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Original Article

Do Technological Factors Significantly Influence Cloud Computing Adoption among SMEs?

James Anankack Kadia

Department of Computer Science and Technology, European Institute of management and technology, Zug, Switzerland

Corresponding Author : jmskadia@gmail.com

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Abstract - *The objective of this meta-analysis was to evaluate the impact of technological factors on the implementation of cloud computing among Small and Medium-sized Enterprises (SMEs) using secondary data gathered from recently published scholarly sources. The study included only quantitative studies published in 2020 and beyond, and it was based on the relationship between technological factors and cloud computing implementation. Eight studies satisfied the eligibility criteria for this meta-analysis. Two models were estimated. The first model estimated the overall pooled effect of various technological factors. This positive model was statistically significant, indicating that technological factors substantially impact cloud computing implementation in SMEs. The second model was a subgroup analysis in which the pooled effect of various technological factors - complexity, compatibility, security, performance, price, and general technological factors was determined. Findings showed that cost, compatibility, and other general technological factors substantially affect SMEs' use of cloud computing. Such results are crucial in shedding light on the essential role technological aspects play in the adoption of cloud computing technologies in SMEs.*

Keywords - *Cloud computing, Technological factors, SMEs, Technology adoption, TOE framework.*

1. Introduction

Technological advancements have been integrated with many industries, particularly Small and Medium-scale Enterprises (SMEs). Among these technological innovations, cloud computing has become a disruptive force transforming business operations and services (Almeida et al., 2020). Cloud computing has been the technology of choice for SMEs because of the high popularity of cloud technology within a short time and lasting rewards, including value for money and higher productivity (Almeida et al., 2020; Hanney et al., 2022). Cichosz et al. (2020) also pointed out that businesses that are implementing cloud computing technologies have been observed to have experienced an enhanced level of operational efficiency and productivity. When using cloud computing, SMEs remove redundancies to accelerate time-to-market; it will be possible to collaborate internally and externally through the cloud using digital assets. Using cloud computing, SMEs can access the major value of cost savings and technical advantages (Cichosz et al., 2020).

With the increased usage of cloud computing, adoption among SMEs has remained inconsistent. Some technological factors that have mainly influenced this difference in adoption include perceived ease of use, compatibility with the rest of the systems used, security concerns, and infrastructure requirements (Kabuye, 2023). However, there is limited modern research that communicates in a way that clarifies how these technological variables combine to affect cloud computing uptake among SMEs (Alighar et al., 2023; Kabuye, 2023). Although some studies present individual perspectives, there is a lack of a synthesis of results from many different studies toward forming a picture for the whole (Ayadi, 2022; Trenerry et al., 2021). Additionally, many studies remain outdated because they have not caught up with modern cloud technologies, and much of the existing literature is based on old data published before 2020 (Morrison-Smith & Ruiz, 2020; Skafi et al., 2020). This dearth of literature creates a research gap regarding the role of technological factors in stimulating or hindering cloud computing uptake among SMEs.

In this meta-analysis, the authors aimed to address this gap by evaluating the effects of technological aspects on cloud computing implementation in SMEs, drawing on the most recent scholarly sources from 2020 to 2025. The novelty of this research is that it assembles contemporary research, thus creating new knowledge on how particular technological factors are highly instrumental in adoption. The knowledge from this study may provide a more holistic and latest perspective regarding the technological factors behind the adoption of cloud computing in SMEs. The meta-analysis seeks to answer the following question: *To what extent do*

technological factors influence the adoption of cloud computing in small and medium-sized enterprises?

2. Review of Literature

Cloud computing implementations have rapidly transformed the business world, allowing enterprises to control their assets from afar and run operations. Rather than traditional servers on-premises, cloud computing is a network of remote digital devices where the data is located, maintained, and analyzed online (Omurgonulsen et al., 2021). According to the IDG survey results, globally, cloud computing technologies have a growth rate of 95% annually, which is considered a strong adoption trend, mainly in minute enterprises (Kushagra & Dhingra, 2022; Wynn, 2022). Smaller and medium-sized enterprises (SMEs) are adopting cloud computing to enhance business transactions, control complex data, and stratify decision-making processes (Cichosz et al., 2020). However, such enhanced interest in cloud computing is not experienced by the uniform implementation of cloud computing in SMEs because it mainly depends on various technological factors.

The Technology-Organization-Environment (TOE) offers a strong lens for analyzing the factors that trigger the adoption of cloud computing in SMEs. This framework organizes adoption factors into three broad areas of context (Tornatzky & Fleischer, 1990). The first context is the technological context, the technologies available to an organization, both existing and new. The institutional environment is grounded by the institution's characteristics, resources, and capabilities, including size, structure, and executive commitment. Environmental setting refers to outside aspects, such as industry regulations, competition, and technological framework available in a given industry in the external environment (Tornatzky & Fleischer, 1990). Although the TOE structure elaborates on the factors that influence technology incorporation, this research particularly focuses on technological aspects and how internal and external support for technology affects cloud computing incorporation in SMEs (Tornatzky & Fleischer, 1990). These include the integration of new cloud technologies into a system already in existence, perceived feasibility, compatibility, and the value of these technologies to small businesses.

Different technological factors that shape the perceived value and the practicality of such technologies influence the incorporation of SMEs in the case of cloud computing. Theoretical accessibility, for example, is a key factor determining the adoption rate (Morrison-Smith & Ruiz, 2020). SMEs tend to adopt user-friendly cloud computing systems that need minimum training. According to Kabuye (2023), the easier it is to incorporate cloud technologies into business operations, the higher the chances of its successful adoption. This ease of application is especially pertinent to SMEs with a small budget to train their staff or to overhaul existing systems. Yarberry and Sims (2021) contended that cloud computing usability increases in importance when business competition becomes more intense, which can help small business enterprises continue to have a competitive advantage in their styling. Additionally, Morrison-Smith and Ruiz (2020) argued that cloud computing can establish a robust digital infrastructure that supports the in-depth development and optimization of the entire business.

