International Journal of Learning Management Systems

http://dx.doi.org/

Prioritizing the CSFS of Cloud-Based M-Learning Analytic Hierarchy Process and Blackboard Case Study

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Received: 10 Jan. 2023, Revised: 25 Feb. 2023, Accepted: 20 Mar. 2023.
Published online: 1 April 2023.

Abstract: This study presents a comprehensive framework for cloud-based mobile learning, which investigates critical success factors (CSFs) for effective implementation. The researcher utilizes a multi-method approach consisting of a literature review, expert review, and Analytic Hierarchy Process (AHP) to collect and analyze data. The literature review covers e-learning, mobile learning, and cloud computing to identify the seven major domains containing sub-factors: Mobile Device Compatibility, Data Security, Learner Engagement, Content Quality, Learning Management, Scalability, and Instructor Support. The AHP method is used to select the most significant factors from the literature review. An expert review is conducted to ensure the framework's comprehensiveness and applicability. The study's findings can assist organizations in implementing cloud-based mobile learning by using the identified CSFs to ensure successful competitive performance. Overall, this study provides a comprehensive framework for cloud-based mobile learning using a multi-method approach.

Keywords: Cloud-based mobile learning (CBML), Critical Success Factors (CSFs), Analytic Hierarchy Process (AHP), Pedagogy, Quality content.

Introduction:

The advancements in technology have transformed the traditional education system, and e-learning has emerged as an efficient and effective mode of learning. The integration of cloud computing with e-learning has further enhanced the quality and accessibility of education. Cloud-based mobile learning (CBML) has gained immense popularity, and educational institutions worldwide are adopting this technology to improve the learning experience of their students. However, the success of cloud-based mobile learning depends on various critical factors that need to be identified and addressed.

This study aims to evaluate and rank the critical success factors (CSFs) for cloud-based mobile learning, with a particular focus on Blackboard's content quality CSFs, using the Analytical Hierarchy Process (AHP) method. The AHP method is a multi-criteria decision-making tool that can help identify and prioritize the critical success factors for CBML.To the best of our knowledge, there is limited research on the use of AHP for evaluating and ranking the CSFs for CBML, specifically focusing on Blackboard's content quality CSFs. Therefore, this study contributes to the existing literature by providing insights into the critical success factors of CBML, which can help educational institutions develop effective strategies for implementing and improving cloud-based mobile learning.

Research has already been done on important success factors for cloud-based mobile learning as well as e-learning systems, but this study builds upon existing research. In various studies, fuzzy AHP, multi-criteria decision-making, and Delphi methods have been used to identify critical success factors for e-learning systems. (Anggrainingsih et al., 2018), Fathian et al. (2019), and Naveed et al. (2020) have identified critical success factors for e-learning using fuzzy AHP and suggested frameworks for successful implementation. According to (Muhammad et al., 2020), and Kurniawan and Andriani (2020), different approaches can be used to identify critical success factors for cloud-based mobile learning.

By using the AHP method, this study aims to fill the research gap by evaluating and ranking the critical success factors for cloud-based mobile learning, specifically Blackboard's content quality CSFs. CBML success factors can help educational institutions develop effective strategies for implementing and improving cloud-based mobile learning based on the findings of this study.

1.1.Research Objectives:

- To identify the key dimensions and CSFs of cloud-based m-learning.
- To rank the importance of dimensions and CSFs using the Analytical Hierarchy Process (AHP) method.
- To evaluate the CSFs of Blackboard in the context of cloud-based m-learning.
- To provide practical recommendations for improving cloud-based m-learning.

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1.2. Research Questions:

- What are the key dimensions and CSFs of cloud-based m-learning؟
- How can the dimensions and CSFs of cloud-based m-learning be ranked؟
- How do Blackboard's CSFs compare to the overall CSFs of cloud-based m-learning؟
- What are the practical recommendations for improving cloud-based m-learning.؟

1.3. Problem Statement:

Cloud-based mobile learning (CBML) will be evaluated for its effectiveness by identifying and evaluating critical success factors (CSFs). Using the Analytic Hierarchy Process (AHP) method, key dimensions and CSFs of CBML are identified and ranked. Furthermore, the study evaluates the CSFs of Blackboard in the context of CBML and provides recommendations for improving CBML. CBML implementation can be improved by identifying and addressing factors influencing the achievement of learning outcomes. This study is vital to assisting educational institutions in addressing those factors (Naveed et al., 2023).

2 Research Methodology:

Critical success factors (CSFs) refer to the limited number of areas that, if satisfactory, will ensure an organization's successful competitive performance. The theory of CSFs is commonly used in the field of information systems and mobile learning. In this study, a multi-method approach will be used for data collection and analysis, consisting of several steps:

Step 1: Formulating Research Questions: The primary objective is to identify critical success factors that are essential for the effective implementation of cloud-based mobile learning.

Step 2: Reviewing the Literature: The author conducted a comprehensive literature review on e-learning, mobile learning, and cloud computing to identify critical success factors for cloud-based mobile learning. The review was likely conducted systematically to ensure that all relevant studies were included. Keywords were used to locate relevant literature on CSFs for cloud computing, cloud-based e-learning, and mobile cloud-based learning.

Step 3: Selecting and Evaluating Studies: The researcher focused on important factors for model building, in general, in the context of cloud computing CSFs. After selecting and evaluating 15 relevant articles, the author identified seven areas of critical success factors for mobile cloud-based learning. These factors included Mobile Device Compatibility, Data Security, Learner Engagement ،Content Quality, Learning Management, Scalability, and Instructor Support.

