CLOUD COMPUTING EFFECTIVENESS ASSESSMENT

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF INFORMATICS
OF
THE MIDDLE EAST TECHNICAL UNIVERSITY

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN
THE DEPARTMENT OF INFORMATION SYSTEMS

JUNE 2014

CLOUD COMPUTING EFFECTIVENESS ASSESSMENT

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ABSTRACT

CLOUD COMPUTING EFFECTIVENESS ASSESSMENT

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June 2014, 164 pages

A comprehensive model is presented for cloud computing effectiveness assessment. The model consists of technical, organizational, economic and external dimensions and addresses users as well as providers of various levels of cloud computing service. Independent and dependent characteristics of effectiveness are identified. Measures of each of the four dimensions of the model are defined and their assessment is presented in the form of footprint diagrams. In the research that led to the final model, after a detailed literature review, a large number of experts were interviewed and questionnaires were applied to construct the initial model. By applying factor and reliability analysis to the results of a survey of cloud computing organizations, the model was updated. Then, four qualitative exploratory case studies in 10 companies were carried out to finalize the model. The model was validated through four further confirmatory case studies. This model can be used for identifying strengths and weaknesses as well as benchmarking and comparing different organizations.

Keywords: Cloud Computing Effectiveness Assessment, Technical Effectiveness, Organizational Effectiveness, Economic Effectiveness, External Effectiveness.

ÖZ

BULUT BİLİŞİM ETKİNLİK DEĞERLENDİRMESİ

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Haziran 2014, 164 sayfa

Bulut bilişim etkinlik değerlendirmesi için kapsamlı bir model sunulmaktadır. Model teknik, kurumsal, ekonomik ve dışsal değişkenleri içermektedir ve bulut bilişim kullanıcıları ile değişik seviyelerde bulut bilişim hizmeti sağlayanları hedeflemektedir. Etkinliğin bağımlı ve bağımsız ayırıcı özellikleri tanımlanmaktadır. Modelin dört boyutunun herbirinin ölçütleri tanımlanmaktadır ve onların değerlendirmeleri ayakizi diyagramları biçiminde sunulmaktadır. En son modele götüren araştırmada, detaylı literatür taramasından sonra, çok sayıda uzman ile görüşüldü ve başlangıç modelini oluşturmak için anketler uygulandı. Bulut bilişim kurumlarındaki anket sonuçlarına güvenilirlik ve faktör analizleri uygulanarak, model güncellendi. Daha sonra ise modeli sonuçlandırmak için dört niteliksel keşfedici durum çalışması 10 şirkette uygulandı. Model, dört ilave doğrulayıcı durum çalışması ile doğrulandı. Bu model, kuruluşların güçlü ve zayıf yanlarını belirlemede ve değişik kurumların örnek alınmasında ya da kıyaslamasında kullanılabilecektir.

Anahtar Kelimeler: Bulut Bilişim Etkinlik Değerlendirmesi, Teknik Etkinlik, Kurumsal Etkinlik, Ekonomik Etkinlik, Dışsal Etkinlik.

To My Parents

ACKNOWLEDGMENTS

I express sincere appreciation to Prof. Dr. Semih Bilgen for his guidance and insight throughout this study. I thank my parents, my sister and my sister's husband for their support throughout the research. I thank TÜBİTAK for their scholarship during my doctorate studies. I am also thankful to the staff of the organizations who participated in this research.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADM: Administration