Another critical technological factor affecting cloud adoption is the ability to be compatible with existing systems. Many SMEs work with minimal IT resourcing and infrastructure that may not always suit new cloud-based systems. Mishra (2023) described that insufficient infrastructure is always a problem for SMEs seeking to embrace cloud computing. Therefore, cloud computing must be integrated effectively into the SME's legacy systems for the transition to be successful. The scarcity of resources highlights that cloud computing is needed and compatible with SMEs' current technological settings.

Security issues are another key area that SMEs should consider when deploying cloud-based solutions. Due to the lack of resources to deploy full-scale cybersecurity methods, concerns over data privacy and cloud-based systems security will act as barriers to adopting these services (Trenerry et al., 2021). Mishra (2023) indicated that SME leaders are expected to determine where to invest to limit such concerns under their control. Such preventive actions safeguard sensitive business records and keep all SMEs competitive in a fast-changing digital milieu. Furthermore, technical assistance is another vital aspect of cloud adoption. SMEs depend on service providers for continuous technical support (Trenerry et al., 2021). Reliable support services may be a factor that determines if an SME is successful or faces problems in combining cloud technologies.

Despite the lack of credible evidence on cloud computing adoption, the existing literature provides inconsistent results. Some studies concentrate on the research of security issues and technological support services (Ayadi, 2022), while others focus on the research of the apparent user-friendliness and compatibility with the existing systems as the most important (Salam & Ali, 2020). According to the available studies, research on cloud adoption within SMEs is heterogeneous since the studies concentrate on individual variables, while other reasons can be generalized. This research gap illustrates the need for a more comprehensive synthesis of the current literature to understand better the interaction of various technological aspects applicable in determining cloud computing adoption.

The available literature has also not been able to generalize the outcomes of other research, particularly those done after 2020. Therefore, a way of addressing how the existing technological advancements and challenges affect the processes of adoption becomes a gap. To address this

knowledge gap, this meta-analysis consisted of synthesizing recent empirical studies on the deploration of cloud computing and contributing to providing a clearer picture of technology aspects. The results of this research can deliver current information on how technological variables influence the decision-making process of SMEs and a single approach toward deploying cloud-based solutions in this area while gathering and reviewing findings from studies that were carried out between the years 2020 and 2025.

The primary aim of this meta-analysis analysis was to find the impact of technological patterns on SMEs' deployment of cloud-based solutions. This research justifies meta-analysis because of the limited investigation on cloud computing that leads to conflicting empirical evidence (Paul & Barari, 2022). Therefore, applying meta-analysis as a tool to synthesize various research data when examining research on cloud computing will help establish trends and make it possible to have a holistic view of how the factors of technology affect the use of cloud computing in SMEs. Moreover, meta-analysis is necessary for this study as the progress of technologies can require a synthesis of up-to-date research findings, considering that a meta-analysis is an amalgamation process of incorporating current findings from research, ensuring that the results and the conclusions obtained from different studies are appropriate and compatible with the existing technological settings (Paul & Barari, 2022). Therefore, a meta-analysis helped the researcher to identify how systematically and rigorously diverse studies with empirical evidence can be synthesized to yield insightful information about the technological aspects that shape the integration of cloud computing among SMEs.

3. Materials and Methods

A meta-analysis approach was used to examine the function of technological factors in the implementation of cloud computing. This approach offered a robust method to synthesize studies on the association between technological aspects and the adoption of cloud computing. The choice of this approach was informed by its ability to solve the problem of conflicting study results regarding the association of these two variables. Meta-analysis provided detailed insight into the research question: How do technology-based aspects affect *the uptake of cloud computing?*

3.1. Data Collection

This analysis used data from previously published journals and dissertations on the association between technological factors and cloud computing deployment. These journals and dissertations were identified using a structured review of the literature. Since the study focused on the association between variables, this study relied on studies that used Multiple Linear Regression (MLR) and Structural Equation Modeling (SEM) to determine the effect size. This study also relied on the studies published between 2020 and 2025 since the researcher intended to delve into the current practices, trends, and advancements in this phenomenon of cloud computing. Studies with inadequate statistical reporting and poor data presentation were also excluded since they posed difficulty for meta-analysis.

Keywords related to technological factors were as follows: technological factors, technology readiness, IT infrastructure, apparent value, Intuitive usability, relative advantage, IT capability, complexity, and compatibility. The keywords related to cloud computing adoption were as follows: cloud-based solutions, IaaS, PaaS, SaaS, cloud services adoption, and cloud computing adoption. Lastly, keywords related to the concept of SMEs were as follows: SMEs, small and medium-sized enterprises, small firms, small-scale businesses, small-scale companies, and medium-sized firms. These keywords were used to construct search strings to query previously identified academic databases. The following search string was constructed using Boolean operators:

Search string: ("technological factors" OR "technology readiness" OR "IT infrastructure" OR "perceived usefulness" OR "perceived ease of use" OR "complexity" OR "IT capability" OR "relative advantage" OR "complexity") AND ("cloud computing adoption" OR "cloud-based solutions" OR "SaaS" OR "PaaS" OR "IaaS" OR "cloud services adoption") AND ("SMEs" OR "small and medium-sized enterprises" OR "small firms" OR "small-scale businesses" OR "medium-sized firms")

Using the search string above, the authors queried the following databases for relevant academic articles regarding the link between technological factors and the uptake of cloud computing by small and medium-sized enterprises: IEEE Xplore, JSTOR, ScienceDirect, Web of Science, ProQuest, Google Scholar, Scopus, SpringerLink, Wiley Online Library, EBSCOhost, and SAGE Journals.

