# An Approach to Critical Success Factors in Designing Cloud-based Application Solutions

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## Abstract

Recently, the cloud computing is next Internet technology, many companies have designed a comprehensive cloud--based system to consider functional and nonfunctional requirements. Therefore, this paper conducts a two-stage experiments and analysis. In the first stage, we invite professionals to interview and fill out the questionnaire, and then conduct a reliability analysis through the SPSS tool to validate corrections in the questionnaire. This stage erases unnecessary influence factors to find out the CSFs. Secondly, they calculate the weight ratio and rank the sequence for each of the CSFs through analysis of the AHP for questionnaire. After performing above experiments, it obtains the most important CSFs for each facet: the facet of Input Editing is User Experience; the facet of Processing Feature is Computing Logic; the facet of Output Result is Data Accuracy; the facet of Security and Privacy is Data Privacy; the facet of System Architecture is Accessibility; the facet of System Performance is Reliability. In the final calculation of the overall weights of CSFs across all six facets, the top six ranked CSFs cover Data Accuracy, Reliability, Computing Logic, Robustness, Accessibility, and Data Privacy and Encryption. In the future, the proposed methodology can be applied to innovative Cloud-based applications.

**Keywords:** Cloud computing, Cloud-based application system, Critical success factors (CSFs), Analytical hierarchy process (AHP)

## 1. Introduction

The following section provides an introduction to the background and purposes of this paper.

### 1.1 Research Background

With the development and popularization of Cloud-based technology in the modern world, many governments and enterprises have shifted their systems from Web-based to Cloud-based platforms. The functions and services of Cloud-based application systems, provided by cloud service providers (CSPs), help government and enterprise users solve the problems of spending large amounts of money to set up computer rooms and their information equipment [1]. At present, there are some well-known CSPs, such as Amazon Web Services (AWS), Microsoft Azure, and the Google Cloud Platform (GCP), which help governments and enterprises establish favorable Cloud application systems.

When CSPs design Cloud-based application systems, they have to consider user needs in order to work out solutions so that users can operate their information system directly on the Cloud. The CSPs need help users to prevent increasing operating costs by not downloading too much software and increasing manpower to maintain the computing resources in Cloud data center. At present, there is a limited amount of literature on the specifications for designing Cloud-based application system solutions. Therefore, this paper will primarily study the critical factors for success, and more attention will be given to the relevant research. This will be done so that system developers of CSPs can appreciate the solutions in Cloud-based application systems, and then prioritize these critical success factors to promote the development and maintenance of a more efficient design of Cloud-based application systems.

Commonly used statistical methods include regression analysis, factor analysis, the Delphi Method, and analytical hierarchy process (AHP). The main point of both regression analysis and factor analysis is to learn about the linear relationship between factors. However, it is not likely to show the priority among each of the factors. The Delphi method focuses more on the integrity of comprehensiveness of the hierarchical structure as it carries out review. Because the theory of AHP can integrate the opinions provided by most experts, the researchers of this paper have chosen to utilize AHP for analysis.

### 1.2 Research Purpose

The main purpose of this paper is to study and discuss critical success factors (CSFs) of cloud service provider (CSP) when designing Cloud-based application systems, so that designers can identify the most noteworthy CSFs for functional and non-functional requirements when designing a Cloud-based system. Therefore, the designing cloud-based application solution is divided into the functional requirements of this research, namely: input editing, processing features and output results; and various aspects of non-functional requirements, including: security and privacy, system architecture, and system performance. The influencing factors on the design of cloud-based systems for each facet were put forth, and scholars and experts

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from cloud-related industries were invited for discussion, brainstorming, and then rigorous selection. Then, the CSFs that were screened were sent to various scholars and experts in cloud-related industries for evaluation, and the evaluated data were analyzed through AHP research methods. Next, CSFs from each facet with regard to functional requirements and non-functional requirements were provided as references for designers of cloud-based systems in the industry.

This paper divides the purpose of the research into the following four tasks:

- The relevant literature on Cloud-based systems will be examined in order to identify the facets functional and non-functional required to find an overall solution for Cloud-based application systems and their influencing factors.
- A questionnaire will be completed in the first stage of discussion by scholars and experts. During this stage, SPSS (Statistical Product and Service Solutions) analysis will be used to examine the CSFs. This will then inform the design of the second-stage questionnaire.
- For the second-stage questionnaire, scholars, experts, and engineers in the related industry will be invited to complete the second-stage questionnaire for CSFs. Thereafter, the analytical hierarchy process (AHP) will be used to analyze and calculate the weights of CSFs, and ranking them.
- According to the prioritization of facets and CSFs put forth in this paper, the results will first be analyzed and used as a basis for CSP in designing the overall solutions for Cloud-based application systems.

The rest of this paper is organized as follows. Section 1 will introduce the research background and its purpose. Section 2 will explore the literature and related studies on Cloud computing, Cloud-based application systems and related applications, analytical hierarchy process (AHP) and its applications, and the relevant literature on critical success factors (CSFs). Section 3 will propose a research framework and outline the research methodology. It will also elaborate on the six facets of the research and CSFs. In Section 4, the research results and analysis can be presented, including the results of the two-stage questionnaire. In last Section, we summarize the total research results, make the research contributions and management implications and also indicate the future research direction.