Ag: Agility

Aint: Application integration

API: Application Programming Interface

Av: Availability

AWS: Amazon Web Services

BPaaS: Business Process as a Service

CBA: Cost-benefit analysis

Cc: Computing capacity

CCEAM: Cloud Computing Effectiveness Assessment Model

Cdm: Cloud delivery models

Cdt: Cloud deployment type

Cla: Cloud applications

Clam: Cloud application migration

CLAMIGCOS: Cloud application migration cost

Cli: Cloud interoperability

CLSTR: Cloud strategy

CLSUPSEL: Cloud supplier selection

Cp: Cloud performance

CPR: Companies that provide as well as receive cloud computing service

CPU: Central Processing Unit

CRM: Customer Relationship Management

Crt: Cloud response time

Cs: Cloud security

CSP: Cloud Service Provider

CU: Cloud user

Di: Data integrity

Dis: Distance

Dl: Locality of Reference to Data

DNS: Domain Name System

EFL: Economic flexibility

FMCICOS: Future Major Cloud Infrastructure Cost

Hv: Hardware virtualization

IaaS: Infrastructure as a Service

INV: Innovation

Isf: Isolation failure

IT: Information Technology

LEGENV: Legal environment of cloud computing

LOBETH: Level of business ethics

MNG: Manageability

Mul: Multiplicity

Nv: Network virtualization

ODC: Outage duration cost

OEF: Operational efficiency

PaaS: Platform as a Service

Rel: Reliability

REV: Revenue

Rs: Resilience

SaaS: Software as a Service

Sc: Scalability

SLA: Service Level Agreement

SLAEC: SLA as an economic dimension

Slt: SLA as a technical dimension

SME: Small and Medium Enterprises

SOA: Service Oriented Architecture

SOCF: Social factor

SPCSP: Solution Providers for Cloud Service Providers

TCAO: Total cost of application ownership

Tfl: Technical flexibility

VLID: Vendor lock-in degree

CHAPTER 1

INTRODUCTION

A definition of cloud computing is “a computing capability that provides an abstraction between the computing resource and its underlying technical architecture (e.g., servers, storage, networks), enabling convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interactions” [1]. In this definition, the most important features of cloud computing are identified as on-demand self-service, resource pooling, broad network access, measured service and rapid elasticity, respectively.

Within the context of our study, cloud computing is defined as Internet-based advanced distributed computing through which all of the shared computing resources among cloud service providers and cloud customers are provided to the cloud computing users over virtualized and dynamically scalable computing facilities. In cloud computing, cloud users can access the applications and computing resources over the Internet, generally without the need for prior installation on their client facilities.

Cloud computing can be compared with traditional approaches in terms of many perspectives, which emphasize the increase of its usage in the recent years. According to the traditional approaches, software applications are developed to run on a specific computer that users of the application are able to access. With the rapid growth of Internet, this paradigm has changed. Specifically, through cloud computing, applications can now be developed to run on a virtual computer that runs on the Internet [2]-[3]. Cloud Computing does not only bring about differences in terms of its integration and deployment ability but it is also different in terms of its software development paradigm.

Traditional software development approaches generally adopt and follow locking concurrency models and synchronous processing mechanisms for development. This perspective causes much dependency on hardware so as to satisfy the requirements of reliability and scalability. On the other hand, in case of cloud as a new development paradigm, different design principles and design architectures have to be taken into consideration. According to the software architecture principle of multitenancy, the application, which is shared by multiple cloud users, runs on the same operating system through the usage of common hardware and data storage mechanisms agreed by all of the users. On the other hand, concurrency model and parallel distributed processing in cloud computing provide the ability to design processes to execute in parallel. The last important design principle which differentiates cloud from traditional development principle is its service composition which enables optimal distribution of its components of services. All these architecture principles are specific to cloud and they help software developers to exploit cloud computing as a software development paradigm more easily. Since cloud computing architecture is suitable for handling very large scale processing which can not be achieved with traditional architectures, cloud computing provides strategic and competitive advantage to software developers [2]-[5].

Cloud computing is also a business model comprised of technical, economic, organizational and external dimensions. The term “effectiveness” refers to the level of achievement of desired effects. That is, in our context, the degree to which cloud computing objectives are achieved and the extent to which problems targeted in providing and/or receiving cloud computing service are solved.

1.1. History and Background of Cloud Computing

The first academic definition of cloud computing was made by Ramnath Chellappa in 1997. In his definition, he stated that the economic and technical conditions of organizations all together specify the limitations and restrictions of computing in case of cloud computing usage. In other words, he suggested the organizations to evaluate both their economic and technical conditions before cloud computing usage because their conditions may be not suitable for cloud computing [6]. Amazon started to offer their customers to access to their systems and associated applications via their web services in 2005 [7]. Their web services made an important contribution to their web services project through the over-simplification feature [8].

HP, Intel and Yahoo developed together a test bed for cloud computing in 2008, named as Open Cirrus [9], which provides to research on cloud computing, cloud computing services, data center, and the management of them.

In 2010, Microsoft and HP came to an agreement to invest approximately 250 million $ in order to make the usage of applications easier through using the advantages of cloud computing. They also decided to work together on engineering issues such as interoperability of application platforms, virtualization, and management of cloud environment [10].

Microsoft and Google increased their investment in cloud computing so as to develop their own cloud computing platforms at the beginning of 2009 [11]. Global IT (Information Technology) companies also began to adopt cloud applications developed by professionals from developing countries. Specifically, global IT companies began to investigate the cloud computing field and its advancement in these countries [11]-[12].

