user involvement would improve requirements quality and suggested that users should not only be passive informants but must actively contribute from the beginning of IS development.

The following two most significant factors are (3) skills and knowledge and (4) understanding and awareness. Both factors are related to an individual's ability in the software development team. Memon et al. (2010) stated that skill shortage is one of the biggest challenges in executing RE processes. This finding supports the importance of skills and knowledge factors in determining the success of RE. While Ouhbi et al. (2013) also state that RE failure is caused by a lack of skills, knowledge, and awareness related to RE.

The last factor in the top five most crucial factors is (5) implementing best practices throughout the RE processes. Best practices have been implemented in various domains. They have been proven the correct way to do many things, including RE, through trial and error. Previous studies have proposed various RE best practices, such as Young (2004), who suggests 30 best practices for implementing requirements development and management. Fricker et al. (2015) also proposed three RE success-correlating practices, i.e., defining scenarios for sequential use and system development, developing business cases to consider the business consequences, and conducting workshops.

The sixth to last ranks are occupied by (6) the organization's technical maturity, (7) the relationships among stakeholders, (8) techniques and tools, (9) management support, (10) organizational environment and culture, and (11) training. Although these factors were discussed previously as CSF, the findings of this study show otherwise. Four of the six factors with the lowest ranking align with Saleh et al. (2021), namely, the organization's technical maturity, the relationships among stakeholders, management support, and organizational environment and culture. Regarding the technique and tools factors, some researchers argue that there is no comprehensive specific technique for performing RE (Davis and Zowghi 2006). Existing techniques are used inconsistently, as some techniques may be used by some projects but not by others (Neill and Laplante 2003). Some preferences regarding the techniques and equipment used include Quality Function Deployment, prototyping, Data Flow Diagrams, role-playing, and decision trees (Rouibah and Al-Rafee 2009). However, it is not stated whether any of these techniques is correlated with the success of RE (Fricker et al. 2015).

Conclusion

This study identified and prioritized CSF of RE using the Analytical Hierarchy Process. The initial model was developed from literature review and validated using evidence from empirical research. The results show the ranking of the criteria affecting the success of RE is, starting from the most significant to the least significant: (1) user satisfaction, (2) fitness to organization, (3) quality of cost/benefit analysis, (4) quality of architecture, and (5) cost-effectiveness. Meanwhile, the order of significance of CSF for RE is (1) project scope and goals, (2) user involvement, (3) skills and knowledge, (4) understanding and awareness, (5) best practices, (6) the organization's technical maturity, (7) relationship among stakeholders, (8) techniques and tools, (9) management support, (10) organizational environment and culture, and (11) training. The results of ranking the determinants of the success of

RE using the AHP method above show the most crucial factors. Therefore, these factors can be prioritized when executing RE.

Although the criteria for measuring the success of RE have been discussed, limited attention has been given to prioritizing the criteria using the AHP method. The results of this study complement (Emam and Madhavji 1995) by ranking the CSF of RE. Practically, the results of this study can contribute to developing strategies that minimize the risk of project failure. Based on the results of the ranking criteria, user satisfaction is the most crucial. Therefore, in the RE processes, the team is advised to focus on user satisfaction as the primary criterion for RE success.

Additionally, the software development teams can also invest more time and resources when defining the scope and objectives of the project since it is the most significant factor contributing to the success of RE. The team can also consider increasing user involvement in RE processes. The next two important factors are closely related to the individual abilities of team members. Therefore, to increase the success of RE, the teams can accommodate up-skill and awareness-building programs to improve RE processes.

This research has some limitations. It used a quantitative approach. Future research can use a qualitative approach through interviews or focus group discussions on triangulating the results of this study. Further research can investigate other criteria or factors not included in this study. Future avenues can also discuss the implementation of the CSF, such as how to precisely define project boundaries and objectives, increase user involvement, and individual team members' abilities in terms of expertise, knowledge, understanding, and awareness of RE.

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