## 2 Literature Review and Related Work

This section is a review of the literature on Cloud computing, Cloud-based system applications, as well as analytical hierarchy process (AHP) and its applications with the aim of informing the investigation to be conducted.

### 2.1 An Overview of Cloud Computing

Cloud computing has developed into a widespread and popular sector in the field of Information Technology (IT). According to the definition by the National Institute of Standards and Technology (NIST), Cloud computing is regarded as a model in computer resources that can be accessed conveniently via a network [2]. In recent years, the rapid development of the Internet has brought about many cost problems in the construction of computer rooms and their information equipment. As for the Cloud computing sector, CSP will only charge for the supplied resources according to usage [3]. This is why many governments and enterprises have, after evaluating its benefits, transferred their systems from Web-based to Cloud-based technology.

- Cloud computing is made up of five basic features, four deployment models, and three service types listed as follows:
- The five basic features of Cloud computing are on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service.
- The four types of deployment are Public Cloud, Private Cloud, Community Cloud, and Hybrid Cloud.
- The three types of services are Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS).

As shown in Table 1, the part labeled “V” is the resource managed by the CSP, while “O” is managed by the user.

**Table 1.** Resources managed by CSP/user

| Service model / Manage resources | On-premises | IaaS | PaaS | SaaS |
|---|---|---|---|---|
| Applications | O | O | O | V |
| Data | O | O | O | V |
| Runtime | O | O | V | V |
| Middleware | O | O | V | V |
| O/S | O | O | V | V |
| Virtualization | O | V | V | V |
| Servers | O | V | V | V |
| Storage | O | V | V | V |
| Network | O | V | V | V |

Also, the cloud computing services are mainly divided into the three models: Infrastructure as a Service (IaaS). Platform as a Service (PaaS), and Software as a Service (SaaS) [1].

### 2.2 Cloud-based Application Systems and Related Studies

Amazon provided a new form of Cloud computing services in 2002, including human intelligence, and computing and storage. The service provided is called Amazon Mechanical Turk (MTurk), while Google and Microsoft also developed related services soon thereafter.

With the rapid development of modern technology, the use of Cloud systems has already grown to be an indispensable mode of technology [4-5]. Rashid, A., & Chaturvedi, A. discuss Cloud-based application systems provided by CSPs such as Amazon, Google and Apple in 2019, which are Cloud-based application systems that many users are familiar with and widely used today. These are listed below [6]:

- Google: Google offers a Cloud computing service, with all its storage found online, so that it can be used alongside Cloud application systems like Google Docs, Google Sheets, and Google Slides. In fact, most of the Google services can be regarded as Cloud computing, such as Gmail, Google Maps and Google Analytics.

- Apple iCloud: Apple Cloud service is mainly used for online storage, backup, and synchronization of emails, contacts, calendars, etc. All the needed data can still be used on iOS, Mac OS, or Windows devices.
- Amazon Cloud Drive: The storage of large-scale retailers is mainly used for music (especially MP3s purchased) and image storage. If users subscribe to Amazon Prime, they are entitled to unlimited space for image storage.

The cloud-based system is found to have the following six characteristics [7]:

- On-demand access: It can quickly meet user's on-demand computing needs and has the continuous ability to accommodate such needs.
- Rapid Elasticity: CSPs can provide users with on-line scale-in or scale-out computing resource or amount of usage.
- Pay-per-use: The charge is made based on the usage amount of computing resources.
- Broad Network Access: All servers are connected to a high-speed network that allows data to flow to the Internet and domain between computing and storage resources.
- Resource pooling: The infrastructure of CSPs provides certain resources for sharing among cloud tenants; as such, it helps offer economies of scale for computing resource pool at any service level.
- Abstracted infrastructure: Cloud tenants may not know the exact location or computer type where their applications are in operation, but CSPs provide performance indicators to ensure service quality.

### 2.3 Hierarchical Analysis Process and Its Application

The analytic hierarchy process (AHP) was proposed by Thomas L. Saaty, a professor from the University of Pittsburgh. AHP is a Multiple Criteria Decision Making (MCDM). AHP can integrate the opinions of scholars and experts in an uncertain situation with multiple objectives and evaluation criteria. Pairwise Comparison Matrix can then be generated for each hierarchy as opinions of scholars and experts are integrated and then transformed into a quantitative measure, thus calculating eigenvalues. Eigenvalues can be used to evaluate the strength of each pairwise matrix, and it can provide the decision-makers with sufficient decision-making information, evaluation conditions or criteria, weight, and analysis to organize related decision-making. As such, it serves as a reference and helps reduce the risk of decision-making errors [8].

Since the theory of AHP is both clear and practical, it can effectively help decision-makers have an overall understanding of an event, and the analysis can be applied to the following 12 types of decision-making: Setting Priorities, Generating a Set of Alternative, Choosing a Best Policy Alternative, Determining Requirements, Allocating Resources, Predicting Outcomes and Risk Assessment, Measuring Performance, Designing Systems, Ensuring System Stability, Optimizing, Planning, and Conflict Resolution.

