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Critical Decision-Making on Cloud Computing Adoption in Organizations Based on Augmented Force Field Analysis

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ABSTRACT Cloud Computing (CC) has become an important milestone information technology that attracts many organizations. With the potential to transform business processes, lower IT expenses, and offer access to unlimited computing resources with minimal management effort, organizations look to cloud-based solutions to achieve business efficiencies. Thus, it would seem that these organizations could easily migrate to CC. However, enterprises are still concerned about moving their business-critical applications to the cloud. Among the reasons are that it is an emerging technology that has not reached a level of maturity; the lack of industry-specific conformity to standards; and a high level of security risks. As a result, there is a big dispute among organizations on the decision of whether it is more business-efficient to embark on the cloud or remain with their interior IT infrastructures. In this paper, we aim to solve this debate by proposing a novel approach that supports decision-making on CC adoption in organizations. Unlike traditional decision-making approaches that pay little or no consideration to organizational high-level business objectives, our proposed approach is driven by the business objectives of the organization. First, we identify driving and restraining forces that influence CC adoption in organizations. Second, a formal decision-making model is proposed based on Force Field Analysis (FFA) augmented by pairwise comparison and Delphi methods, this model estimates the values of the driving and restraining forces based on their impacts on the organization's objectives. By analyzing the forces for and against CC adoption, organizations can decide whether or not to move forward with the adoption. Alternatively, organizations can use the analysis to think about how they can strengthen the forces that support the adoption and weaken the forces opposing it, so that the adoption is more successful. The proposed model is validated for usability and applicability through a use case scenario.

INDEX TERMS Cloud computing, decision making, force field analysis (FFA), pairwise comparison, Delphi method.

I. INTRODUCTION

Cloud Computing (CC) is an emerging technology that promises many benefits over conventional on-premises computing. It provides vast opportunities for organizations to have more flexible and easy-running business models [9]. As the strategic focus on flexibility, innovation, and economic gains increases, organizations can no longer ignore CC's benefits. Recently, enterprises have shown increasing interest in the adoption of CC services to support critical business functions. According to Forbes, CC market is projected to reach $411B by 2020 [40]. A survey conducted by Logic-Monitor revealed that 83% of enterprise workloads will be in the Cloud by 2020 [43]. CC offers for companies a wide variety of IT services at a low cost. With decreased costs and less effort required to invest in and maintain hardware, license new software, or train new personnel, enterprises have more time to focus on their core business activities. In addition, CC services offer features such as elasticity and scalability that enhance the agility required to carry out the necessary business changes in an innovative and competitive environment [5].

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Although several benefits of CC are well known and documented, evidence suggests that not all companies are rushing to adopt cloud-based solutions [6]. As highlighted by Mindshift Technologies, Inc. [41] many small businesses are still setting on the fence contemplating whether to move to or not to move to CC [7]. The reluctance to adopt CC services in organizations is due to different concerns about this technology. For instance, the distributed nature of CC leads to many different issues, including security and privacy threats, national and international regulations, latency and unplanned outage. Compatibility issues (e.g., vendor interoperability, connectivity to existing technology, inter-organizational connectivity) have been identified as an adoption inhibitor [5]. Moreover, reliability, trust and start-up costs are emphasized as barriers in particular for Small and Medium Enterprises (SMEs). SMEs have many worries concerning CC adoption since they have only a modest investment in technology, a limited technical capabilities and often rely on smaller groups of IT staff for their IT needs. Clearly, the cloud phenomenon is not a magic solution for all organizations and its costs may outweigh its benefits. The reluctance to adopt CC solutions is therefore real and noteworthy and a well-informed decision has to be made in organizations on whether to move to the cloud or not [6].

While there are many studies that have focused on operational issues regarding evaluation and selection of CC services [1], [2], [12], [17]]–[21] and technical issues regarding security [3], [4], [8], [22]–[27] and risk assessment [13], [14], [28]–[30], the research on issues concerning the adoption of CC is still in a nascent stage and there is a lack of knowledge among organizations on how to make a well-informed decision on CC adoption [5], [10], [11]. The decision regarding whether to adopt Cloud solutions is additionally complicated by the issue of how CC adoption impact the achievement of high-level business objectives of the organizations. This paper aims to fill this research gap and proposes a novel approach that supports decision-making on CC adoption. Unlike traditional decision-making approaches that pay little or no consideration to organizational high-level business objectives, our proposed approach is driven by the business objectives of the organization. First, we identify driving and restraining forces that influence CC adoption in organizations. Second, a formal decision-making model is proposed based on Force Field Analysis (FFA) augmented by pairwise comparison and Delphi methods, this model estimates the values of the driving and restraining forces based on their impacts on the organization's objectives. By analyzing the forces for and against CC adoption, organizations can decide whether or not to move forward with the adoption. Alternatively, organizations can use the analysis to think about how they can strengthen the forces that support the adoption and weaken the forces opposing it, so that the adoption is more successful. The proposed model is validated for usability and applicability through a use case scenario.