Step 4: Analysis and Synthesis: Using AHP methods, the author evaluated and ranked the critical success factors for cloud-based m-learning, specifically focusing on Blackboard Content Quality CSF files. The most common and essential influencing factors were selected and divided into seven major domains each containing sub-factors.

Step 5: Expert Review: The author conducted an expert review of the proposed framework to ensure that it was comprehensive and applicable. The results were presented using AHP methods to annotate CSFs and were discussed to facilitate their practical application.

To collect data, the author created a Google questionnaire and distributed it to faculty participants from different departments at Al-Jouf University, Saudi Arabia. Only 74 participants completed the questionnaire, and the results were analyzed using a Likert scale with five points (1, 3, 5, 7, and 9) to capture and calculate a measure of relative importance and to construct a choice matrix.

3 Related Work:

The literature review will provide a comprehensive review of the existing literature on cloud-based M-learning and its dimensions and CSFs. The review will identify the most relevant dimensions of cloud-based M-learning and their corresponding CSFs. The review will also analyze previous research that used ranking methods for evaluating dimensions and CSFs.

E-learning has become an increasingly popular method of education delivery, particularly in the context of the COVID-19 pandemic, which has forced many educational institutions to move their teaching online. However, the success of e-learning depends on various factors and identifying these critical success factors (CSFs) is crucial for the effective implementation of e-learning systems. This literature review aims to critically analyze and synthesize 10 articles that focus on evaluating and ranking CSFs for e-learning.

This study proposes a combinatorial approach to evaluating and ranking CSFs for cloud-based e-learning. The authors identified 24 CSFs and developed a hierarchical model to evaluate and rank them. The study found that "learner satisfaction" and "content quality" were the two most critical factors. However, the researchers neglected to evaluate CSF from the perspectives of instructors and administrators (Naveed et al., 2019).

This study used a multi-criteria decision-making approach to evaluate and rank CSFs for e-learning system implementation. The authors identified 25 CSFs and evaluated them based on four criteria: "user satisfaction," "technology infrastructure," "instructional design," and "institutional support." The study found that "user satisfaction" was the most critical factor, followed by "institutional support." The study did not take into account the fuzzy nature of decision-making, (Naveed et al., 2020).

This study proposes a fuzzy multi-criteria decision-making method for selecting criteria for an e-learning platform. The authors identified 13 criteria and evaluated them using the fuzzy analytical hierarchy process (FAHP). The study found that "technology infrastructure" and "instructional design" were the two most critical criteria. In selecting criteria, Güldeş et al. (2022) did not include the perspectives of different stakeholders.

This study analyzed CSFs for sustainable cloud-based mobile learning (CBML) using both crisp and fuzzy decision-making methods. The authors identified 14 CSFs and evaluated them using an analytical hierarchy process (AHP) and fuzzy AHP (FAHP). The study found that "learner satisfaction" was the most critical factor, followed by "quality of content." However, different stakeholders were not considered in evaluating CSF (Naveed et al., 2023).

This study aimed to restructure the CSFs for e-learning deployment based on a comprehensive review of the literature. The authors identified 15 CSFs and classified them into three dimensions: "pedagogical," "technological," and "institutional." The study found that "pedagogical dimension" was the most critical dimension, followed by "technological dimension." The study failed to provide a clear methodology for evaluating and ranking CSFs (Frimpon, 2012).

This study identified 22 CSFs for e-learning systems from a quality perspective. The authors evaluated and ranked these factors using the AHP method. The study found that "learner satisfaction" was the most critical factor, followed by "instructional design." CSFs were not evaluated from the perspective of other stakeholders (Farid et al., 2018).

This study used fuzzy AHP to evaluate and rank CSFs for e-learning success factors in higher education based on the user perspective. The authors identified 17 CSFs and evaluated them from the perspective of students, faculty, and administrators. The study found that "ease of use" and "interaction and collaboration" were the two most critical factors, followed by "quality of content." Other stakeholders, such as IT staff and instructional designers were not considered (Anggrainingsih et al., 2018).

This study proposes a framework for evaluating CSFs for e-learning implementation in higher education institutions. The authors identified 13 CSFs and classified them into four dimensions: "pedagogical," "technical," "organizational," and "institutional." The study found that "pedagogical dimension" was the most critical dimension, followed by "technical dimension." Despite that, the study did not provide a clear methodology for assessing and ranking CSFs (Prof. H. Magd, 2022).

This study identified 17 CSFs for cloud-based e-learning and evaluated them using the AHP method. The authors found that "quality of content" was the most critical factor, followed by "learner satisfaction" and "interaction and collaboration." Difficulties in evaluating CSFs have also been cited by other stakeholders (Naveed & Ahmad, 2019).

This study investigated the factors affecting academic integrity in e-learning at Saudi Arabian universities using Delphi and AHP methods. The authors identified 10 factors and found that "faculty development" and "technology support" were the two most critical factors. In addition, the study did not consider the perspectives of other stakeholders, such as students and administrators (Muhammad et al., 2020).

A review of the literature found significant agreement among studies that "learner satisfaction," "quality of content," and "interaction and collaboration" are critical to e-learning's success. There are, however, differences in the number of CSFs identified and the methodologies used to evaluate and rank them, along with the methodology used to identify the CSFs. Furthermore, the studies do have limitations, for instance, they do not consider the perspectives of all stakeholders and the subjective nature of decision-making can also be seen in their findings. A future research study should address these limitations and develop a comprehensive, robust framework for evaluating and ranking CSFs for e-learning that is comprehensive and robust.