Many researchers have adopted AHP for analysis. For example, Yang, S. J., & Liao, C. H. proposed "A Study of Critical Success Factors on Software Quality Assurance of Cloud Networking Devices" in 2016 [9], and this paper is an AHP analysis method to evaluate information-related issues. Khowfa, W., & Silasai, O. proposed "The Integration of Association Rules and AHP in Cloud Service Selection" in 2017 [10], and this paper is to evaluate suitable services based on QoS through association rules and AHP, and effectively evaluate and select suitable cloud services. Mishra, S., Sharma, S. K., & Alowaidi, M. A. proposed "Analysis of Security Issues of Cloud-based Web Applications" in 2020 [11], and this paper is based on AHP to evaluate the security issues and related countermeasures of the cloud on the Web. Kinjo, EM, & Librarantz, AFH proposed "Criticality assessment of the components of IoT system in health using the AHP method" in 2021 [12], Research on the evaluation of the importance of the health Internet of Things, this paper is also analyzed through AHP.

Among the aforementioned 12 types of strategies, there are types of strategies that meet the needs of this paper, such as Designing Systems, Determining Requirements, Ensuring System Stability and Setting Priorities. Therefore, this research has employed AHP as the research method for this study.

### 2.4 Critical Success Factors

A critical success factor (CSF) refers to an important factor that a company must carry out efficiently in order to achieve success in its work [13]. Thomas L. Saaty, a professor from the University of Pittsburgh in the United States, believes that CSF can be categorized by using analytical hierarchy process (AHP) for analysis [14].

The definition of CSF consists of the following five points [15]:

- These factors must be strictly identified and handled carefully, both internal and external to the enterprise, for they may affect the achievement of company goals and even threaten the survival of the company.
- Special attention must be paid to these factors, as they will lead to significant consequences for the enterprise.
- These factors may be internal or external to the enterprise and may have either positive or negative impacts.
- Special attention must be paid to these factors to assist with effectively handling emergencies and to ensure that opportunities are not overlooked.
- These factors can be affirmed by evaluating corporate strategy, environment, resources, and operations.

## 3 Research Structure and Methodology

This section explains the research framework and methodology, which included a two-stage questionnaire, which were handled using SPSS and analytical hierarchy process (AHP) methods respectively. First, every facet and its influencing factors are proposed and explained, and then questionnaire design and expert background information of the two-stage experiment are provided to screen and select the CSFs. Next, the weight and ranking of CSFs are calculated and the experimental results are presented.

### 3.1 Research Structure and Process Description

The research structure is illustrated as shown in Figure 1.

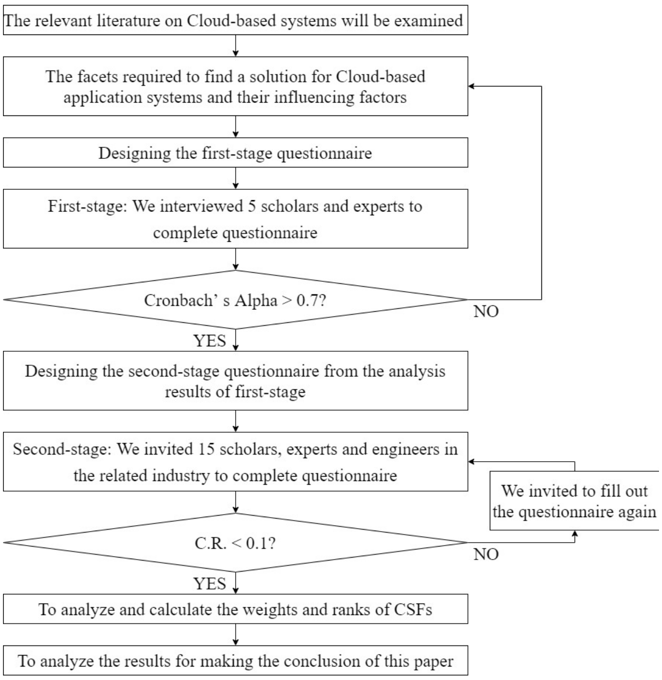


**Figure 1.** Research structure chart

### 3.2 Methodology

By drawing on the relevant literature and influencing factors, the researchers invited scholars and experts to take part in the first stage of a scholar-expert discussion. Thereafter, suggestions from scholars and experts were collected to revise incomplete or unclear wording from each facet and influencing factor. They were then requested to fill out the questionnaire to select the influencing factors relevant to the design of solutions for Cloud-based application systems.

The first-stage questionnaire ranked the importance of each influencing factor according to five levels, with the levels of importance increasing from 1 through to 5. After scholars and experts filled out the questionnaire, the scores of various influencing factors were added, and the factors scoring the lowest were removed. Afterwards, SPSS was employed to conduct a reliability analysis, which was used to determine the validity and reliability of the questionnaire. For higher questionnaire reliability, it indicates higher stability; on the other hand, lower questionnaire reliability indicates lower stability. This paper has made use of Cronbach's Alpha, which is commonly used in statistical data, as the basis for determining validity and reliability. When the coefficient is greater than 0.7, the credibility is very dependable.

The questionnaire sample of the first stage is shown in Table 2. In the table, we have divided the importance of each influencing factor from the questionnaire into five levels, with importance progressively increasing from 1 to 5, where 1 is the least important and 5 is the most important.