The rest of this paper is organized as follows: in section 2, we present key concepts on CC and FFA. In section 3, previous studies regarding CC adoption are reviewed. Section 4 outlines our proposed approach. The driving forces (motivators) for CC adoption and restraining forces (inhibitors) are identified in section 5. Section 6 describes the proposed decision-making model in detail. In section 7, the usability and applicability of the proposed model is validated through a use-case scenario. Finally, in section 8, we give our conclusion remarks and future work.

II. ESSENTIAL CONCEPTS

A. CLOUD COMPUTING

The most widely used definition of CC is introduced by the U.S. National Institute of Standards and Technology (NIST) [42] as: "*A model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction*". This cloud model comprises five essential characteristics which are: *on demand self-service; broad network access; resource pooling; rapid elasticity; and measured service,* three service models, and four deployment models.

The three service models are: *Software as a Service (SaaS); Platform as a Service (PaaS);* and *Infrastructure as a Service (IaaS)* and they are described below [1], [2], [6], [7], [15], [42].

- **Software as a Service (SaaS):** instead of installing and updating software on the client's machine with regular patches, frequent version upgrades etc., applications such as CRM (Customer Relationship Management) and ERP (Enterprise Resource Planning) are hosted on the cloud (on the internet) for end-user consumption. Using different client devices, consumers can access the applications via a client interface such as a web browser. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities.
- **Platform-as-a-Service (PaaS):** platforms and Software Development Kits (SDK) and tools (such as Java,.NET, Python, Ruby on Rails) are made available over the Internet instead of purchasing software licenses for platforms such as operating systems, databases and middleware. PaaS provides an integrated solution stack for consumers to create and deploy cloud-based applications. An advantage of this model is the ability to deliver all aspects of software development over the Internet (design, testing, version control, maintenance, and hosting). The consumer does not manage or control the underlying cloud infrastructure, but has control over the deployed applications.
- **Infrastructure-as-a-Service (IaaS):** this refers to the physical devices such as servers, storage devices, network transfer, which are physically located in one central place (data center) but they can be accessed and used over the Internet from any terminal or device.

The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications.

The four deployment models are: *private cloud; community cloud; public cloud;* and *hybrid cloud* and they are described below [1], [2], [6], [7], [15], [42].

- **Private cloud:** the cloud infrastructure is exclusively used by a single organization comprising multiple business units. It may be owned, managed, and operated by the organization, a third party, or some combination of them, and it may exist on or off premises.
- **Community cloud:** the cloud infrastructure is exclusively used by a specific community of organizations that have shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them, and it may exist on or off premises.
- **Public cloud:** the cloud infrastructure is used by the general public. It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the cloud provider.
- **Hybrid cloud:** the cloud infrastructure consists of two or more different cloud infrastructures (private, community, or public) that remain distinct, but are bound together by standardized or proprietary technology that enables data and application portability).

B. FORCE FIELD ANALYSIS

Making complex decisions in organizations is often difficult because many factors are at play, each with differing degrees of importance. For example, ''Should a firm purchase a new ERP software?'' ''Should a factory upgrade with a new manufacturing machinery?'' and ''Should an organization adopt an emerging IT technology?'' are just a few complex questions organizations may ask. Force Field Analysis (FFA) [16] was developed by Kurt Lewin (1951) and is widely used to inform decision-making, particularly in planning and implementing changes in organizations. It is a powerful method of gaining a comprehensive overview of the different forces acting on a potential organizational change issue. The decision regarding change is made by looking at both the driving and restraining forces that influence a change in an organization. Assuming a change of some sort has been suggested, the framework of FFA shown in figure 1 helps organizations identify the forces that would support the change and the forces that would act against it.

The following steps may be used to conduct FFA.

1. Determine the change that your organization is considering.
2. Identify all forces for the change **(Driving Forces)** on one side and all forces against the change **(Restraining Forces)** on the other side.

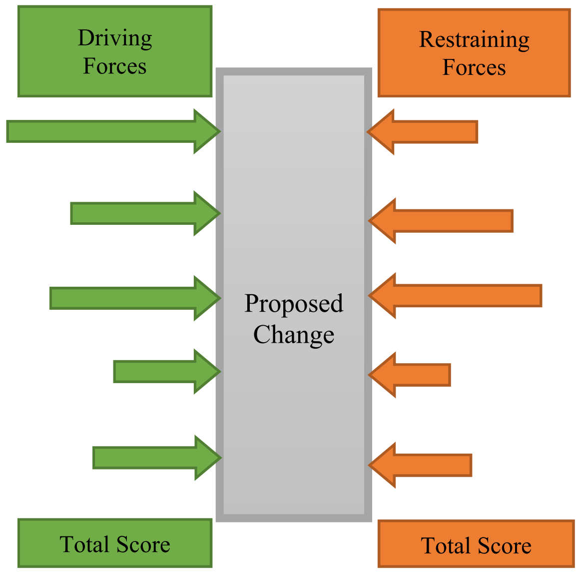

FIGURE 1. A prototypical FFA layout.

3. Score the impact of each force on an appropriate scale.
4. Total the scores on each side. If the score of **Driving Forces** outweigh the score of **Restraining Forces**, then it is likely that your organization should make the change, otherwise consider what steps might be taken to shift the imbalance.