Table 1: Summarize of studies in cloud-based learning CSFs

Study	Theory used	Significant factors	Limitations	Findings

[1] /	Combinatorial Approach	Security, Content Quality, Cost, User Interface, Accessibility, Reliability, Scalability	Limited to cloud-based e-learning and critical success factors only.	Identified critical success factors for cloud-based e-learning.
[2]/	Multi-Criteria Decision Making	User Satisfaction, Training and Support, Technological Infrastructure, Content Quality, Instructional Design, Pedagogy	Single case study approach used for e-learning implementation	Identified critical success factors for e-learning implementation.
[3]	Fuzzy Multi-Criteria Decision Making	Content Quality, User Satisfaction, Technological Infrastructure, Instructional Design, Pedagogy	Limited to selection criteria for e-learning platform and fuzzy multi-criteria decision-making.	Developed a method for selecting criteria for an e-learning platform.
[4] /	Crisp and Fuzzy Environment	Accessibility, Content Quality, User Satisfaction, Technological Infrastructure, Pedagogy, Reliability	Limited to cloud-based mobile learning and critical success factors only.	Identified critical success factors for sustainable cloud-based mobile learning.
[5]/	Fuzzy AHP and Delphi technique	Technological Infrastructure, Pedagogy, Content Quality, User Satisfaction, Instructor Training	Limited to critical success factors and e-learning deployment only.	Proposed a re-structured model of critical success factors for e-learning deployment.
[6] /	Survey questionnaire and statistical analysis	Quality of Content, Quality of Instructional Design, Instructor Training and Support, User Satisfaction	Single case study approach used for quality perspective of e-learning systems.	Identified critical success factors for e-learning systems from a quality perspective.
[7] /	Fuzzy Analytic Hierarchy Process	Content Quality, Instructor Support, User Satisfaction, Pedagogy, Technological Infrastructure	Limited to higher education and user perspective using Fuzzy AHP.	Identified e-learning success factors for higher education from a user perspective.
[8]	Systematic Literature Review	Technological Infrastructure, Instructor Training, Content Quality, Pedagogy, User Satisfaction	Proposed framework for e-learning implementation in HEIs only.	Proposed a framework for critical success factors of e-learning implementation.
[9] /	Combinatorial approach and (MCDM)	Scalability, Accessibility, Security, Content Quality, User Satisfaction	Limited to cloud-based e-learning and critical success factors only.	Identified critical success factors for cloud-based e-learning.
[10] /	Delphi and Analytic Hierarchy Process	Instructor Support and Training, Student Awareness, Technological Infrastructure, Assessment and Evaluation	Limited to academic integrity in e-learning of KSA universities and used Delphi and AHP.	Identified factors affecting academic integrity in e-learning of KSA universities.
[11] /	Systematic Literature Review	Pedagogy, Technological Infrastructure, Content Quality, User Satisfaction	Review article with no primary data collection.	Reviewed critical factors of adopting cloud mobile learning.
[12] /	Survey questionnaire and statistical analysis	Instructor Support, User Satisfaction, Content Quality, Technological Infrastructure	Single case study approach used for exploring critical success factors of mobile learning.	Identified critical success factors for mobile learning from the perspective of students.
[13]	ANN-SEM Modelling Technique	Perceived Usefulness, Perceived Ease of Use, Attitude towards Technology, System Quality, Information Quality	Limited to the acceptance of M-learning application in HE during COVID-19 and used ANN-SEM modelling technique.	Identified factors affecting students' acceptance of mobile learning applications.
[14] /	Structural Equation Modeling and Regression Analysis	Instructor Support, User Satisfaction, Technological Infrastructure, Pedagogy, Content Quality	Small sample size, limited to the Australian Higher Education Sector	Identified factors affecting the adoption of cloud-based interactive mobile learning.

[15]	TAM, UTAUT, DOI.	Perceived usefulness, ease of use, self-efficacy, social influence, facilitating conditions, compatibility, relative advantage	Limited studies in non-English speaking countries, limited impact on academic achievement	Efficacy, social influence, and facilitation make a difference. Adoption is also affected by compatibility.

4 Five_ phase Framework of CSFs in Cloud-based m-learning (CBML):

After analyzing the critical success factors (CSFs) for mobile and cloud-based learning, a proposed framework can be used to identify CSFs in cloud-based learning (CBML) by utilizing the Analytic Hierarchy Process (AHP). This decision-making method involves a structured molecule and seven criteria used to evaluate and rank CSFs for cloud mobile learning, which helps reach an agreement among group decision makers and selected experts for handling complex decisions. To improve decision-making, the problem is organized into a framework that forms a hierarchy, which can be systematically evaluated. The basic stages of AHP applications include the following:

First phase: Analytic hierarchy process (AHP):

The AHP methodology is a systematic decision-support approach developed by T.L. Saaty and widely used by researchers to solve problems that involve hierarchies ranging from simple to complex.

This study uses the AHP methodology as a systematic decision-support method to evaluate and rank critical success factors (CSFs) for cloud-based M-learning. The AHP procedure is effective in resolving simple or complex problems consisting of conflicting criteria with varying levels of hierarchy and structural complexity in (Saaty, 1988). The application of AHP can be found in various research areas and applications, such as business, engineering, social sciences, and educational technology De Felice et al. (2016). Specifically, your study applies the AHP methodology to evaluate and rank Blackboard's CSFs for successful implementation of cloud-based M-learning.