**Table 2.** The questionnaire sample of the first stage

| Influencing factors | Description | Importance | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| A | Description of influencing factors A | | | | | |
| B | Description of influencing factors B | | | | | |
| C | Description of influencing factors C | | | | | |

Thereafter, the second-stage questionnaire was designed based on the critical success factors (CSFs) selected after the data from the first-stage questionnaire was analyzed. Consequently, scholars, experts, engineers in the related industry were invited to fill out this questionnaire. The questionnaire data was then analyzed using analytical hierarchy process (AHP) to determine the importance and weight of CSFs. When AHP was employed, the ratio scale utilized in the evaluation was divided into five categories: equally important, slightly important, quite important, extremely important, and absolutely important, with measurement values of 1, 3, 5, 7, and 9, respectively.

In the second stage, CSFs found in the first stage were adopted to conduct the questionnaire, and the questionnaire sample of the second stage is shown in Table 3. In this questionnaire, CSFs on the corresponding left and right side of the table are done with correlation. With the analysis results, they were classified as slightly important, quite important, extremely important, and absolutely important respectively, and if two CSFs were found to be tantamount, they were considered equally important.

**Table 3.** The questionnaire sample of the second stage

| | The left side is more important | | | | | The right side is more important | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| CSF | Absolutely important | Extremely important | Quite important | Slightly important | Equally important | Slightly important | Quite important | Extremely important | Absolutely important | CSF |
| | 9:1 | 7:1 | 5:1 | 3:1 | 1:1 | 1:3 | 1:5 | 1:7 | 1:9 | |
| A | | | | | | | | | | B<br>C<br>D |
| B | | | | | | | | | | C<br>D |

Of the data from the second-stage questionnaire, it was first arranged into the pairwise comparison matrix A, in which the comparison results of n critical success factors were measured, and its value is $a_{ij} = w_i / w_j$, which was then placed at the upper triangular part of the pairwise comparison matrix A. As for the lower triangular part, it is the reciprocal of the upper triangular part, which is $a_{ji} = 1 / a_{ij}$, while the main diagonal part is the comparison itself, so that the value is 1 as depicted in Formula (1).

$$A = \left[a_{ij}\right] = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ 1/a_{n1} & 1/a_{n2} & \cdots & 1 \end{bmatrix}. \quad \textbf{(1)}$$

After the eigenvectors and eigenvalues ($\lambda_{max}$) were obtained through standardized calculation of the column vector average value, Formula (2) was used to calculate the Consistency Index (C.I.), with the corresponding Random Index (R.I.) chosen from the random index value comparison table in Table 4, and Formula (3) was utilized to calculate the Consistency Radio (C.R.) at the end. When the value of the C.R. is smaller than, or equal to 0.1, it means that the overall subjects share consistent views towards questionnaire content. When the value of the C.R. is larger than 0.1, it means that the subjects share inconsistent views towards questionnaire content.

$$\text{C.I.} = (\lambda_{max} - n) / (n - 1). \quad \textbf{(2)}$$

$$\text{C.R.} = \text{C.I.} / \text{R.I.} \quad \textbf{(3)}$$

**Table 4.** Random Index (R.I.) reference values

| Order | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| R.I. | 0.00 | 0.00 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 |

### 3.3 Facet Analysis and Description of Critical Success Factors

This subsection of this section elaborates on the functional requirement facets which are concentrated on system specifications of this research, namely: Input Editing, Processing Features, and Output Result; as well as the facets of non-functional requirements, which included: Security and Privacy, System Architecture, and System Performance. Table 5 provides a detailed description of the six facets compiled in this study.

In each facet, there are five to eight influencing factors that affect the design of Cloud-based application system solutions. The functional requirement facets are Input Editing is shown in Table 6, and the Processing Features are shown in Table 7; Output Results are shown in Table 8. The non-functional requirement facets that are focused on QoS (Quality of Service) and QoE (Quality of Experience) are illustrated as follows. The Security and Privacy facet is shown in Table 9; the System Architecture facet is shown in Table 10; and the System Performance facet is shown in Table 11.

**Table 5.** Descriptions of each facet

| Requirement type | Facets | Descriptions |
|---|---|---|
| Functional requirements | Input editing | Through interaction and discussion with users, observing user habits, and customizing a set of signals or data that is convenient for users to input, and it is necessary to check and edit a Cloud-based application system during input. |
| | Processing features | The signal or data input by the user is processed and stored so that the system function is sufficient to accommodate the user's processing and functional requirements based on the processing characteristics. |
| | Output result | Through a Cloud-based application system, signal or data of the results that the user has to process is then output. |
| Non-functional requirements | Security and privacy | This means that users can ensure the security of the system and their information, with the prevention of leaking corporate or personal data when using Cloud-based application systems. |
| | System architecture | The set-up of the structural and practical framework is constructed by system engineers, based on their knowledge and experience and the feedback from users on Cloud-based application systems. |
| | System performance | It indicates that the processing performance from the results produced is in line with the expected objective during the operation of a Cloud-based application system. |