III. LITERATURE REVIEW

Yang and Tate [11] conducted a descriptive literature review of 205 refereed journal articles on CC research, their study indicates that research on CC is skewed mostly toward technological issues. They highlighted the scarcity of cumulative research to address the social, organizational, and environmental perspectives of CC. In spite of that, we have conducted an extensive survey on the issue of CC adoption in organizations. Our goal is to gain an insight on the various factors affecting CC adoption that have been investigated in previous studies. Popular theories such as the Technology Acceptance Model (TAM) [35], [36], the Theory of Planned Behavior (TPB) [37], and the Unified Theory of Acceptance and Use of Technology (UTAUT) [38] were deployed to evaluate CC adoption from individual's user perspective. Other studies have approached the problem from an organizational perspective [5]–[7], [15], [45]–[55]. Two theories are commonly used to study the adoption of CC in organizations. They are the Diffusion of Innovation (DOI) [39] theory and the Technology-Organization-Environment (TOE) [44] model. A common research methodology in these studies consists of four steps:

1) identify the factors influencing CC adoption based on TOE, DOI or Systematic Literature Review (SLR), 2) make hypotheses on the effect (i.e., positive or negative) of each factor, 3) conduct a questionnaire-based survey to collect data regarding these factors from individuals of the organizations considered in the study, 4) statistically analyze the collected

TABLE 1. Summary of previous studies on CC adoption in organizations.

Research methodology	factors investigated	source
TOE and DOI	relative advantage, firm size, top management support, competitive pressure, trading partner pressure, complexity, compatibility, and technology readiness	[6,45]
DOI	relative advantage, compatibility, complexity, trialability, observability	[51]
TOE	technology (relative advantage, complexity, compatibility), organization (top management support, firm size, technology readiness), and environment (competitive pressure, trading partner pressure)	[52,53]
IPV and DOI	business process complexity, entrepreneurial culture, compatibility and application functionality	[54]
Group meeting & Questionnaire	costs reduction for software, hardware and IT staff, scalability and flexibility in the IT use, access to IT resources	[55]
SEM, ANN, TOE	perceived IT security risk, risk analysis, technology innovation, management style and trust	[46]
SLR and interviews	effective network, data storage location, availability of different service providers, policy makers, a limited understanding of the cloud and business transformation	[7]
SLR and statistical analysis	ease of use, convenience, security, privacy and reduction	[15]
TOE and HOT-fit	data security, perceived technical competence, cost, top manager support, and complexity	[47]
Delphi	security, strategy and legal and ethical issues	[5]
SLR and SEM	quality of service, trust, security and privacy	[49]
SLR, interviews, and SEM	security, need, supplier availability, on demand service, cost, legislation and regulations, and other factors (reliability, maintenance, virtualization, integration, and performance)	[48]
TAM, ANN, Multiple Linear Regression (MLR)	Computer self-efficacy, perceived usefulness, trust, ease of use, job opportunity	[50]

data to validate the hypotheses. Table 1 summarizes some previous studies on CC adoption in organizations.

Low *et al.* [45] used the DOI and TOE framework to investigate the adoption of CC in the Taiwanese high-tech industry. The eight factors examined in this study are relative advantage, complexity, compatibility, top management support, firm size, technology readiness, competitive pressure, and trading partner pressure. A questionnaire-based survey was used to collect data from 111 firms belonging to the high-tech industry in Taiwan. The findings revealed that five variables (i.e. relative advantage, firm size, top management support, competitive pressure, and trading partner pressure) were found to be significant determinants of CC adoption, and three variables (i.e. complexity, compatibility, and technology readiness) were found to be insignificant determinants of CC adoption.

Priyadarshinee *et al.* [46] developed a hybrid two-stage, Structural Equation Modeling (SEM) – Artificial Neural Network (ANN) model to predict motivators affecting CC adoption services in the Indian private organizations. They proposed a new paradigm by extending the (TOE) with external factors for the first time in a technology adoption study, namely perceived IT security risk and risk analysis. Data from 660 professional experts were collected and analyzed using SEM and ANN modeling structural equation. The SEM results showed that perceived IT security risk, risk analysis, technology innovation, management style and trust have a significant influence on CC adoption. In addition, the results obtained from SEM were used as input to the ANN model and the results showed that the most important predictors in CC adoption were trust, perceived IT security risk and management style.

Lian *et al.* [47] investigated the critical factors that will affect the decision in developing countries to adopt CC technology, particularly in the hospital industry in Taiwan. In order to understand this issue, this study mainly integrates the TOE framework and HOT-fit (human-organization-technology fit) model. Information was gathered through the use of a research questionnaire design for Taiwan hospital CIOs. The results obtained indicate that data security, perceived technical competence, cost, top manager support, and complexity are the five most critical factors. El-Gazzar *et al.* [5] conducted a Delphi study and follow-up interviews to understand the issues facing businesses when making decisions on CC adoption. The findings indicated that the most important issues are security, strategy and legal and ethical issues.