Cumulatively, 314 scholarly articles were found in the academic data storage system specified above. However, not all the 314 articles were subjected to screening. Before screening, 122 articles were removed because they were duplicate records. Automation tools removed 33 articles, while 12 were removed for other reasons, such as not being published in English. The remaining 147 articles were subjected to title and abstract screening. The authors performed the screening process manually and excluded 83 articles that did not focus on the relationship between technological factors and cloud computing deployment. From the 147 articles initially screened, only 64 were sought for retrieval. However, 27 articles could not be retrieved successfully, and only 37 were assessed for eligibility.

Eligibility assessment involved examining each study to ensure it (a) focuses on the relationship between technological factors and cloud computing adoption, (b) employed either

linear regression or structural equation modeling, and (c) was published not earlier than 2020. After a full-text review of each of the 37 articles, three were excluded because they did not use linear regression or structural equation modeling to examine the relationship between technological factors and cloud computing adoption. Another seven articles were excluded because they were published earlier than 2020 and hence were not regarded as fresh sources of evidence. Lastly, nine articles were excluded because they did not focus on the relationship between technological factors and cloud computing adoption. After a thorough assessment and removal of ineligible articles, only 8 articles remained. Therefore, only eight studies were identified and included in the meta-analysis, as indicated in Figure 1. The PRISMA flow chart in Figure 1 maps out the phases of identifying, retrieving, and filtering studies that were relied on for this meta-analysis.

Quantitative data was carefully extracted from each of the 15 scholarly articles and recorded in an Excel sheet. Since only studies that employed regression analysis or structural equation modeling were included in this analysis, the findings extracted comprised the following statistics: sample size, standard error, and raw beta coefficient. Additional information from the studies included the specific technological factors examined and the author(s) name(s). The authors collapsed the specific technological factors examined in different studies into six major categories: cost of adoption, security concerns, performance and perceived usefulness, the complexity of the cloud computing infrastructure and environment, compatibility with legacy systems, and other general technological factors. A snapshot of the dataset is shown in Figure 2 below:

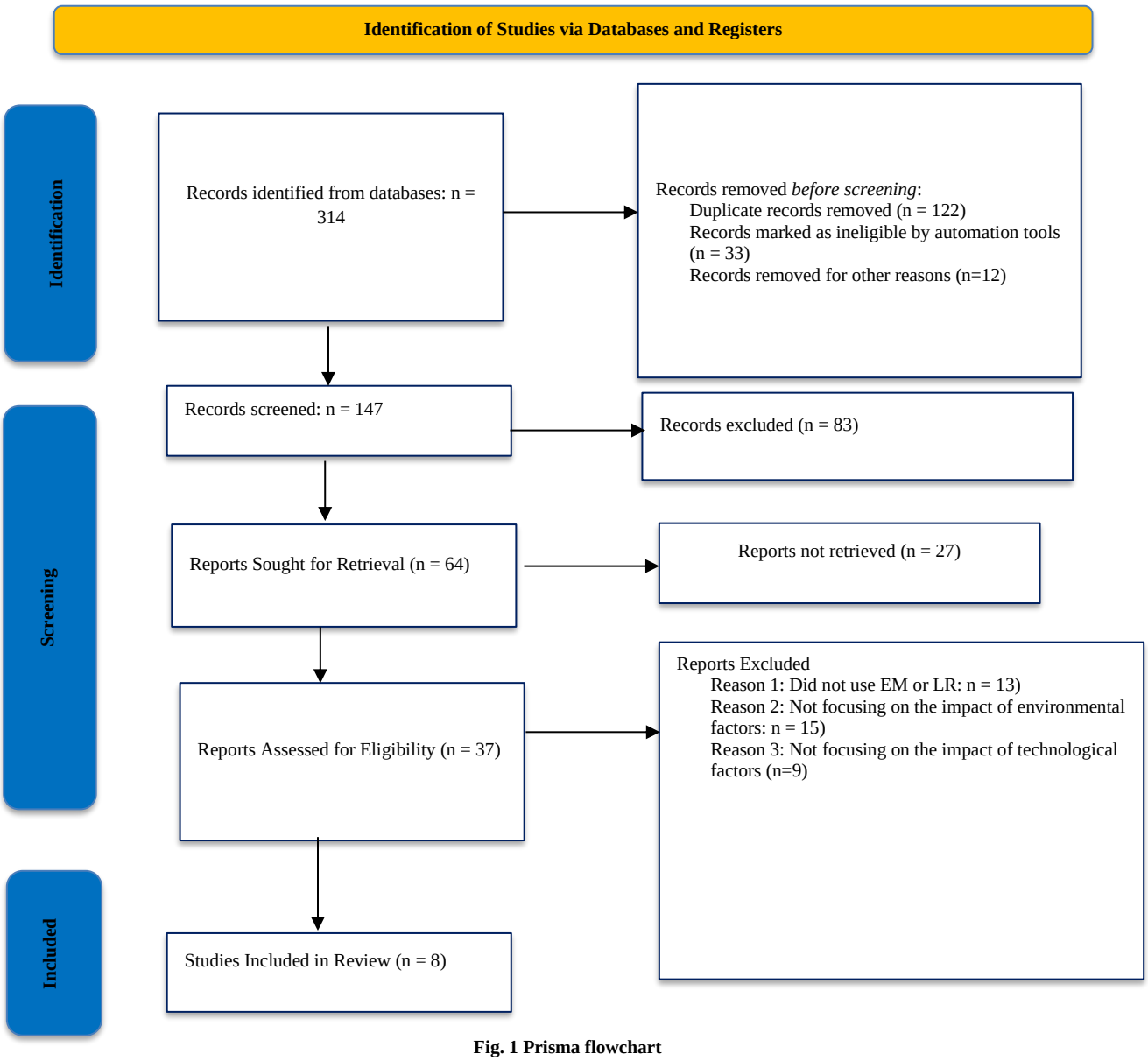

Fig. 1 Prisma flowchart

Table 1. A Snapshot of Metadata on the Impact of Technological Factors on Cloud Computing