Many cloud computing research and data centers in China, Brazil and South Korea have been founded by IBM corporation. Other important cloud computing companies such as Microsoft and Salesforce also have been investigating how technical advancements realized in these countries can be adapted into cloud computing. These developing countries which have more technical expertise are expected to reach the same level as developed countries in terms of cloud computing in the near future since they will be able to access the same applications and resources through cloud computing. This means that collaboration on cloud computing among developing and developed countries will be significant, through which more technical expertise will be reflected to the development of cloud computing applications and even higher levels of expenditure and investment are to be expected in this field [12].

In the developing countries, cloud experts deal mainly with software development and offshoring areas, which requires a higher level of technical expertise. For instance, the experts in the cloud computing centers of IBM in developing countries offer services in the field of software development to the software engineers and developers from various countries [12].

The cloud paradigm provides various economic and business-oriented advantages to its users. In the cloud computing environment, there is little or no capital expenditures required. Besides, the startup costs are low and computing resources are used more efficiently in cloud computing. The expectations of cloud customers are provided on-demand basis in cloud computing and cloud computing offers a pay-per-use payment structure. This means that the customers pay for the cloud services according to their consumption and usage levels. The operations and tasks are accomplished faster compared to traditional approaches. This means processing times are lower due to the absence of time consuming processes inside the cloud environment, which leads to the acceptance of cloud computing approach by many companies [4], [13]-[15].

Organizations mainly decide on cloud computing adoption and/or migration by comparing their current traditional computing systems with cloud computing. In traditional computing systems, many processes have to be supported by companies to manage hardware, software stacks, licensing, security, and outsourcing [2], [15]. On the other hand, in cloud computing, there is no hardware, or a complex suite of software stacks involved in developing software on a cloud platform [3]-[4], [15].

Performance is an other important measure to compare traditional IT services with cloud computing services. For that reason, the indicators to measure the performance of cloud computing services have been formulated by companies by taking the specific features of cloud computing into consideration. Cost, time, quality and profitability are the most common type of indicators for assessing the performance of cloud computing services [2], [16]-[17].

The major characteristics of cloud computing can be summarized as follows [18]-[22]:

- Cloud computing is related with using computing resources in an Internet environment.
- It supports the aggregation of heterogeneous resources.
- It has the advanced virtualization, reconfigurability, self-healing, hardware scalability, automatic resizing of virtualized hardware resources features.
- It also aims to increase flexibility and reliability as well as decreasing the costs.
- Since cloud computing systems include application domain independent software, applications can be deployed into cloud easily.

Comparison of the concepts of cloud and grid computing is another important topic discussed by computer scientists, academicians and information technology experts. Both of these two recent major computing paradigms certainly have similar aims to increase flexibility and reliability as well as decreasing costs by combining advanced networking with their virtualization abilities. Major differences between cloud computing and grid computing can be summarized as follows [18]-[22], [73], [262]:

- Grid computing enables sharing resources across organizations through its resource sharing ability. On the other hand, cloud computing provides on demand resources that service providers and/or customers require.

- On-demand self service and reconfigurability features of cloud computing enable cloud customer companies to provision their own computing capabilities without requiring additional help from cloud service provider company. Grid computing has reconfigurability feature. On the other hand, cloud computing has a reconfigurability and self healing feature.
- In cloud computing, workflow, which implies the automation of a business process according to a set of procedural rules is not essential for most applications, but it is required in grid computing.
- Programming, deploying and executing complex applications are typically problematic issues for grid computing because only applications compatible with grid environment and application domain-dependent software are accepted. On the other hand, these are not issues for cloud computing because it incorporates application domain-independent software.

The following are widely accepted about cloud computing [18]-[24]:

- It involves mainly management, performance, reliability, security, application and data-oriented issues.
- Interoperability is a significant issue for cloud computing because there is a lack of cloud interoperability standards.
- People related issues are also important since adapting a new computing system in a company leads to many problems, especially associated with change management.

1.2. The Need for a New Approach for Cloud Computing Effectiveness Assessment

Cloud computing may bring many benefits to IT. Before implementing cloud technologies, the organization has to determine whether the cloud solution is applicable in the organization. Detailed planning is necessary for this assessment.

Results of the cloud assessment can be used to formulate the most cost-effective, appropriate cloud adoption and implementation plans to meet corporate goals. This would measure the potential of a candidate company for implementing cloud solutions.