Akar and Mardikyan [48] conducted a study that analyze factors affecting the adoption of CC in Turkey. The methodology used in this study integrates three techniques: first, a literature review is conducted to obtain factors from the literature. Second, factors are evaluated by IT experts to determine whether they are important and testable for the organizations in Turkey or not. Third, a questionnaire is prepared to measure the effects of the collected factors on CC adoption. Data are collected from 306 IT personnel in different Turkish organizations. SEM technique is then applied to measure the effects of these factors. The results revealed that seven main factors are the most important factors affecting CC adoption which are security, organization's need, supplier availability, on demand service, cost, legislation and regulations, and other factors (reliability, maintenance, virtualization, integration, and performance).

IV. OUTLINE OF THE PROPOSED APPROACH

When organizations make critical decisions on adopting new technologies, they pay to use an effective, structured decision-making technique that will improve the quality of their decisions and increase their chances of success. As an emerging technology, the decision on whether to adopt CC in an organization continues to be a confusing issue that needs more effort from the research community. We aim to fill this gap by proposing a novel approach for critical decision-making on CC adoption in organizations based on FFA augmented by pairwise comparison and Delphi methods. FFA is a powerful decision-making tool widely used in organizational change management. The idea behind our proposed approach is that CC adoption is maintained by an equilibrium between forces that drive adoption and others that resist adoption. For the adoption to happen, the driving forces must offset the resisting forces. By analyzing the forces for and against adoption, organizations can decide whether or not to move forward with the adoption. Alternatively, organizations can use the analysis to think about how they can strengthen the forces that support the adoption and weaken the forces opposing it, so that the adoption is more successful.

To carry out our approach, we propose that an organization performs the following procedure:

1. Identify driving and restraining forces that influence CC adoption in organizations based on literature review.
2. Identify the organization's business objectives using SWOT analysis and SMART model.
3. Estimate the relative weights for the organization's objectives using Delphi and pairwise comparison methods.
4. Customize the forces identified in step 1 and specify a subset of driving and restraining forces that have impacts (positive or negative) on organization's objectives.
5. Estimate the impact of each force on each objective using Delphi technique.
6. Evaluate each driving and restraining force based on its impacts on the organization's objectives.
7. Find the total value of the driving forces, D_t, the total value of restraining forces, R_t, and compute the net force ($F_{net} = D_t\text{-}R_t$).
8. Make adoption decision based on F_{net}.

V. DRIVING AND RESTRAINING FORCES

In the light of the literature review conducted in section 3, we now identify driving and restraining forces for CC adoption in organizations. These forces are the basis of our proposed decision-making model.

A. IDENTYING DRIVING FORCES

CC provides many benefits that drive organizations to adopt its services. The potential benefits of adopting CC can be assessed from both resource management and the financial savings perspectives. Its notable features include its market-oriented architecture. Unlike a traditional system-centric resource management architecture, a cloud-based architecture is regulated by the supply and demand of cloud resources at market equilibrium (i.e., pay-per-use). Services are typically provided on the basis of Service Level Agreements (SLAs) and, depending on a particular organization's needs and expectations, can meet different Quality of Service (QoS) criteria. We have identified the driving forces to adopt CC as follows:

1) ***Scalability:*** the ability to accommodate the increase in workload size by increasing infrastructure resources within one system (scale-up) or across multiple systems (scale-out) so that applications have the room to meet the expected increasing demands and to prevent a lack of resources from hindering performance. The cloud is a large scale solution, CSP (e.g., Google, Yahoo, and Amazon) have hundred thousands of servers around the world. They can add new nodes and servers to cloud with minor modifications to cloud infrastructure and software. Cloud provides organizations with virtually unlimited computing and storage capabilities.
2) ***Elasticity:*** is the ability to grow (scale-up) or shrink (scale-down) infrastructure resources dynamically as needed to adapt to workload changes in an autonomic manner, maximizing resources utilization.
3) ***Virtualization:*** cloud isolates physical resources from users at the virtual level, hence, user can create virtual servers, infrastructures, devices and other virtual resources. Virtual resources are location-independent in the sense that their location is generally not controlled or known by the user. Users can access any resources they need without worrying about the details of physical interconnection.
4) ***On-Demand Self-Services:*** cloud services such as web applications, server time, processing power, storage and networks can be delivered automatically as needed by consumers.
5) ***Reliability:*** multiple redundant computer nodes (replication) ensure high service reliability and make cloud more reliable than local computers. High reliability makes the cloud an ideal solution for the recovery of disasters and critical business tasks.
6) ***Broad Network Access (accessibility):*** users can access cloud resources over the Internet through various platform types (e.g. mobile phones, laptops, and PDAs) at any time and from anywhere.
7) ***Resource Pooling (multitenancy):*** physical resources are assembled into one cloud pool. The resources on one physical pool can support multiple virtual systems that are used by different clients, thereby, a cloud can provide services to multiple users at the same time. While users share physical resources at the network level, host level and application level, each user is isolated within his customized virtual application instance.
8) ***Measured Services:*** cloud services are optimized through a pay-per-use business model. Cloud services generally charge users per hour of resource usage, or based on the number of certain kinds of transactions that have occurred, amount of storage in use, and the amount of data transferred over a network, all usage is measured.