**Table 6.** Influencing factors on the input editing facet

| Influencing factors | Descriptions | References |
|---|---|---|
| User Interface (UI) | When designing a Cloud-based application system, it helps to consider how the system can be displayed to achieve better visualization for users. | [16] |
| User Experience (UX) | When designing a Cloud-based application system, it helps to consider man-machine interaction so that the system can meet the behavior and user needs. It helps to achieve user consistency when they use any equipment or device. | [16] |
| Configuration capability | When designing a Cloud-based application system, this system can be used on any device anytime and anywhere. | This study prepared |
| System start-up | Perform standardized or consistent start-up procedures for Cloud-based application systems. | This study prepared |
| Item editing | The user will first edit the category of data and will then send the data to a Cloud-based application system. | This study prepared |

**Table 7.** Influencing factors on the processing features facet

| Influencing factors | Descriptions | References |
|---|---|---|
| Computing logic | The computing function of a Cloud-based application system conforms to logic rules required by the user. | This study prepared |
| Error handling time | When an error occurs on a Cloud-based application system, the system engineer can handle it in real-time. | This study prepared |
| Interoperability | To design a Cloud-based application system so that users can communicate at different Cloud platforms and achieve information sharing. | [17] |
| System resilience | When the system failure due to power failure or related problems, the system will conduct the necessary procedures to restore data. | [17] |
| Disaster recovery | When the system encounters a disaster, it helps a Cloud-based application system to be restored for normal operation. | [18] |
| Backup | To design of backup programs or data on the Cloud-based application system. | [17] |

**Table 8.** Influencing factors on the output result facet

| Influencing factors | Descriptions | References |
|---|---|---|
| Data accuracy | When a Cloud-based application system outputs data, it ensures the correctness of data. | [19] |
| Open source code | With the source code revealed through a Cloud-based application system, it allows users to better understand the workflow of the system operation. | This study prepared |
| Normal termination | When a Cloud-based application system is about to be turned off, it can end normally without causing an error to start next. | This study prepared |
| Transaction record | There are the transaction records of data changes of all devices on the Cloud-based application system. | This study prepared |
| Report format | Format of each data item in the report is to improve report readability. | This study prepared |
| Open data | Data on a Cloud-based application system can be used or modified by anyone without restrictions on distribution or use. | This study prepared |

**Table 9.** Influencing factors on the safety and privacy facet

| Influencing factors | Descriptions | References |
|---|---|---|
| Programing vulnerability | When designing a Cloud-based application system, program weaknesses are focused on reporting on in real time. | This study prepared |
| System holes protection | Safeguard vulnerabilities of data security in a Cloud-based application system to strengthen the protection of system vulnerabilities. | [17] |
| Data privacy and encryption | Encrypt confidential or sensitive data to protect the privacy of confidential data in a Cloud-based application system. | [17] |
| Data hiding | To properly hide or watermark confidential or sensitive information to prevent leakage of personal information. | This study prepared |
| Audit | To provide execution log of data changes in a Cloud-based application system to check or verify if it meets the audit requirements of the system. | This study prepared |
| Approval activity record | The history data of all legitimate execution measures on the device can be recorded in a Cloud-based application system. | This study prepared |

**Table 10.** Influencing factors on the system architecture facet

| Influencing factors | Descriptions | References |
|---|---|---|
| Maintainability | The cloud-based application system has adopted a modular design so that it has higher maintainability. Hence, when an error occurs in the system, it is easy to maintain and uphold its normal operation. | [17] |
| Accessibility | When designing a Cloud-based application system, the access rights of every user can be defined. | [17-18] |
| Portability | When designing a Cloud-based application system, one shouldn't have to modify the program before users can make use of it across platforms. | [17] |
| Verification and validation | The user of a designed Cloud-based application system can verify its testability and validity. | This study prepared |
| Deployment | The Cloud-based application system can quickly and correctly complete deployment so that the downtime required for deployment can be minimized. | This study prepared |
| Scalability | It means that a Cloud-based application system can be modularized to quickly add or adjust current computing resources without affecting the existing availability or service quality of the performance. | [17-18] |
| Existing and future capacity | After understanding the resource utility status of a Cloud-based application system, one can effectively plan the resource requirements of existing and future systems. | This study prepared |
| Rapid development | To develop a Cloud-based application system in a modular manner so that it carries out efficient and rapid development and shorten the time span. | This study prepared |

**Table 11.** Influencing factors on the system performance facet

| Influencing factors | Descriptions | References |
|---|---|---|
| Response time | It refers to the time to process a transaction by the system in a certain interval. | [17] |
| Throughput | It refers to the transaction volume that a Cloud-based application system can complete in a certain interval. | [17] |
| Reliability | The expected correctness of all functions for processing required by a Cloud application system can be anticipated. | [17-18] |
| Robustness | Show the completeness of data and programs in the design of a Cloud-based application system, so that the programs and data can meet actual requirements. | [17] |
| Availability | The time period that a system engineer of a Cloud-based application system can guarantee for normal and continuous operation under normal conditions. | [17] |
| Green computing | System engineer needs to consider the environmental impact when designing a Cloud-based application system. | This study prepared |

### 3.4 Questionnaire Design and Experts Background

In the first stage, two scholars from academia and three experts from the trade were invited. Their details are provided in Table 12. During the discussion, the scholars and experts talked about facets and influencing factors of the questionnaire to understand if there were any ambiguities in the questionnaire. After the questionnaire was revised and formally produced, it was then distributed to the scholars and experts to complete.