First_phase.1 Data Analysis:

The data analysis will involve calculating the overall rankings of the dimensions and CSFs using the AHP method. The data will be presented using tables, graphs, and charts to facilitate interpretation.

First_phase.2

Table 2: T. L. Saaty (1980) an AHP scale table:

AHP Scale	**Definition**
1	Equal importance
3	Moderate importance of one over another
5	Strong importance of one over another
7	Very strong importance of one over another
9	Extreme importance of one over another
2, 4, 6, 8	Intermediate values for the judgments between the two adjacent judgments

Second_phase. Application of AHP in CBML: Second_phase.1: Identify the main categories of CSFs**:** Start by identifying the main categories of CSFs that are relevant to cloud-based m-learning. These may include factors related to mobile device compatibility (MDC), learning management systems (LMS), scalability (Scal), instructor support (IS), content quality (CQ), and others.

Table 3: Overall Main_CSFs for CBML

Code	**Overall Main_CSFs for CBML**
MDC	Mobile_Device_Compatibility
LM	Learning_Management
Scal	Scalability
DS	Data_Security
IS	Instructor_Support
LE	Learner_Engagement
CQ	Content_Quality

Second_phase.2: Identify the sub-factors within each category: Within each category of CSFs, identify the specific sub-factors that are most critical for the success of cloud-based m-learning. This can be done using methods such as the analytic hierarchy process (AHP) to evaluate and rank the sub-factors based on their importance.

Table 4: Code of Sub_CSFs related to CBML

Code	**Main Factor**	**Sub_Factore**
Q1_MDC1	Mobile Device Compatibility	Compatibility with different mobile devices and operating systems
Q2_MDC2		Easy-to-use user interface and user experience design
Q3_MDC3		Mobile-friendly content and multimedia elements
Q4_MDC4		Mobile-specific features, such as push notifications and offline access
Q5_MDC5		Mobile analytics and performance metrics
Q6_DS1	Data Security	Data encryption and security protocols
Q7_DS2		User authentication and access controls
Q8_DS3		Data backup and disaster recovery measures
Q9_DS4		Compliance with data protection regulations
Q10_DS5		Incident response and data breach management procedures
Q11_DS6		User privacy and confidentiality measures
Q12_LE1	Learner Engagement	User interface and experience design
Q13_LE2		Customization and adaptive learning features
Q14_LE3		Social learning features and collaboration tools
Q15_LE4		Feedback mechanisms and evaluation tools
Q16_LE5		Accessibility and ease of use
Q17_LE6		Engaging and interactive content
Q18_LE7		Feedback and evaluation tools that enhance learning and progress
Q19_CQ1	Content Quality	Content accuracy and importance
Q20_CQ2		Content design and format
Q21_CQ3		Interaction elements and multimedia
Q22_CQ4		High-quality visual aids
Q23_CQ5		Accessibility to content
Q24_CQ6		User-generated content and peer review
Q25_LM1	Learning Management	Course management and scheduling tools
Q26_LM2		Learner progress tracking and reporting
Q27_LM3		Assessment and testing tools
Q28_LM4		Learning analytics and performance metrics
Q29_LM5		Integration with other learning management systems
Q30_LM6		Teacher management and support tools
Q31_Scal1	Scalability	Scalability of technical infrastructure
Q32_Scal2		Scalability of learning management system
Q33_Scal3		Ability to handle large numbers of users and data
Q34_Scal4		Scalability of teacher support system
Q35_Scal5		Scalability of content creation and management process
Q36_IS1	Instructor Support	Trainer availability and accessibility
Q37_IS2		Trainer training and support resources
Q38_IS3		Communication and collaboration tools for trainers
Q39_IS4		Feedback and evaluation tools for trainers
Q40_IS5		Teacher performance metrics and reporting.

Third_phase: Calculate CBML Local Ranking

CSFs from CBML While cloud-based learning systems are still in their infancy, they have proven to be beneficial when deployed in higher education. Mobile technology and cloud computing have several significant advantages Naveed et al. (2023). CSFs related to CBML were categorized into seven major domains, comprising different sub-factors, for the current study.

Table 5: Main-Criteria CBML Ranking

Main-Criteria Ranking of CSFs of CBML	**N**	**Local Ranking**	**Mean**	**Std. Deviation**

Mobile_Device_Compatibility	74	1	3.99	0.71
Learning_Management	74	2	3.93	0.91
Scalability	74	3	3.85	0.93
Data_Security	74	4	3.82	0.82
Instructor_Support	74	5	3.60	0.98
Learner_Engagement	74	6	3.42	1.01
Content_Quality	74	7	3.38	0.99