9) ***Versatility:*** cloud computing doesn't aim to certain special application. A lot of applications are supported by the cloud and can be run in parallel.
10) ***IT Cost Reduction:*** cloud can be cost efficient in terms of infrastructure, software, and management. Infrastructure cost can be reduced in organizations in the sense that cloud datacenters are built by very inexpensive nodes and located close to cheap power stations and in low cost real estate. Thereby, organizations can lease cloud IT infrastructure that match their needs with lower cost instead of investing in complex and expensive infrastructure. Many applications such as Gmail, Google Docs, and Google Maps can be set up for mostly free, saving cost of licensing new software. In addition, the centered management of CC saves the cost and burden associated with hardware and software maintenance and training new personnel.
11) ***Easy Management:*** applications that are quite storage extensive are easier to use and manage in the cloud environment than within the organization. What you need mostly is a simple web browser with Internet connectivity, also at the user level.
12) ***Availability:*** maintaining critical data backed up using cloud storage services is the most organizations' need for an hour. Furthermore, CSP ensures that they have disaster recovery systems in place.
13) ***Collaboration:*** PaaS enables collaborative work within an organization or between different organizations.
14) ***Green Technology:*** the main disadvantage of today's computing systems is harmful emissions due to the extensive use of systems in organizations, electronic waste generated as time goes by and energy consumption. Using cloud services that preserve the environment and generate e-waste to a minimum, harmful emission can be reduced. CC shares resources among users and does not require large, power-consuming resources.
15) ***IT Efficiency:*** CC enables a variable cost model for IT, minimizes overall IT costs (shift CAPEX to OPEX), improves infrastructure resource deployment and utilization through virtualization, and provides a flexible, reusable application development model.
16) ***Business Agility and Market Competitiveness:*** CC enables quicker "time-to-market" by rapid application deployment and reduced infrastructure setup/configuration, reduces switching costs associated with changing business strategies, and allows for outsourcing segments of IT.

B. IDENTYING RESTRAINING FORCES

Despite the potential advantages provided by CC, there are still several challenges and issues for its adoption in organizations. Concerns about CC relate to security, privacy and trust issues, latency and unplanned outage, and compatibility and interoperability issues. All of these and others are critical concerns for organizations. Security issues include access; availability and backup; control over data lifecycle; and audit. Privacy issues include lack of user control; unauthorized secondary usage; and trans-border data flow and data proliferation and trust is also a significant issue [3], [4], [7]. We have identified the restraining forces to adopt CC as follows:

1) ***Abuse of CC:*** the cloud is a relatively open environment; consumers from all over the world can easily register with a valid credit card to use their cost-effective services. The ease and anonymity of cloud registration has encouraged attackers to perform their malicious activities.
2) ***Insecure Interfaces and APIs:*** cloud Service Consumers (CSC) interact with the cloud via a set of CSP-provided user interfaces and APIs. These interfaces may not be designed to prevent unauthorized access, week authentication, manipulation of data and other malicious activities.
3) ***Malicious Insiders:*** employees hired by CSP are allowed to access confidential data without being detected and to fully control cloud services. CSP shows little or no transparency on how people are hired, how cloud resources are accessed, or how they are monitored.
4) ***Shared Technology Issues:*** while cloud customers are isolated by virtualization technology from each other, a customer may still have access to actual or residual data, network traffic, operations, etc. from other customers. This is because the physical components of the cloud are not designed to provide the multitenant structure with strong isolation properties.
5) ***Data Loss or Leakage:*** data may be compromised in CC differently from deletion or modification without backup to loss of encoding key and for various reasons such as unauthorized access, inadequate authentication or inconsistent use of encryption keys.
6) ***Account or Service Hijacking:*** there are several known account hijacking methods, including phishing, fraud detection and man-in-the-middle attacks. Attackers may use stolen credentials or passwords to jeopardize cloud services' confidentiality, integrity, and availability.
7) ***Unknown Risk Profile:*** customers usually do not know about code updates, intrusion attempts, vulnerability profiles, and security practices. CSP often do not inform customers about how data and related logs are stored and who has access to them. There may be serious threats to this unknown risk profile.
8) ***Loss of Governance:*** refers to the loss of CSC control over CSP services that may result in security gaps in the availability, integrity and confidentiality of data.
9) ***Vendor Lock-in:*** CSC is unable to move their programs and data between CSP due to lack of standardization.
10) ***Lack of Compliance:*** CSP may not be able to provide their customers with proof of compliance and may not allow them to audit cloud processes.
11) ***Unplanned Outage:*** while cloud services are available from anywhere and at any time via broadband network access via different platform types, some outages have occurred in the past, such as the 2009 Gmail outage and

2019 Facebook outage. Also other cloud vendors such as EC2 have failed at some point of time.

12) ***High Latency:*** this is due to the distance between client devices and data processing centers. This problem is magnified especially when no effective Internet connection is available.
13) ***Data Storage Location:*** the lack of clarity of CSP with the placement of data and who access it is a big concern to some organizations.
14) ***Trust:*** distrust between CSC and CSP does arise during deployment of cloud-based services. For example, CSC are concerned that their data would be lost in the event that the cloud storage provider either goes bankrupt or is bought out.
15) ***Data Management:*** these are concerns relate to data storage; data segmentation and recovery; data resiliency; data fragmentation and duplication; and data backup. Other issues include data processing, data provenance, and data anonymization.
16) ***Privacy:*** privacy issues in CC relate to data privacy protection in situations of data transfer, usage, apportionment, archiving and elimination. This is crucial especially for services dealing with highly sensitive information, especially information relating to location, preferences, social networks of individuals and personal health data.
17) ***Integration:*** the risk of the data programs and software not being able to work properly and match, as the cloud model requires, is a potential cause of failure of the adoption. Lack of integration between networks makes it difficult for organizations to combine their IT systems with CC and realize the gains from the technology.