In the second stage, the questionnaire was conducted based on the CSFs identified in the first stage. During this stage, a total of 15 scholars and experts as well as engineers from the related information industry filled in the questionnaire, of which five were scholars and experts from the first stage of seminar, as already shown in Table 10, while the remaining 10 are shown in Table 13. Through the second-stage questionnaire, the weight of each CSF was calculated and ranked.

**Table 12.** Participant list of scholars and experts in the first-stage discussion

| Service organization | Title | Professionals | Job tenure |
|---|---|---|---|
| National Taipei University of Business | Professor | Cloud application, IoT, AI | 16~20 years |
| Shih Hsin University | Associate professor | Cloud application, Software development and design, Information system analysis, Project management | Over 30 years |
| BankPro E Service Technology Co Ltd. | Senior project manager | Cloud application, Software development and design, Information system analysis, Project management | 21~25 years |
| Chain Sea Information Group | Project manager | Software development and design, Information system analysis, Project management | 11~15 years |
| BankPro E Service Technology Co Ltd. | System engineer | Software development and design, Information system analysis, Project management | 11~15 years |

**Table 13.** Respondents of the second stage questionnaire

| No. | Job title | Professionals | Job tenure |
|---|---|---|---|
| 1 | CEO | Cloud application, Software development and design, Information system analysis, Project management | 21~25 years |
| 2 | General manager | Cloud application, Project management | Over 30 years |
| 3 | Test engineer | Cloud application, Software development and design | 6~10 years |
| 4 | Programming engineer | Software development and design, Information system analysis | 6~10 years |
| 5 | Senior programming engineer | Software development and design, Information system analysis | 6~10 years |
| 6 | Senior programming engineer | Cloud application, Software development and design | 6~10 years |
| 7 | Software engineer | Software development and design | 6~10 years |
| 8 | Software engineer | Software development and design | 1~5 years |
| 9 | Front-end engineer | Web design | 1~5 years |
| 10 | ASP.NET programming engineer | Software development and design | 1~5 years |

# 4 Research Results and Analysis

This section elaborates on the first-stage questionnaire and explains the influencing factors deleted from this questionnaire. After an analysis of the second-stage questionnaire, the priority of facets and their critical success factors (CSFs) are proposed.

The results of the first-stage questionnaire survey can be found in Table 14. The importance of the scores of the various influencing factors was calculated, and the nine influencing factors whose total scores were less than 18 points were deleted, which is displayed as Item Editing, Interoperability, Open Source Code, Open Data, Approval Activity Record, Portability, Existing and Future Capacity, Rapid Development, and Green Computing.

**Table 14.** Investigation results after the first-stage questionnaire and discussions

| Analysis facets | Influencing factors | Score |
|---|---|---|
| Input editing | User Interface (UI) | 18 |
| | User Experience (UX) | 23 |
| | Configuration capability | 19 |
| | System start-up | 18 |
| | Item editing | 14 |
| Processing feature | Computing logic | 22 |
| | Error handling time | 18 |
| | Interoperability | 16 |
| | System resilience | 23 |
| | Disaster recovery | 23 |
| | Backup | 24 |
| Output result | Data accuracy | 25 |
| | Open source code | 10 |
| | Normal termination | 23 |
| | Transaction record | 21 |
| | Report format | 18 |
| | Open data | 11 |
| Security and privacy | Programing vulnerability | 20 |
| | System holes protection | 24 |
| | Data privacy and encryption | 22 |
| | Data hiding | 22 |
| | Audit | 19 |
| | Approval activity record | 16 |
| System architecture | Maintainability | 23 |
| | Accessibility | 24 |
| | Portability | 16 |
| | Verification and validation | 19 |
| | Deployment | 22 |
| | Scalability | 22 |
| | Existing and future capacity | 17 |
| | Rapid development | 17 |
| System performance | Response time | 20 |
| | Throughput | 20 |
| | Reliability | 25 |
| | Robustness | 24 |
| | Availability | 21 |
| | Green computing | 14 |

Nine of the influencing factors mentioned above were deleted, and the scholars and experts summarized the reasons why they were deleted from the first questionnaire seminar. Since these less important influencing factors fell below the total score of 18 points, we therefore deleted them from this paper based on the standard of less than 18 points. Among them, item editing was considered a necessary solution more than an important influencing factor; as for the problem of open source code, it is good enough for cloud users to use without the need for them to understand the source code in the system. If too much information is made available, it may have jeopardized personal privacy, so there is not much need to disclose such information. With regard to green computing, it is viewed from the perspective of system design and it often ignores such issues as impact to the environment and rapid development when designing a system because the operation and integrity of the system are relatively more important, with speed trailing behind.

After the aforementioned screening, the analysis hierarchy structure diagram of six selected facets and 28 CSFs are shown in Figure 2.