Author	Predictor	Type	Sample Size	Beta Coefficient	Standard Error
Kabuye (2023)	Technological Factors	General Technological Factors	329	0.659	0.01930000
Skafi et al. (2020)	IT Infrastructure	General Technological Factors	139	-0.569	0.08200000
Skafi et al. (2020)	Relative Advantage	Performance-related Factors	139	-0.453	0.35500000
Skafi et al. (2020)	Cost effect	Cost-related Factors	139	-0.543	0.35200000
Skafi et al. (2020)	Compatibility	Compatibility-related Factors	139	0.450	0.26000000
Skafi et al. (2020)	Complexity	Complexity-related Factors	139	-0.371	0.34300000
Skafi et al. (2020)	Trialability	General Technological Factors	139	0.411	0.39700000
Skafi et al. (2020)	Innovativeness	Performance-related Factors	139	0.426	0.36300000
Skafi et al. (2020)	Technology Experience	General Technological Factors	139	1.413	0.66600000
Ali et al. (2020)	Compatibility	Compatibility-related Factors	140	0.577	0.26600000
Ali et al. (2020)	Complexity	Complexity-related Factors	140	0.269	0.16000000
Ali et al. (2020)	Cost	Cost-related Factors	140	0.269	0.16500000
Salim & Ali (2020)	Effort Expectancy	Complexity-related Factors	123	0.228	0.11970000
Salim & Ali (2020)	Performance Expectancy	Performance-related Factors	123	1.063	0.27090000
Salim & Ali (2020)	Perceived Confidentiality	Security-related Factors	123	0.191	0.13500000
Salim & Ali (2020)	Perceived Integrity	Security-related Factors	123	0.059	0.12060000
Salim & Ali (2020)	Perceived Availability	Security-related Factors	123	2.980	0.15300000
Qatawneh (2024)	Technology related factors	General Technological Factors	373	0.390	0.12400000
Qatawneh (2024)	Complexity	Complexity-related Factors	373	0.181	0.12900000
Qatawneh (2024)	Compatibility	Compatibility-related Factors	373	0.189	0.08000000
Qatawneh (2024)	Relative Advantage	Performance-related Factors	373	0.399	0.11800000
Qatawneh (2024)	Cost	Cost-related Factors	373	0.350	0.13700000
Aligarh et al. (2023)	Relative Advantage	Performance-related Factors	197	0.356	0.09000000
Ayadi (2022)	Security	Security-related Factors	123	0.150	0.15410000
Ayadi (2022)	Compatibility	Compatibility-related Factors	123	0.195	0.15300000
Ayadi (2022)	Costs	Cost-related Factors	123	-0.118	0.10020000
Hussein Alghumami et al. (2020)	Top Management Support	Management Support	328	0.139	0.04750000
Hussein Alghumami et al. (2020)	Technology Readiness	Organizational Readiness	328	0.176	0.05385000
Hussein Alghumami et al. (2020)	Security	Security-related Factors	328	0.230	0.04875000

3.2. Data Analysis

A meta-analysis of evidence gathered from recently published academic material was conducted to determine if technological factors heavily influence the adoption of cloud computing technology in SMEs. R software facilitated the analysis. Specifically, the researcher relied on the meta library. Although not part of the core R software, the library package contains functions for calculating pooled effect sizes and confidence intervals in meta-analysis.

The authors estimated two models. In the first model, the authors computed the pooled effect size representing technological factors' overall effect on cloud computing adoption. Due to significant heterogeneity (reported under the results section), the random effects model was preferred to the fixed-effects model. In the second model, the authors conducted a subgroup meta-analysis where the pooled effect of each of the five major categories of technological factors was estimated alongside the confidence intervals for determining statistical significance. The results are reported in the next section.

4. Results

Eight unique quantitative studies concentrated on the effect of technological aspects on cloud computing adoption in small and medium businesses. Out of the eight studies, four focused on the cost of implementation as a crucial element affecting the deployment of cloud computing technology (Ali et al., 2020; Ayadi et al., 2022; Qatawneh, 2024; Skafi et al., 2020). Three other studies examined security concerns as a critical factor driving cloud-based computing deployment (Ayadi, 2022; Hussein et al., 2020; Salim & Ali, 2020). Salim and Ali (2020) presented evidence on various security-related factors, including the perceived Data security, integrity, and availability of data after transferring it to the cloud. However, Ayadi (2022) and Hussein et al. (2020) did not analyze the effect of individual-level security-related items.

The performance and perceived usefulness of cloud-based solutions were other important elements studied in previous quantitative research. Reports were published from six studies regarding evidence on the impact of productivity and perceived usefulness (Ayadi, 2022; Alighar et al., 2023; Hussein et al., 2020; Qatawneh, 2024; Salim & Ali, 2020; Skafi et al., 2020). As established from across five studies, the most significant performance-related variable analyzed in previous literature has been the comparative advantage of using cloud computing instead of local computing.