Table 6: Sub-Criteria CBML Ranking

Sub-Criteria Ranking of CSFs of CBML	**N**	**Ranking**	**Mean**	**Std. Deviation**	**Variance**
Mobile_Device_Compatibility					
Q3_MDC3	74	1	4.2	0.793	0.63
Q1_MDC1	74	2	4.08	0.84	0.706
Q2_MDC2	74	3	4.05	0.842	0.709
Q5_MDC5	74	4	4	1.034	1.068
Q4_MDC4	74	5	3.61	1.203	1.447
Data_Security	N	Ranking	Mean	Std. Deviation	Variance
Q9_DS4	74	1	3.93	0.912	0.831
Q10_DS5	74	2	3.85	0.932	0.868
Q6_DS1	74	3	3.82	0.817	0.667
Q11_DS6	74	4	3.59	0.978	0.957
Q7_DS2	74	5	3.42	1.007	1.014
Q8_DS3	74	6	3.38	0.989	0.978
Learner_Engagement	N	Ranking	Mean	Std. Deviation	Variance
Q17_LE6	74	1	4	0.844	0.712
Q13_LE2	74	2	3.96	0.971	0.944
Q18_LE7	74	3	3.81	1.002	1.005
Q16_LE5	74	4	3.35	1.039	1.08
Q12_LE1	74	5	3.3	1.144	1.308
Q15_LE4	74	6	3.19	1.289	1.662
Q14_LE3	74	7	3.01	1.255	1.575
Content_Quality	N	Ranking	Mean	Std. Deviation	Variance
Q24_CQ6	74	1	4.14	0.782	0.612
Q23_CQ5	74	2	4.12	0.827	0.684
Q21_CQ3	74	3	3.95	0.964	0.929
Q22_CQ4	74	4	3.57	1.217	1.482
Q19_CQ1	74	5	3.51	1.024	1.048
Q20_CQ2	74	6	3.5	1.101	1.212
Learning_Management	N	Ranking	Mean	Std. Deviation	Variance
Q27_LM3	74	1	4.46	0.80	0.64
Q29_LM5	74	2	3.88	1.07	1.15
Q25_LM1	74	3	3.73	0.93	0.86
Q26_LM2	74	4	3.73	1.06	1.13
Q30_LM6	74	5	3.68	0.91	0.83
Q28_LM4	74	6	3.62	1.11	1.23
Scalability	N	Ranking	Mean	Std. Deviation	Variance
Q34_Scal4	74	1	3.66	1.04	1.08
Q31_Scal1	74	2	3.45	1.10	1.21
Q32_Scal2	74	3	3.43	1.17	1.37
Q33_Scal3	74	4	3.42	1.05	1.10
Q35_Scal5	74	5	3.16	1.27	1.62
Instructor_Support	N	Ranking	Mean	Std. Deviation	Variance
Q37_IS2	74	1	3.89	1.02	1.03
Q40_IS5	74	2	3.61	0.95	0.90
Q38_IS3	74	3	3.61	1.11	1.23
Q39_IS4	74	4	2.89	1.07	1.14

Q36_IS1	74	5	2.61	1.23	1.50

Fourth_phase: Prioritize the identified CSFs: Once the main categories and sub-factors have been identified, prioritize them based on their relative importance. This can be done by assigning weights to each sub-factor within its category and ranking them accordingly.

Fourth_phase.1 Develop a pairwise comparison matrix: Using the AHP method, in T. L. Saaty (1996) the pairwise comparison matrix for the top level (CSFs for mobile cloud learning) is as follows:

Construct the decision matrix, A = [a_ij], with the dimensions m * n, where "a_ij "represents the importance of criterion "i " relative to criterion "j".

Table 7: Pairwise comparison matrix of the main_CSFs of CBML using AHP

Criteria	**MDC**	**LM**	**Scal**	**DS**	**IS**	**LE**	**CQ**
M_Compatibility	1	0.14	0.2	1.00	0.50	0.20	0.33
Learning_Management	7.00	1	1	2	1.00	0.20	0.50
Scalability	5.00	1.00	1	2	1.00	0.50	1.00
Data_Security	1.00	0.50	0.5	1	1.00	0.11	1.00
Instructor_Support	2.00	1.00	1.00	1.00	1	1.00	1.00
Learner_Engagement	5.00	5.00	2.00	9.00	1.00	1	6.00
Content_Quality	3.00	2.00	1.00	1.00	1.00	0.17	1

Fourth_phase.2: Calculate the Global-weights for main-Criteria: Use the AHP method to calculate the weights of each criterion at each level of the hierarchy. According to T. L. Saaty (2000), the normalized values for the top level pairwise comparison matrix are as follows:

- Normalize the decision matrix, A, by dividing each column by the sum of its values to obtain the matrix, W = [w_ij], with dimensions m*n, where w_ij = a_ij/∑a_kj.

- For each criterion k, calculate the matrix S_k = [s_kij] with dimensions m*m, where

s_kij = w_ik * b_kij

- Calculate the vector C_i with dimensions mx1, where c_i = ∑s_kij, for each alternative i

- Normalize the vector, C_i, by dividing each element by the sum of all elements to obtain the final priority vector, P_i, where p_i = c_i/∑c_i.

Table 8: normalized main_CSFs of CBML using AHP

Criteria	**Normalized Values**	**Global Weight**	**Global Ranking**
Mobile Device Compatibility	0.1349	0.208	2
Data_Security	0.1053	0.237	1
Learning_Management	0.1473	0.193	3
Content_Quality	0.1058	0.182	4
Learner_Engagement	0.1282	0.091	5
Scalability	0.1835	0.062	6
Instructor_Support	0.0951	0.027	7

Based on these values, it appears that "Scalability" and "Learning Management" are the two most critical factors for the study, with weights of 0.1835 and 0.1473, respectively. "Mobile Device Compatibility" and "Learner Engagement" are also relatively important, with weights of 0.1349 and 0.1282, respectively. In contrast, "Data_Security," "Content_Quality", and "Instructor_Support" appear to be less important factors in the study, with weights of 0.1053, 0.1058, and 0.0951, respectively.

These normalized values suggest that the study places greater emphasis on factors related to the Scalability of the cloud-based M-learning system, as well as the "Learning Management" process. Additionally, the study prioritizes factors related to the "Mobile Device Compatibility" and "Learner Engagement" of the system, likely due to their critical role in ensuring the system can handle large amounts of data securely.