VI. THE PROPOSED MODEL

We now propose a formal model to support decision-making on CC adoption in organizations based on FFA augmented by pairwise comparison and Delphi methods. This model is illustrated in figure 2. In practice, a specific organization would consider a subset of driving and restraining forces that impact its high-level business objectives. Thus, the first step in the proposed model is to identify the organization's objectives and weigh their importance to the organization. The next step is to specify a subset of driving and restraining forces that impact organization's objectives, estimate their impacts, and evaluate the forces in order to make the decision according to their values. These steps are described in detail in the following subsections.

A. IDENTIFYING ORGANIZATION OBJECTIVES

Organizational objectives are short-term and medium-term goals that an organization seeks to accomplish. Achievement of these objectives helps an organization reach its overall strategic goals. Therefore, the proposed decision support model is driven by the organization's high-level objectives. Organizational objectives are usually set by top management. Setting these objectives is established through

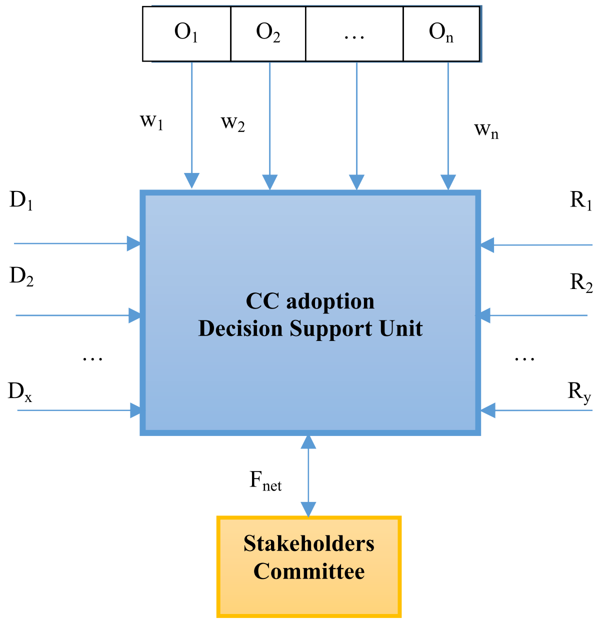

FIGURE 2. A conceptual model for the proposed approach.

understanding the overall internal culture (e.g. vision, mission, etc.) of the organization as well as a number of environmental analyses that include identifying the constraints and opportunities of the operating environment. To set the organization's objectives, we propose to conduct SWOT analysis [56] where an organization can identify its internal **S**trengths and **W**eaknesses as well as external **O**pportunities and **T**hreats. This information allows CEO to develop objectives and strategies that are relevant and realistic to his organization. In addition, organizational objectives should follow the SMART model (i.e., should be **S**pecific, **M**easurable, **A**ttainable, **R**elevant, and **T**ime bound). To apply the SMART model, CEO has to answer the following questions when setting organization' objectives:

- **Specific** – What type of company do you want to be the best at?
- **Measurable** –What benchmarks are you going to use to measure your success?
- **Attainable** – Is this objective achievable given your resources?
- **Relevant** – How relevant is this objective to the company and its employees? Will it benefit your organization?
- **Time bound** – When do you want to achieve this objective by?

Examples for good organization objectives are: achieving financial success, increasing sales figures, improving human resources, retaining talented employees, focusing on customer service, and establishing brand awareness.

The outcome of this step is a set of organizational objectives which is denoted as:

$$\boldsymbol{O} = \{O_1, O_2, \ldots, O_n\}, \quad \text{where n is a positive integer}$$

B. ESTIMATE RELATIVE WEIGHTS OF OBJECTIVES

Organizational objectives differ in their importance, in order to estimate the relative importance (weights) of organization's objectives, we apply the *pairwise comparison* approach [31], [32]. Pairwise comparison generally is any process of comparing entities in pairs to judge which of each entity is preferred, or has a greater amount of some quantitative property, or whether or not the two entities are identical. It stems from the Analytic Hierarchy Process (AHP) [31], [32], a famous multi-criteria decision-making framework which is used in the scientific study of preferences, voting systems and requirements engineering. We apply pairwise comparison approach to assign relative weights for organization objectives as follows:

Step1: Completion of the pairwise comparison matrix. Two objectives are evaluated at a time in terms of their relative importance. Index values from 1 to 9 are used. If objective O_i is exactly as important as objective O_j, this pair receives an index of 1. If O_i is extremely more important than O_j, the index is 9. All gradations are possible in between as shown in table 2. For a "less important" relationship, the fractions 1/1 to 1/9 are available: if O_i is extremely less important than O_j, the rating is 1/9. These values are estimated using the consensus *Delphi* technique [33], [34].

TABLE 2. Index values in pairwise comparison matrix.