Examples of other performance-related factors investigated in previous literature are the degree to which the deployment of cloud computing promotes innovativeness (Skafi et al., 2020), reliability of cloud computing (Hussein et al., 2020), and overall performance expectancy (Salim & Ali, 2020). As has been reviewed in earlier studies, one of the core factors that influenced cloud computing deployment was the complexity of the cloud computing infrastructure and the environment itself. Using the information from six studies (Ayadi, 2022; Aligarh et al., 2023; Salim & Ali, 2020; Ali et al., 2020; Qatawneh, 2024; and Skafi et al., 2020), evidence on this factor was reported. The congruence of cloud computing systems with ongoing legacy frameworks also surfaced as a key factor hypothesized to influence the adoption of cloud computing, studies which are reported in five studies, namely Skafi et al. (2020), Ali et al. (2020), Qatawneh (2024), Ayadi (2022), and Hussein et al. (2020). Other factors were classified under the general technology factor. These factors included its infrastructure, trialability, and technological experience (Skafi et al., 2020).

4.1. Overall Model

The outcome of the overall structure is shown in Figure 3. The random effects model was preferred since heterogeneity was high (98%). The overall random effects model was statistically significant (95% C.I. [0.11; 0.48]), with a standardized effect of 0.3919. Given this result, there is a considerable positive relationship between technological factors and the adoption of cloud computing among small and medium-sized enterprises. This pooled estimate was expected since most of the studies in the overall model reported statistically significant effects, as evidenced by the 95% confidence intervals shown in Figure 3. Only a few studies, like 'Skafi et al. (2020) - IT Infrastructure,' 'Skafi et al. (2020) - Complexity,' 'Ayadi (2022) - Cost,' and 'Ayadi (2022) - Relative Advantage.' The results of this overall pooled effect estimation are shown in Figure 3.

4.2. Subgroup Results

Since technological factors likely influence adoption differently, subgroup analysis was done to determine the influence of specific technological factors. Figure 4 presents the outcomes of the subgroup meta-analysis. The first subgroup consisted of performance-related factors, which included the comparative benefit of cloud computing compared to other computing solutions, innovativeness, performance expectancy, and consistency of cloud computing.

All the studies that examined the effect of performance-related factors reported positive and statistically significant effects except Skafi et al. (2020), who found relative advantage and innovativeness not be significantly associated with cloud computing usage, and Ayadi (2020), who reported a significant relationship between comparative benefit and cloud computing deployment. Heterogeneity in this subgroup was high (I2 = 97%), suggesting differences across the individual studies that examined the effect of performance-related factors. Given such high heterogeneity, the random effects model was chosen over the fixed-effects model. Considering the random-effects model, the pooled effect of these performance-related factors was positive (0.33) but not statistically significant (95% C.I [-0.11; 0.77]).

Table 2. Overall Radom Effect Model Results

Study or Subgroup	TE	SE	Weight (common)	Weight (random)	SMD [95% CI]
Kabuye (2023) - Technological Factors	0.3333	0.1090	1.4%	3.3%	0.33 [0.12; 0.55]
Skafi et al. (2020) - IT Infrastructure	-0.1772	0.2800	0.2%	2.7%	-0.36 [-0.79; 0.07]
Skafi et al. (2020) - Relative Advantage	0.0721	0.5120	0.1%	1.7%	0.06 [-0.25; 0.39]
Skafi et al. (2020) - Cost effect	-0.5430	0.3690	0.6%	1.9%	-0.56 [-1.03; -0.08]
Skafi et al. (2020) - Compatibility	0.2760	0.2720	0.2%	2.7%	0.27 [-0.18; 0.73]
Skafi et al. (2020) - Complexity	-0.1820	0.3440	0.1%	2.4%	-0.18 [-0.85; 0.49]
Skafi et al. (2020) - Trialability	0.0880	0.3930	0.1%	1.2%	0.09 [-0.68; 0.86]
Salim & Ali (2020) - Performance Expectancy	1.7555	0.0970	1.8%	3.9%	1.44 [1.02; 1.87]
Qatawneh (2024) - Technology-related factors	0.3320	0.5730	3.4%	5.1%	0.16 [-0.23; 0.79]
Ali et al. (2020) - Compatibility	0.2148	0.2700	0.3%	2.9%	0.18 [-0.13; 0.66]
Ayadi (2022) - Relative Advantage	-0.1470	0.1012	1.6%	1.6%	-0.15 [-0.34; 0.15]
Hussein Alghumami et al. (2020) - Reliability	0.1436	0.0408	3.4%	9.3%	0.14 [0.06; 0.22]
Total (common effect, 95% CI)			100%	100%	0.25 [0.23; 0.28]
Total (random effect, 95% CI)			100%	100%	0.30 [0.11; 0.48]
Prediction Interval					[-0.77; 1.36]
Heterogeneity $Tau^2 = 0.2635$	$Chi^2 = 658.03$, df = 32 ($P < 0.01$); $I^2 = 95\%$				
Test for subgroup differences (common effect)	$Chi^2 = 13.92$, df = 5 ($P < 0.01$)				
Test for subgroup differences (random effect)	$Chi^2 = 4.75$, df = 5 ($P = 0.45$)				

The second subgroup consisted of cost-related factors. Four of the eight studies in this meta-analysis examined the impact of cost-related aspects on cloud computing deployment (Aligarh et al., 2023; Ayadi, 2022; Hussein et al., 2020; Salim; Ali, 2020; Skafi et al., 2020). Heterogeneity in this subgroup was quite low ($I^2 = 40\%$), suggesting that the four studies did not significantly differ in research design. Due to low heterogeneity, the common effects model was preferred for this subgroup. As shown in Figure 4, the pooled effect of cost-related factors was positive (B = 0.32) and analytically meaningful (95% CI [0.23; 0.41]). This result shows that the original setup and maintenance costs considerably impact SMEs' implementation of cloud computing.

The third subgroup consisted of compatibility-related factors. In the case of cloud computing, conformity is the extent to which the specific cloud computing framework being adopted is in line with existing systems (Hussein et al., 2020). This subgroup had no heterogeneity ($I^2 = 0\%$); hence, the common effects model was preferred.