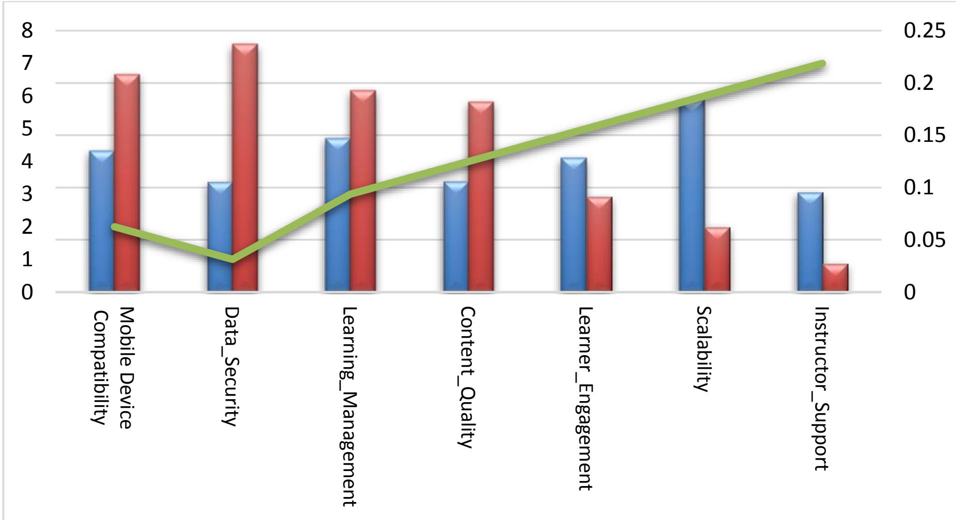

Fig. 1: Normalized Main_CSFs of CBML using AHP

It is important to note that these weights are based on the pairwise comparisons made by the study participants and are only one component of the AHP analysis. Additional analyses, such as the consistency ratio or sensitivity analysis, should be conducted to ensure the robustness of the results.

Check consistency: Check the consistency of the pairwise comparison matrix using the consistency index (CI) and consistency ratio (CR). If the CR is less than 0.1, then the pairwise comparisons are considered to be consistent.

To calculate the Consistency Ratio (CR), we first need to calculate the Consistency Index (CI) using the following formula:

$CI = (\lambda_{max} - n) / (n - 1)$, T. L. Saaty (1996)

For Main Criteria: $CI = (7.3318 - 7) / (7 - 1) = 0.553$

Where λmax is the maximum eigenvalue of the pairwise comparison matrix and n is the number of criteria or sub-criteria being compared. Next, calculate the Random Index (RI) using a table of pre-determined values based on the number of criteria or sub-criteria being compared. According to Saaty, T. L. (1996) random index value "RI" for 7 criteria approximately is "1.32".

Table 9: Random Index values

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.53	1.56	1.57	1.59

Finally, calculate the Consistency Ratio (CR) using the following formula:

$CR = CI / RI$

For Main Criteria: $CR = (0.0553) / 1.32 = 0.0419$

Fourth_phase.3: Calculate the Global-weights for Sub-Criteria: Prioritizing CBML Sub-CSFs involves calculating their global weights. AHP can be used for this purpose. To obtain the weight vectors for each criterion, the AHP method constructs a pairwise comparison matrix and normalizes the decision matrix. In the same way as the main-CSFs, Sub-CSFs can be ranked and weighed. CBML's global weights are presented in the (table.10).

Based on the pairwise comparison matrix for the sub-factors, it appears that "Q3_MDC3" is the most critical sub-factor for the study, with a global weight of "0.773" and the highest global ranking of "1". This suggests that this sub-factor, which is related to the usability of mobile devices for cloud-based M-learning, is considered the most important sub-factor in the study.

In addition to Q3_MDC3, several other sub-factors are also considered relatively important in the study, including "Q27_LM3" (related to the effectiveness of the learning management system), "Q34_Scal4" (related to the scalability of the system), and "Q37_IS2" (related to the availability of instructor support). These sub-factors have global weights of 0.352, 0.278, and 0.286, respectively, and are ranked 2nd, 7th, and 6th, respectively.

On the other hand, several sub-factors are considered less important in the study, including "Q36_IS1, "Q38_IS3," Q39_IS4," and "Q40_IS5" (all related to Instructor_Support), as well as " Q20_CQ2," " Q19_CQ1," and " Q22_CQ4" (all related to content quality). These sub-factors have global weights of 0.086, 0.083, 0.063, 0.117, 0.115, and 0.111, respectively, and are ranked 38th, 39th, 40th, 28th, 29th, and 30th, respectively.