Definition	Index	Definition	Index
Equally important	1	Equally important	1/1
Equally or slightly more important	2	Equally or slightly less important	1/2
Slightly more important	3	Slightly less important	1/3
Slightly to much more important	4	Slightly to much less important	1/4
Much more important	5	Much less important	1/5
Much to far more important	6	Much to far less important	1/6
Far more important	7	Far less important	1/7
Far to extremely more important	8	Far to extremely less important	1/8
Extremely more important	9	Extremely less important	1/9

In Delphi technique, a diverse committee (e.g., manager, system analyst, sponsor, etc.) from organization's stakeholders is formed, a committee member (moderator) controls and facilitates information gathering from the other committee members. During the Delphi process, each committee member is asked to provide his best numerical estimates of the relative importance of the objectives as per table 2. Then, the moderator collects the estimates from all participants in anonymous presentation, shares and discusses the combined results with all participants. Participants are encouraged to iteratively reconsider and modify their estimates based on the feedback from their discussion. When estimates reach a consensus (e.g. 85% or more), the moderator records and reports the final estimates.

The final estimates are entered row by row into a cross-matrix C (n x n). First, the diagonal of C is filled by values of 1 as per equation 1. Second, the right upper half of C is filled until each objective has been compared to every other one. If O_i to O_j was rated with the relative importance of m (*i.e.*, $C_{ij} = m$), O_j to O_i has to be rated with 1/m (*i.e.*, $C_{ji} = 1/m$). Last, the lower left half of C is filled with the corresponding fractions as per equation 2. (Note that i and j are positive integers ≤ n, C_{ij} is the element of C located in row i and column j).

$$C_{ij} = 1, \quad i = j \tag{1}$$

$$C_{ij} = \frac{1}{C_{ji}}, \quad i \neq j \tag{2}$$

- **Step2: Calculate the normalized comparison matrix.** A normalized comparison matrix C' is created by dividing each element in matrix C by the sum of the elements in its column. This is shown in equation 3.

$$C'_{ij} = C_{ij} / \sum\nolimits_{i=1}^{n} C_{ij} \tag{3}$$

- **Step3: Calculation of the relative weights of the objectives.** To get the weight w_i of each individual objective O_i, the mean of each row in C' is calculated as shown by equation 4.

$$w_i = \frac{1}{n} \sum\nolimits_{j=1}^{n} C'_{ij} \tag{4}$$

These weights are already normalized; their sum is 1, as illustrated in equations 5.

$$0 \leq w_i \leq 1$$
$$\sum\nolimits_{i=1}^{n} w_i = 1 \tag{5}$$

C. SPECIFYING AND EVALUATING FORCES

Let's assume that **D** and **R** are subsets of driving and restraining forces identified in sections 5.A and 5.B respectively. **D** and **R** are defined below:

$$\boldsymbol{D} = \{D_1, D_2, \ldots, D_x\}, \quad \text{where x is a positive integer} \leq 1$$
$$\boldsymbol{R} = \left\{R_1, R_2, \ldots, R_y\right\}, \quad \text{where y is a positive integer} \leq 1$$

Let:

$I(D_k, O_i)$: Impact of D_k on O_i, evaluated on a scale 1-100,

$$1 \leq I(D_k, O_i) \leq 100$$

where k is a positive integer ≤ x.

$I(R_l, O_i)$:Impact of R_l on O_i, evaluated on a scale 1-100,

$$1 \leq I(R_l, O_i) \leq 100$$

where l is a positive integer ≤ y.

These impacts can be estimated using the Delphi method described in section 6.B. The value of each force D_k and R_l can be estimated using equation (6) and (7) respectively.

$$|D_k| = \sum\nolimits_{i=1}^{n} (w_i \times I(D_k, O_i)) \tag{6}$$

$$|R_l| = \sum\nolimits_{i=1}^{n} (w_i \times I(R_l, O_i)) \tag{7}$$

The total value of driving and retraining forces (D_t *and* R_t) are computed from equations (8) and (9) respectively and the net force, F_{net} is computed as shown in equation 10.

$$D_t = \sum\nolimits_{k=1}^{x} |D_k| \tag{8}$$

$$R_t = \sum\nolimits_{l=1}^{y} |R_l| \tag{9}$$

$$F_{net} = D_t - R_t \tag{10}$$

TABLE 3. Identified objectives for MMG organization.

Symbol	Objective
O_1	Serve our customers' diverse needs with a portfolio of strong brands and improve customer satisfaction
O_2	Assume responsibility regarding the environment, safety and social issues
O_3	Act with integrity and build on reliability, quality and passion as the foundation for our work
O_4	Increase profitability and decrease operational costs

D. MAKING THE ADOPTION DECISION

The last step in the proposed approach is to make the adoption decision based on the value of F_{net}. If F_{net} is greater enough than zero then it is likely that the organization should adopt CC, otherwise the adoption is not recommended. However, the stakeholder's committee should take a step back and view the process holistically. Have a conversation with other stakeholders about the collective forces for adoption. While it is often the best strategy is to try and minimize the forces against adoption, in some circumstances, the overriding forces against adoption may be so overwhelming that adoption may not be feasible.