As per the common effects model, the pooled effect of compatibility-related factors was positive (B =0.18) and statistically significant (95% CI [0.10; 0.25]). As such, the conformity of cloud computing technology and current legacy systems significantly impacts cloud computing deployment among SMEs.

The fourth subgroup consisted of complexity-related factors - the level at which potential adopters perceived cloud computing or its adoption as complex. Six studies reported findings on the impact of perceived complexity on cloud computing adoption. Heterogeneity was extremely high in this group (I^2 = 97%); hence the random effects model was preferred.

As per the random effects model results shown in Figure 4, the pooled effect of aspects associated with complexity, like effort expectancy and perceived complexity, was positive (B = 0.34) but not statistically significant (95% CI [-0.22; 0.90]). This result indicates no recent literature evidence that complexity significantly influences cloud computing deployment among SMEs.

The fifth factor included security-related aspects such as perceived confidentiality, integrity, availability, and data security. Three studies reported evidence of the impact of security-related factors on cloud computing implementation (Ayadi, 2022; Hussein et al., 2020; Salim & Ali, 2020). Heterogeneity in this subgroup was high (I^2 = 98%); hence, the random effects model was chosen over the fixed-effects one. The aggregated effect of security-related factors was positive (B = 0.53). However, there was no evidence in support of a meaningful connection between safety-related factors and cloud computing deployment (95% CI [-0.20; 1.26]).

The last subgroup consisted of different factors assigned the umbrella term' general technological factors.' These factors could not fit into the above five subgroups, nor could they be collapsed into categories with shared semantic similarity since they were few and widely unrelated. Factors under this last subgroup include IT infrastructure, trialability, and technological experience.

Researchers such as Kabuye (2023) and Qatawneh (2024) examined 'technological factors' as a composite variable; hence, their findings were included in this last subgroup. Heterogeneity was extremely low in this subgroup (I^2 = 0%); hence the common effects model was preferred. The pooled effect was positive (B = 0.31) and statistically significant (95% CI [0.19; 0.42]).

Table 3. Subgroup Meta-analysis Results

Study or Subgroup	SMD	SE	Weight (common)	Weight (random)	SMD [95% CI]
Type = General Technological Factors					
Kabuye (2023) - Technological Factors	0.3330	0.1090	1.4%	3.3%	0.33 [0.12; 0.55]
Skafi et al. (2020) - IT Infrastructure	-0.1772	0.2800	0.2%	2.7%	-0.36 [-0.79; 0.07]
Skafi et al. (2020) - Trialability	0.0880	0.3930	0.1%	1.2%	0.09 [-0.68; 0.86]
Skafi et al. (2020) - Technology Experience	0.1802	0.6600	0.2%	2.3%	0.18 [-0.46; 0.81]
Qatawneh (2024) - Technology related factors	0.3320	0.5730	3.4%	5.1%	0.16 [-0.23; 0.79]
Total (common effect, 95% CI)			12.8%	19.6%	0.31 [0.19; 0.42]
Total (random effect, 95% CI)			5.1%	12.8%	0.31 [0.12; 0.47]
Heterogeneity Tau^2 = 0.0	Chi^2 = 3.49, df = 4 (P = 0.48); I^2 = 0%				
Type = Performance-related Factors					
Skafi et al. (2020) - Relative Advantage	0.0721	0.5120	0.1%	0.2%	0.06 [-0.25; 0.39]
Skafi et al. (2020) - Innovativeness	0.1066	0.3390	0.1%	2.4%	0.11 [-0.56; 0.67]
Salim & Ali (2020) - Performance Expectancy	1.7555	0.0590	1.8%	3.4%	1.44 [1.02; 1.87]
Qatawneh (2024) - Relative Advantage	0.1479	0.3700	1.6%	2.8%	0.15 [-0.17; 0.74]

Aligarh et al. (2023) - Relative Advantage	0.1053	0.4590	0.5%	3.2%	0.13 [-0.32; 0.57]
Ayadi (2022) - Relative Advantage	-0.1470	0.1012	1.6%	1.6%	-0.15 [-0.34; 0.15]
Hussein Alghumami et al. (2020) - Relative Advantage	0.2427	0.0298	18.5%	9.6%	0.23 [0.19; 0.27]
Hussein Alghumami et al. (2020) - Reliability	0.1436	0.0408	3.4%	9.3%	0.14 [0.06; 0.22]
Total (common effect, 95% CI)			40.1%	40.1%	0.14 [0.05; 0.77]
Total (random effect, 95% CI)			40.1%	40.1%	0.13 [0.01; 0.51]
Heterogeneity Tau^2 = 0.3643	Chi^2 = 278.64, df = 7 (P < 0.01); I^2 = 97%				
Test for subgroup differences (common effect)	Chi^2 = 13.92, df = 5 (P < 0.01)				
Test for subgroup differences (random effect)	Chi^2 = 4.75, df = 5 (P = 0.45)				
Study or Subgroup	SMD	SE	Weight (common)	Weight (random)	SMD [95% CI]
Type = Cost-related Factors					
Skafi et al. (2020) - Cost effect	0.0449	0.3850	0.1%	2.2%	0.34 [-0.71; 0.80]
Ali et al. (2020) - Cost	0.1378	0.1650	0.6%	3.1%	0.10 [-0.19; 0.46]
Qatawneh (2024) - Cost	0.3624	0.5000	6.6%	3.4%	0.46 [-0.32; 0.46]
Ayadi (2022) - Costs	-0.0005	0.2000	0.3%	6.7%	-0.06 [-0.36; 0.35]
Total (common effect, 95% CI)			7.7%	11.8%	0.32 [0.23; 0.41]
Total (random effect, 95% CI)			7.7%	11.8%	0.32 [0.21; 0.43]
Heterogeneity Tau^2 = 0.0205	Chi^2 = 5.02, df = 3 (P = 0.17); I^2 = 40%				
Type = Compatibility-related Factors					
Skafi et al. (2020) - Compatibility	0.2760	0.2720	0.2%	2.7%	0.27 [-0.18; 0.73]
Ali et al. (2020) - Compatibility	0.2148	0.2700	0.3%	2.9%	0.18 [-0.13; 0.66]
Qatawneh (2024) - Compatibility	0.1165	0.0901	2.6%	3.4%	0.27 [-0.10; 0.67]
Ayadi (2022) - Compatibility	0.1951	0.0901	2.6%	3.4%	0.17 [-0.08; 0.60]
Hussein Alghumami et al. (2020) - Compatibility	0.1967	0.0503	6.5%	3.4%	0.20 [0.10; 0.51]
Total (common effect, 95% CI)			11.7%	15.7%	0.18 [0.10; 0.25]
Total (random effect, 95% CI)			11.7%	15.7%	0.18 [0.10; 0.25]
Heterogeneity Tau^2 = 0.000	Chi^2 = 1.11, df = 4 (P = 0.89); I^2 = 0%				