Table 10: Composite rank and weight of main_CSFs and Sub_CSFs of CBML Using AHP

Main-CSFs Cloud Based M-learning	Sub-CSFs	Global Weight	Global Ranking
Mobile_Device_Compatibility (CI = 0.0829)	Q3_MDC3	0.773	1
	Q1_MDC1	0.266	10
	Q2_MDC2	0.262	12
	Q5_MDC5	0.259	14
	Q4_MDC4	0.139	23
Data_Security (CI = 0.0757)	Q9_DS4	0.088	37
	Q10_DS5	0.086	38
	Q6_DS1	0.083	39
	Q11_DS6	0.063	40
	Q7_DS2	0.105	31
	Q8_DS3	0.100	32
Learner_Engagement (CI =0.2296)	Q17_LE6	0.266	11
	Q13_LE2	0.262	13
	Q18_LE7	0.252	16
	Q16_LE5	0.296	5
	Q12_LE1	0.176	17
	Q15_LE4	0.164	22
	Q14_LE3	0.124	27
Content_Quality (CI=0.10394)	Q24_CQ6	0.271	8
	Q23_CQ5	0.269	9
	Q21_CQ3	0.258	15
	Q22_CQ4	0.117	28
	Q19_CQ1	0.115	29
	Q20_CQ2	0.111	30
Learning_Management (CI=0.1001)	Q27_LM3	0.352	2
	Q29_LM5	0.286	6
	Q25_LM1	0.172	18
	Q26_LM2	0.172	19
	Q30_LM6	0.137	24
	Q28_LM4	0.132	25
Scalability (CI=0.1005)	Q34_Scal4	0.306	3
	Q31_Scal1	0.299	4
	Q32_Scal2	0.278	7
	Q33_Scal3	0.168	20
	Q35_Scal5	0.166	21
Instructor_Support (CI=0.0945)	Q37_IS2	0.130	26
	Q40_IS5	0.100	33
	Q38_IS3	0.100	34
	Q39_IS4	0.098	35
	Q36_IS1	0.096	36

Overall, these results suggest that the study places a significant emphasis on sub-factors related to the usability and functionality of mobile devices for cloud-based M-learning, as well as factors related to the effectiveness and scalability of the system. Meanwhile, factors related to learner engagement and content quality are considered less critical in the study. It is important to note that these results should be interpreted in the context of the specific study and its objectives, and that different studies may prioritize different sub-factors depending on their research questions and goals.

Therefore, based on these previous studies, we can conclude that the results of the current study using the AHP method are consistent with the findings of previous research in the field of e-learning and mobile learning. The critical success factors and sub-criteria identified in the current study are similar to those identified in previous studies, which adds to the validity and reliability of the findings obtained using the AHP method.

Fifth_phase. Develop strategies to address each CSF: Finally, develop strategies to address each of the identified CSFs in order to ensure the success of cloud-based m-learning. This may involve developing new technologies, improving existing systems, providing additional support to instructors and learners, and enhancing the quality of content (Ahmad et al., 2020).

Using this framework, institutions and organizations can identify and address the key factors that are critical to cloud-based m-learning's success. These factors should be prioritized, and strategies developed to address them in order for m-learning initiatives to improve effectiveness and efficiency and yield better results.

5 Results and Findings:

The study presented and discussed the results and conclusions in a comprehensive manner, by providing an arrangement of the dimensions and critical success factors (CSFs) of cloud-based mobile learning in order of importance. Through the AHP analysis, the main and sub-critical success factors were identified, and the results obtained were compared with those of previous studies in this field:

- Mobile Device Compatibility: This was identified as the top priority CSF with a global weight of 0.208. This finding is consistent with previous studies that highlight the importance of compatibility and accessibility of mobile devices to support mobile learning as (Sophonhiranrak, 2021).
- Data Security: Data security was identified as the second most critical CSF with a global weight of 0.237. This finding is also consistent with previous studies, such as (Ahmad et al., 2020) that emphasize the importance of data security and privacy in cloud-based learning.
- Learning Management: Learning management was identified as a critical CSF with a global weight of 0.193. This finding aligns with the importance of having an effective learning management system (LMS) to support the delivery of learning content, assessment, and tracking of learners' progress as in (Fagan, 2019).
- Content Quality: Content quality was identified as a critical CSF with a global weight of 0.182. This finding is consistent with previous research that highlights the importance of high-quality, engaging, and relevant learning content to support effective learning outcomes, (Mulhem, 2020).
- Learner Engagement: Learner engagement was identified as a relatively important CSF with a global weight of 0.091. This finding supports the importance of keeping learners engaged and motivated in the learning process to improve learning outcomes, (Heflin et al., 2017).
- Scalability: Scalability was identified as a relatively important CSF with a global weight of 0.062. This finding is consistent with previous research that emphasizes the importance of scalability and flexibility to accommodate different learning needs and environments.
- Instructor Support: Instructor support was identified as the least critical CSF with a global weight of 0.027. This finding suggests that while instructor support is important, it may not be the most critical factor in the success of cloud-based mobile learning, as finding in (Naveed et al., 2020b).

The sub-CSFs identified in the framework are more specific and related to the main CSFs. They can help to further understand the factors that influence the success of cloud-based mobile learning. Here are some more sub-CSFs identified in the study:

- Under the main CSF of "Learning Management," the sub-CSFs include criteria such as Q9_LM1 (Course Organization and Navigation), Q10_LM2 (Assessment and Feedback), and Q11_LM3 (Tracking and Reporting). These sub-CSFs help to identify specific features and functionalities that an effective LMS should have to support cloud-based mobile learning.
- Under the main CSF of "Content Quality," the sub-CSFs include criteria such as Q12_CQ1 (Content Relevance), Q13_CQ2 (Content Interactivity), and Q14_CQ3 (Content Presentation). These sub-CSFs help to identify specific factors that contribute to the quality of learning content, such as its relevance to learners' needs, level of interactivity, and presentation format.
- Under the main CSF of "Learner Engagement," the sub-CSFs include criteria such as Q15_LE1 (Gasification and Rewards), Q16_LE2 (Social Learning), and Q17_LE3 (Personalization). These sub-CSFs help to identify specific strategies and approaches that can be used to engage learners and make the learning experience more enjoyable and effective.
- Under the main CSF of "Scalability," the sub-CSFs include criteria such as Q18_SC1 (User Base Size), Q19_SC2 (Resource Availability), and Q20_SC3 (Technology Compatibility). These sub-CSFs help to identify specific factors

that organizations need to consider when designing and implementing cloud-based mobile learning initiatives that can accommodate different learning needs and environments.