VII. MODEL VALIDATION

In order to validate the proposed model for usability and applicability, we provide a step-by-step scenario that shows how an organization can benefit from the proposed model to make a well-informed decision regarding CC adoption.

Modern Motors Group (MMG) is a multinational automotive manufacturing organization that designs, manufactures and distributes different kinds of vehicles and offers related services. As a part of its strategic plan, the company wishes to deploy some new cutting-edge technologies that may support its business objectives. MMG thought that it would probably be a good idea to adopt CC technology to leverage its operational and financial benefits; however, MMG is still reluctant to adopt CC services due to different concerns about this technology. Our goal is to help MMG make a decision on the adoption of CC using our proposed model.

A. ORGANIZATION OBJECTIVES

MMG's top management utilizes SWOT analysis and SMART model described in section 6.A to identify organizational objectives. The outcome of this step is shown in table 3.

B. RELATIVE WEIGHTS OF OBJECTIVES

A diverse group comprising seven members of the stakeholders is formed by the CEO to give their best estimate for the relative importance of the objectives. Suppose that the pairwise comparison matrix, C, has been estimated by the stakeholder's committee using the Delphi method described in section 6.B as shown in table 4.

The normalized comparison matrix, C', is calculated as per equation 3 and the weights are calculated as per equation 4. This is shown in table 5.

TABLE 4. Pairwise comparison matrix.

	O_1	O_2	O_3	O_4
O_1	1	3	5	6
O_2	1/3	1	4	7
O_3	1/5	1/4	1	2
O_4	1/6	1/7	1/2	1

TABLE 5. Normalized matrix and weights of the objectives.

	O_1	O_2	O_3	O_4	W_i
O_1	0.59	0.68	0.48	0.38	**0.53**
O_2	0.20	0.23	0.38	0.44	**0.31**
O_3	0.12	0.06	0.10	0.13	**0.10**
O_4	0.10	0.03	0.05	0.06	**0.06**

TABLE 6. Identified driving forces.

D_1	Scalability
D_2	Reliability
D_3	IT Cost Reduction
D_4	IT Efficiency
D_5	Business Agility

TABLE 7. Identified restraining forces.

R_1	Data Loss or Leakage
R_2	Lack of Compliance
R_3	High Latency
R_4	Unplanned Outage

C. SPECIFY AND ESTIMATE FORCES

MGG customizes the forces discussed in sections 5.A and 5.B and specify a subset (**D**) of driving forces and a subset (**R**) of restraining forces. Suppose that **D** contains 5 forces, $\boldsymbol{D} = \{D_1, D_2, D_3, D_4, D_5\}$, and **R** contains 4 forces, $\boldsymbol{R} = \{R_1, R_2, R_3, R_4\}$. These forces are listed in tables 6 and 7.

The stakeholder's committee used the Delphi method to estimate the impacts of these forces, $I\ (D_k, O_i)$ and $I\ (R_l, O_i)$, these impacts are listed in tables 8 and 9. The values of the forces are calculated as per equations 6 and 7 and recoded in the last column of the same tables. As per equation 8 and 9, the total score for driving forces (D_t) is 313.75 and the total score for restraining forces (R_t) is 220.9. The net force (F_{net}) given by equation 10 equals 92.85.

D. DECISION MAKING

The score of F_{net} is much larger than zero which means that it is likely that the organization should adopt CC. However, if the stakeholder's committee is not satisfied by this score, they should have a conversation with other stakeholders and discuss various ways to strengthen driving forces and weaken or eliminate restraining forces to improve this score.

TABLE 8. Impacts and values of driving forces.

	O_1 **0.53**	O_2 **0.31**	O_3 **0.10**	O_4 **0.06**	$\lvert D_k \rvert$
D_1	80	75	55	80	**75.98**
D_2	65	67	43	73	**63.93**
D_3	35	86	78	53	**56.16**
D_4	52	20	83	60	**45.6**
D_5	85	65	56	42	**72.08**
total driving forces D_t					**313.75**

TABLE 9. Impacts and values of restraining forces.

	O_1 **0.53**	O_2 **0.31**	O_3 **0.10**	O_4 **0.06**	$\lvert R_l \rvert$
R_1	32	50	42	35	**38.76**
R_2	65	45	65	40	**57.28**
R_3	47	80	70	78	**61.38**
R_4	68	57	83	25	**63.48**
total restraining forces R_t					**220.9**

VIII. CONCLUSION AND FUTURE WORK

The emergence of CC provides firms by opportunities for utilizing cutting edge technologies that previously were not affordable due to the high cost of owning these technologies. CC thus offers management and monetary benefits that businesses can no longer ignore. On the other hand, there are different concerns about this technology that makes many organizations reluctant to adopt it such as security, compatibility, etc. While there are many studies that have focused on technological aspects regarding CC implementation as well as different technical problems, the research on issues concerning the adoption of CC is still in an emerging stage and there is a lack of knowledge among organizations on how to make a well-informed decision on CC adoption. This paper has attempted to address this issue and proposed a novel decision-making model for CC adoption in organizations based on the Force Field Analysis (FFA) augmented by pairwise comparison and Delphi methods. The proposed model has been tested for usability and applicability through a use case scenario. In the future, we plan to explore the problem of making critical decisions on cloud service providers selection.

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