Type = Complexity-related Factors					
Skafi et al. (2020) - Complexity	-0.1820	0.3440	0.1%	2.4%	-0.18 [-0.85; 0.49]
Ali et al. (2020) - Complexity	0.1716	0.0660	3.8%	3.4%	0.17 [0.04; 0.50]
Salim & Ali (2020) - Effort Expectancy	1.1700	0.1193	1.2%	3.4%	1.11 [1.15; 1.49]
Qatawneh (2024) - Complexity	0.1450	0.0500	6.6%	5.2%	0.16 [0.05; 0.58]
Aligarh et al. (2023) - Complexity	0.0221	0.0452	0.3%	2.9%	0.02 [-0.22; 0.26]
Ayadi (2022) - Complexity	0.0494	0.2189	0.3%	6.7%	0.03 [-0.10; 0.61]
Total (common effect, 95% CI)			20.1%	18.8%	0.10 [-0.13; 0.48]
Total (random effect, 95% CI)			20.1%	18.8%	0.10 [-0.13; 0.48]
Heterogeneity Tau² = 0.4619	Chi² = 178.67, df = 5 (P < 0.01); I² = 97%				
Study or Subgroup	SMD	SE	Weight (common)	Weight (random)	SMD [95% CI]
Type = Security-related Factors					
Salim & Ali (2020) - Perceived Confidentiality	0.1300	0.1325	0.9%	3.2%	0.13 [0.13; 0.39]
Salim & Ali (2020) - Perceived Integrity	0.0500	0.1606	0.9%	3.1%	0.06 [-0.13; 0.28]
Salim & Ali (2020) - Perceived Availability	0.2180	0.1331	0.9%	3.3%	0.22 [0.07; 0.37]
Ayadi (2022) - Security	0.1979	0.0933	1.7%	3.3%	0.11 [-0.22; 0.52]
Hussein Alghumami et al. (2020) - Security	0.2533	0.0833	1.3%	5.7%	0.12 [0.02; 0.57]
Total (common effect, 95% CI)			15.4%	16.4%	0.16 [0.05; 0.42]
Total (random effect, 95% CI)			15.4%	16.4%	0.16 [0.05; 0.48]
Heterogeneity Tau² = 0.6727	Chi² = 171.79, df = 4 (P < 0.01); I² = 98%				
Total (common effect, 95% CI)			100.0%	100.0%	0.25 [0.23; 0.28]
Total (random effect, 95% CI)			100.0%	100.0%	0.30 [0.17; 0.48]
Prediction Interval					[-0.77; 1.36]
Heterogeneity Tau² = 0.2635	Chi² = 658.03, df = 32 (P < 0.01); I² = 95%				
Test for subgroup differences (common effect)	Chi² = 13.92, df = 5 (P < 0.01)				
Test for subgroup differences (random effect)	Chi² = 4.75, df = 5 (P = 0.45)				

5. Discussion

The outcomes of this meta-analysis present an important perspective on the impact of technological aspects in the implementation of cloud computing in SMEs. Relying on synthesizing eight distinctive quantitative studies concerned with the impact of technological factors on the usage of cloud computing in small and medium-sized businesses, the current research has shown the relevance of technological factors in the case of the TOE framework, which provides a thorough and organized means by which to explore the ramifications of technological aspects on the implementation of cloud computing within SMEs. This section presents key observations, the implications of these findings, and how they fit the existing empirical publications on cloud computing adoptions.

The meta-analysis results demonstrated a strong positive connection between technological aspects and the practice of cloud computing among SMEs. Technological parameters, such as performance-based factors, may affect the implementation of cloud computing in different ways. The meta-analysis results showed that the effect of performance-related variables on cloud computing adoption was positive but not statistically significant. The findings indicated that SMES perceived improved performance attributed to the importance of adopting cloud computing, and such perceived value would lead them to embrace cloud computing in their operations based on perceived usefulness. The results correspond with the discussed literature on the impact of performance and perceived usefulness on cloud computing implementation based on five studies, which reveal that the common performance-related factor considered in prior literature was cloud computing's superior advantages compared to traditional on-site computing (Ayadi, 2022; Alighar et al., 2023; Alighar et al., 2023; Hussein et al., 2020; Qatawneh, 2024; Salim & Ali, 2020; Skafi et al., 2020).