The 28 CSFs then had to undergo a reliability analysis using SPSS software, the results of which are shown in Table 15. Also, the reliability coefficient intervals are shown in Table 16. As indicated, Cronbach's Alpha of each analysis facet of this study and the entire questionnaire is 0.70 < Reliability ≤ 0.90, indicating the reliability coefficient interval is most credible.

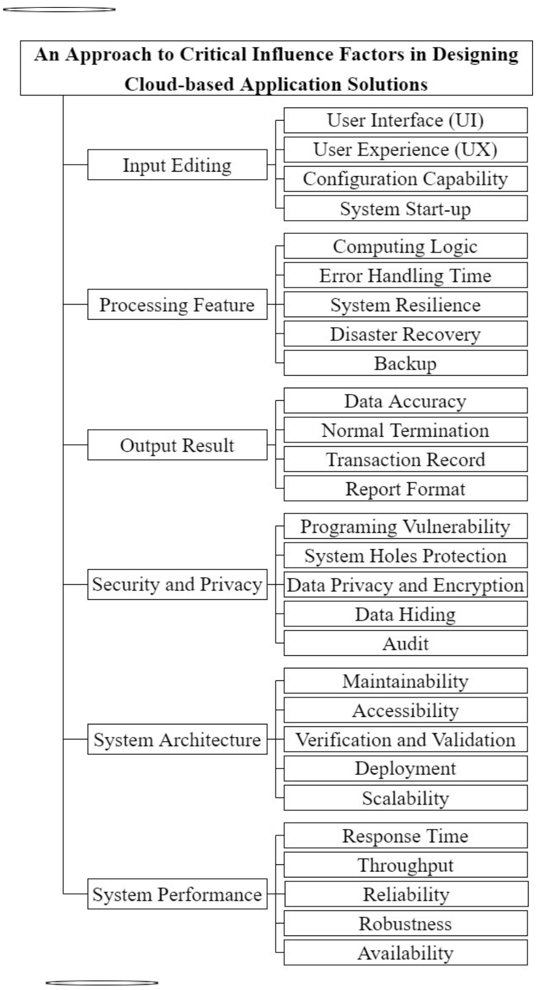


**Figure 2.** CSFs after the first-stage screening

**Table 15.** Reliability analysis of each facet

| Overall Cronbach's α | Analytical facets | Cronbach's α |
|---|---|---|
| 0.745 | Input editing | 0.735 |
| | Processing feature | 0.795 |
| | Output result | 0.864 |
| | Security and privacy | 0.789 |
| | System architecture | 0.821 |
| | System performance | 0.727 |

**Table 16.** Cut-off values for Cronbach's Alpha and consistency index

| Cronbach's α | Internal consistency |
|---|---|
| **α** ≤ 0.50 | Unacceptable |
| 0.50 < **α** ≤ 0.60 | Poor |
| 0.60 < **α** ≤ 0.70 | Acceptable |
| 0.70 < **α** ≤ 0.90 | Good (Low-Stakes testing) |
| 0.90 < **α** | Excellent (High-Stakes testing) |

In the second-stage questionnaire, the AHP was used to conduct weight analysis research results regarding the questionnaires done by 15 scholars, experts, and engineers in the related industry. The results are shown in Table 17.

**Table 17.** Overall evaluation and analysis results of critical success factors for designing cloud-based application systems

| Facets | Weights | CSFs | Weights | Overall weights | Overall orders |
|---|---|---|---|---|---|
| Input editing | 0.1029 | User Interface (UI) | 0.2963 | 0.0414 | 9 |
| | | User Experience (UX) | 0.3076 | 0.043 | 7 |
| | | Configuration capability | 0.2677 | 0.0374 | 12 |
| | | System start-up | 0.1284 | 0.0179 | 27 |
| Processing feature | 0.153 | Computing logic | 0.2881 | 0.0523 | 3 |
| | | Error handling time | 0.1299 | 0.0236 | 22 |
| | | System resilience | 0.2096 | 0.038 | 11 |
| | | Disaster recovery | 0.2023 | 0.0367 | 14 |
| | | Backup | 0.1701 | 0.0309 | 19 |
| Output result | 0.1387 | Data accuracy | 0.4895 | 0.0741 | 1 |
| | | Normal termination | 0.2072 | 0.0314 | 16 |
| | | Transaction record | 0.1728 | 0.0262 | 21 |
| | | Report format | 0.1305 | 0.0198 | 26 |
| Security and privacy | 0.3172 | Programing vulnerability | 0.2017 | 0.035 | 15 |
| | | System holes protection | 0.2424 | 0.0421 | 8 |
| | | Data privacy and encryption | 0.2512 | 0.0436 | 6 |
| | | Data hiding | 0.1699 | 0.0295 | 20 |
| | | Audit | 0.1348 | 0.0234 | 23 |
| System architecture | 0.1227 | Maintainability | 0.1322 | 0.0219 | 25 |
| | | Accessibility | 0.266 | 0.0441 | 5 |
| | | Verification and validation | 0.2251 | 0.0373 | 13 |
| | | Deployment | 0.1878 | 0.0311 | 18 |
| | | Scalability | 0.1889 | 0.0313 | 17 |
| System performance | 0.1655 | Response time | 0.0928 | 0.0174 | 28 |
| | | Throughput | 0.1228 | 0.0231 | 24 |
| | | Reliability | 0.3277 | 0.0616 | 2 |
| | | Robustness | 0.2381 | 0.0448 | 4 |
| | | Availability | 0.2186 | 0.0411 | 10 |