The sub-CSFs identified in this study provide a detailed framework for understanding the critical success factors (CSFs) of cloud-based mobile learning. The main CSFs, such as "Mobile Device Compatibility" and "Data Security," each have specific sub-CSFs that help identify the technical requirements and security measures needed to support cloud-based learning effectively. Educators and learning designers can use these CSFs and sub-CSFs to develop more effective strategies that improve learning outcomes.

Additionally, organizations can use this information to gain a more nuanced understanding of the factors that contribute to the success of cloud-based mobile learning and develop targeted approaches to address specific challenges and opportunities in this field. By focusing on critical sub-CSFs such as "Content Interactivity" and "Social Learning," organizations can develop learning content that provides engaging experiences and incorporates social learning features.

This framework offers a comprehensive understanding of the critical success factors for cloud-based mobile learning and can assist organizations in developing more effective and targeted strategies.

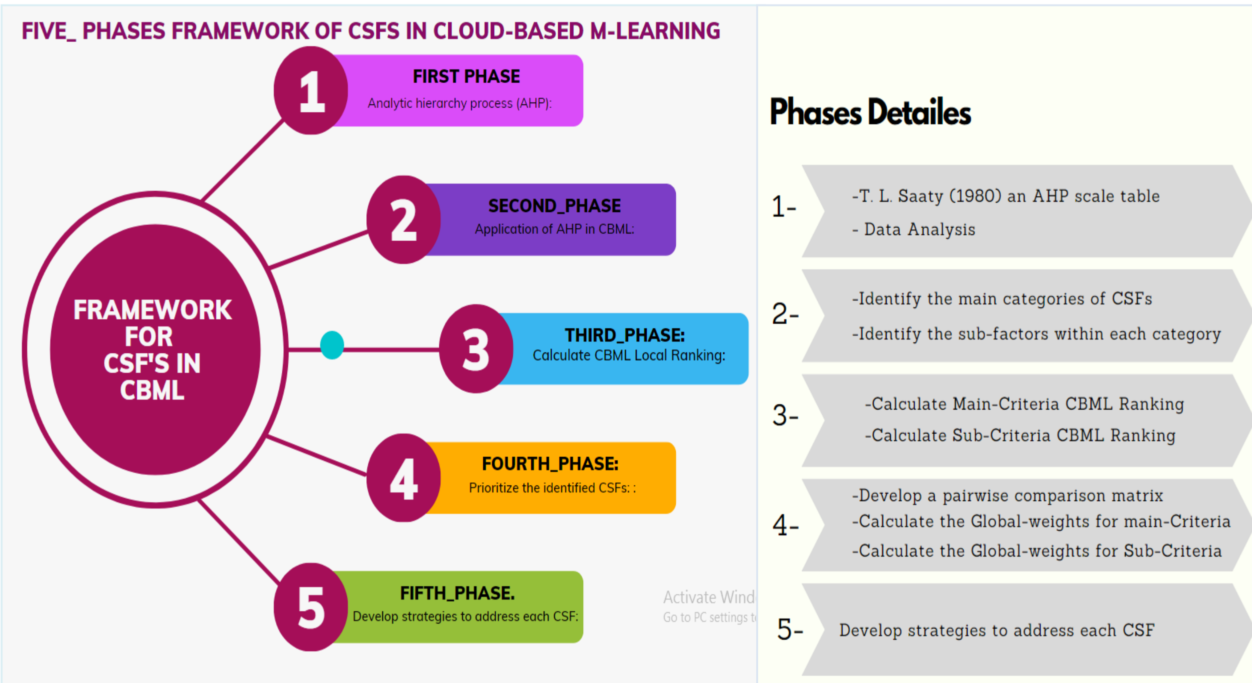

Fig. 2: Framework of CSFs in Cloud-based m-learning (CBML):

6 Conclusion

The objective of this research was to determine the crucial success factors (CSFs) for the effective execution of cloud-based mobile learning (CBML). The study employed multiple approaches such as literature review, expert review, and the Analytical Hierarchy Process (AHP) to identify seven CSF criteria for CBML: Pedagogy, Mobile Compatibility, Data Security, Learning Management, Content Quality, Portability, and Support for Teachers. The study also identified forty sub-criteria for CBML within each of these CSF criteria. Using the AHP method, a comprehensive framework was developed to explain the CSFs, which can be employed by organizations to ensure the successful implementation of CBML and enhance their competitive performance. Furthermore, educators and academic content designers can utilize this framework to devise more effective and tailored strategies to improve learning outcomes and tackle specific challenges and opportunities in the field.

This research provides valuable insights for practitioners and researchers in the field of information systems and mobile cloud learning. Additionally, it contributes to the literature on CSFs by identifying and regulating factors specific to CBML.

7 Future Work and Limitations

The study identified several avenues for future research, including empirical validation of the critical success factors (CSFs), further investigation into the relationships between CSFs and their impact on cloud-based mobile learning (CBML) outcomes, periodic updates to the CSFs and framework to account for fast-paced technological developments, and research on CBML implementation in different contexts. However, the study also has limitations, including its primary focus on experts' perspectives and the need to consider the perspectives of learners and other stakeholders. It also needs to conduct empirical studies to validate the CSFs, consider cultural differences, and evaluate the effectiveness of the proposed framework in real-world settings.

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