Based on the meta-analysis, there were positive and statistically significant effects of cost-related factors on cloud computing implementation by SMEs, such that the cost of implementing cloud computing could influence their adoption. This was because the cost benefits that accrue from the implementation of cloud computing are likely to increase its usage in SME organizations. The meta-analysis findings align with the existing empirical articles that cloud computing has adopted as the latest and greatest technology for significant long-term benefits for small-scale businesses, cost efficiency, and increased productivity (Hanney et al., 2022). According to Cichosz et al. (2020), small business entities that utilize cloud computing as a technological utopia have observed a marginal increase in cost efficiency and productivity. Therefore, using cloud computing technologies can break it down for businesses to connect to the vast potential cost benefits of technology adoption (Cichosz et al., 2020), which may promote cloud computing applications in SMEs.

The overall random effects model was statistically significant (p = 0.0024), positive, and as expected. Statistically significant compatibility-related technological aspects positively impacted cloud implementation in SMEs. This shows that cloud technology must be compatible with the existing technological setup. This concurs with existing empirical studies that suggest that the compatibility of existing systems with technology can influence the implementation of cloud computing technologies in SMEs (Ali et al., 2020). Poor resource allocation may prevent the use of cloud computing as small entities do not have the infrastructure essential for the new cloud computing tools, which may block technological improvements and later adoption (Mishra, 2023). Similar to the current research findings, past literature reported that the congruence of the cloud computing networks with existing legacy systems may be one of the hypothesized critical aspects that could impact cloud computing usage (Ali et al., 2020; Skafi et al., 2020).

Contrary to this, the impact of complexity-related factors was positive but not statistically significant; hence, complexity might influence the implementation of cloud computing, but not at a substantial range. Earlier studies showed the complexity of the cloud computing infrastructure and environment as an important element hypothesized to impact cloud computing usage (Aligarh et al., 2023; Ayadi, 2022). Security-related factors also had positive effects but were not statistically significant as per the meta-analysis findings since SMES perceived privacy and security concerns as affecting their intention of adopting cloud computing, which could discourage them from considering adopting the technology. This finding aligns with previous research findings that security issues can motivate strategic SMEs to adopt cloud computing (Ayadi, 2022; Hussein et al., 2020). Salim and Ali (2020) reported various data related to security aspects, such as the perception of confidentiality of the data when it is transferred into cloud computing, its integrity, etc. The lack of necessary resources and infrastructure to develop cybersecurity measures to protect data and privacy has challenged SMEs regarding data privacy and security (Ria, 2023). This research has shown what is required to implement cloud computing technologies in SMEs.

5.1. Comparison with Existing Research and Novel Contributions

This meta-analysis represents an important contribution as it offers a consolidated overview of the most current works focused on the impact of technological elements in cloud computing implementation in SMEs. In contrast to previous studies that usually study individual factors in decoupled measures, this study summarises results from elsewhere. The study presents a broader picture of how findings fit across multiple studies to describe how user-friendliness, compatibility, safety, and cost influence adoption. With the help of a meta-analytic approach, this research eliminates the drawbacks of previous smaller sample sizes and regional bias

studies, thus writing more sound and generalized conclusions. Notably, despite the positive effects indicated by performance-related factors, the statistical insignificance of these factors accentuates the importance of continued probing to establish how these factors combine with other factors discussed well in prior studies.

The novelty of this research lies primarily in that the analyzed studies are based on works published after 2020, which enabled us to build our work considering the most recent technological advancements in cloud computing. This concentrated on recent literature allows the study to cover current challenges, such as emerging cybersecurity risks and the changing landscape of cloud technology, which the previous studies would have neglected. Using the TOE framework and applying strict meta-analytic methods, the present research clarifies why technological parameters affect the adoption process in SMEs. These contributions make this study different from previous studies, which did not have a comprehensive synthesis or did not consider new technology into account.

7. Implications

Several implications can be derived from the findings of this study. Local and state governments may consider developing policies to favour implementing cloud computing technology in SMEs to enhance investment and innovation. Local and state governments may impose regulatory frameworks and policies that foster or prevent implementing cloud computing services in SMEs. The policies developed by government agencies, including regulatory guidelines for data protection, may help SMEs to ensure they adhere to stipulated regulations when adopting cloud computing enhanced operations and overall performance.

Leaders in SMEs should consider diverse aspects prior to implementing cloud-based services. Thus, they may be required to identify important areas for investments in infrastructure and implement robust measures to address security concerns to enhance customer satisfaction, as customers may influence how they adopt cloud computing. Similarly, tech-savvy professionals in SMEs may use these research results to understand the importance of a competitive edge over competitors by adapting to the ever-evolving technological development in the business context, such as cloud-based services.

This research's findings may help cloud computing service providers understand various environmental factors they must adhere to, including government policies and competitive pressures that may influence how SMEs adopt cloud computing. Therefore, these providers may need to offer cloud-based systems that are user-friendly and compatible with the existing systems within the SMEs to promote the implementation of cloud computing. The need for SMEs to create a strong rivalrous benefit for their services and products on the market may pressure them to adopt innovative strategies such as cloud computing for efficient operations to satisfy the competitive needs in the sector.

8. Conclusion

This research aimed to explore the connection between external ecological aspects and the implementation of cloud computing in SMEs. This study has provided important insights into how external environmental factors impact the endorsement of cloud computing among SMEs. The synthesis of existing empirical literature in this research has provided an understanding of how diverse external environmental factors, including competitive pressures, government policies, customer satisfaction, and peer pressure, affect the implementation of cloud computing in SMEs. Thus, this meta-analysis research findings indicated meaningful implications for institutional heads, local and state governments, decision-makers, professionals in cloud-based services, and cloud computing vendors who would need to consider such factors in future decision-making. This research also offers important background and reference for future research on effective strategies and environmental factors to be considered when promoting the adoption of cloud computing within the SME industry. Therefore, the consistent progression and evolution of cloud computing technologies may dictate the necessity to understand numerous external environmental aspects that may impact the implementation of cloud computing to promote creativity and innovation in diverse industries such as SME organizations.

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