Concerning the Input Editing facet, the top three critical success factors (CSFs) are ranked as follows: User Experience (0.3076), User Interface (0.2963), and Configuration Capability (0.2677). In respect to the Processing Features facet, the top three CSFs are Computing Logic (0.2881), System Resilience (0.2096), and Disaster Recovery (0.2023). The top three CSFs for the Output Result facet are Data Accuracy (0.4895), Normal Termination (0.2072), and Transaction Record (0.1728). For the Security and Privacy facet, the top three CSFs are Data Privacy and Encryption (0.2512), System Holes Protection (0.2424), and Programing Vulnerability (0.2017). Concerning the System Architecture facet, the leading CSFs ranked in order are Accessibility (0.2660), Verification and Validation (0.2251), and Scalability (0.1889). Lastly, for the System Performance facet, the top three CSFs are Reliability (0.3277), Robustness (0.2381), and Availability (0.2186).

When examining the overall ranking of the six facets, the top three are Security and Privacy (0.3172), System Performance (0.1655), and Processing Features (0.153). As for the overall weight results among those six facets, the top five CSFs are Data Accuracy (0.0741), Reliability (0.0616), Computing Logic (0.0523), Robustness (0.0448), and Accessibility (0.0441).

The research results of this paper can be used as a reference basis for cloud service providers to further design overall solutions for cloud-based application systems. In the interview, it has mentioned that is unable to pay attention to all each CSF when designing a cloud-based application system. It may be limited due to shortage issues such as cost and time. In the future, for common cloud-based application systems, we can recommend that the top 10 CSFs as shown in Table 14 are to be the priority factors. If it is a banking application system, we can focus on the Processing Feature and Security and Privacy facets in the CSFs on Table 7 and Table 9. In addition, we can consider the Security and Privacy and System Performance facets in the CSFs for an IoT application system on Table 9 and Table 11.

# 5 Conclusions

### 5.1 Research Results

In the current technological development of cloud-based application systems, many companies and governments usually establish their systems in the cloud to improve the service quality of the system. Therefore, four main research results have been achieved in this paper, which are described as follows:

(1) This research first sorted out a total of six facets in view of the functional and non-functional requirements for the overall solution of cloud-based application systems, as well as a total of 37 influencing factors for each of the facets by studying relevant literature of cloud-based systems and related applications. Then, the questionnaire for the first-stage facet and influencing factors was developed.

(2) Through the first-stage seminar with scholars and experts and their filling-out of the questionnaire, SPSS was then used for reliability analysis, and those influencing factors from the first-stage survey results of the questionnaire with a total score of less than 18 were deleted, which were as follows: Item Editing, Interoperability, Open Source Code, Open Data, Approval Activity Record, Portability, Existing and Future Capacity, Rapid Development, and Green Computing, leaving a total of nine influencing factors. Then, the selected CSFs were used to design the second-stage questionnaire.

(3) In the second-stage questionnaire, 15 relevant scholars, experts, related information industry engineers, and users were invited to fill out the questionnaire on CSFs. Afterwards, data from the questionnaire were analyzed by using the hierarchical analysis method (AHP), with weights of CSFs being calculated and ranked.

(4) Based on the six facets and their CSFs proposed in this paper, weights for each facet, CSFs towards each of the six facets, and overall CSFs were analyzed and ranked, with those ranking results stated as follows:

To be summarized, in the calculation of the overall weights of CSFs among the six facets, the top five ranked were: "Data Accuracy," "Reliability," "Computing Logic," "Robustness," and "Accessibility."

### 5.2 Research Contributions and Management Implications

In this paper, first-stage scholars and experts screened out CSFs, then AHP was utilized to analyze the second-stage questionnaire, and weights for each facet, CSFs of each facet, and overall CSFs were calculated and ranked accordingly. Therefore, the analyzed results have contributed to both academic and practical fields. With regard to the academic field, this paper has divided the facets into functional requirements and non-functional requirements for the design of cloud-based application system solutions. By integrating relevant literature, experienced feedback from academic scholars and practical experts can help facilitate future research for cloud application systems of different types, while the research results can be cited as references for related academic research in the future.

The management implications of this paper illustrate that CSFs from each facet of functional requirements and non-functional requirements can be used as references for system developer in the industry as they develop cloud-based systems. In fact, functional requirements are concentrated on system specifications, and also non-functional requirements are focused on QoS (Quality of Service) and QoE (Quality of Experience). In the future, they can specify how the system will work behind the scenes that are focused on respective functional and non-functional requirements by appreciating the most striking factor, when designers under such a way are to devise and implement cloud-based application solutions.

### 5.3 Future Research

This paper was conducted based on the research of unlimited types of solutions for designing cloud-based systems. In the future, it can be employed to focus on the application systems for such related on-line transaction as the Internet of Things (IoT), smart factories, e-commerce, Internet banking, and communications industries, as well as to compare the differences of their CSFs, each industry should pay attention to their CSFs to design the cloud-based application solutions.

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