As the review of literature to be presented in Chapter 2 has shown, current approaches to cloud computing effectiveness assessment do not deal with technical metrics specifically. They deal mostly with information, system quality, and user satisfaction in a rather general manner. Specific issues such as security, interoperability, data availability, control and management of systems are not explicitly addressed in their scope. Hence, a new approach for cloud computing effectiveness assessment incorporating economic, technical, organizational and external perspectives has to be developed.

If a new model including these perspectives is not developed, companies can not benchmark and compare different organizations in terms of cloud computing effectiveness. Essentially, cloud computing effectiveness assessment is a prerequisite for process improvement.

1.3. Research Problems, Research Method and Maturation of the Model

The present study deals with the problem of constructing a cloud computing effectiveness assessment model (CCEAM), which will be useful for cloud service providers as well as customers. It also investigates the applicability of this model in companies associated with cloud computing.

Our main research problem can be stated as follows:
How can we construct a cloud computing effectiveness assessment model usable by companies associated in various ways with cloud computing.

We divide our research problem into two subproblems, both of which when resolved will result in the solution of the main research problem.

Subproblem 1: Identification of independent and dependent characteristics that affect cloud computing effectiveness; categorizing these characteristics into different dimensions of the model according to their realm, as technical, organizational, economic and external.

In the scope of this subproblem, the following question is formulated:
What are the characteristics that determine cloud computing effectiveness?
A literature survey, a preliminary survey of possible cloud computing firms (hereafter referred as "preliminary survey"), an in-depth survey of cloud computing organizations (hereafter to be referred as "cloud survey") and case studies were conducted to determine these characteristics.

Subproblem 2: Proposing an appropriate method for assessing effectiveness in terms of the characteristics identified, for any service provider or cloud customer.

In the scope of this subproblem, the following two questions are formulated, to address the issues of operationalization and validation:
How can effectiveness be operationally assessed in terms of the identified characteristics?
Following the cloud survey, exploratory qualitative case studies were conducted in 10 companies. The context of our case studies consisted of companies categorized into four classes according to their association with cloud computing: (i) cloud service providers, (ii) companies that provide as well as receive cloud computing service, (iii) solution providers for cloud service providers, and (iv) cloud users. All companies were located in Turkey, where this research was undertaken. Feasibility assessment for full or partial migration to cloud was not included in the scope of our study because potential users considering to migrate their operations fully or partially to the cloud were not included in the case studies. Based on the findings of the case studies, the final model and the measures associated with respective characteristics in all four dimensions of the model were obtained. The values of measures of CCEAM are categorized into three groups: 5-point Likert scale values, 3-point Likert scale values and Percentages.

How can the proposed model be validated? That is, does the model really assess cloud computing effectiveness as intended?
We carried out confirmatory case studies in five companies from the abovementioned four different categories with the aim of validating the finalized CCEAM. Four of these five

companies are different from the companies who participated in exploratory case studies, whereas one of them participated in both exploratory and confirmatory case studies.

Assessment results obtained in those companies via application of CCEAM have been presented in the form of footprint diagrams displaying the normalized values of measures for all characteristics in each of the four dimensions.

Figure 1 summarizes the research process.

First, we investigated 119 resources including scientific papers, web articles, white papers and technical reports. In terms of cloud computing, economic challenges and technology related issues have long been under focus [14], [25]-[26]. We also categorized factors and characteristics at this stage in the technical and economic dimensions. Our draft model thus consisted 16 technical and 6 economic characteristics.

In the second phase of the research, the preliminary survey, responses to a questionnaire consisting of five questions were obtained from 22 companies based in 9 countries (England, USA, Ireland, China, Belgium, Sweden, Canada, France, Romania) participating in the Cloud Expo Europe 2012 conference.

In addition to this, papers, interviews and presentations in Cloud Expo Europe 2012 and CLOSER 2012 were studied. By combining all of these findings, the components of the initial model were defined. The organizational dimension was incorporated to the model. The initial cloud effectiveness assessment model thus consisted of 19 technical, 10 organizational and 7 economic characteristics constituting 3 dimensions.

In the third phase, the cloud survey, a questionnaire aiming to evaluate the initial model was administered to participants from 65 different companies, from 15 different countries, in the Cloud Computing World Forum 2012. A 5-point Likert scale was used in the questionnaire. According to the survey results, seven of the characteristics, the average Likert points of which were below 3.5, were excluded from the initial model. In addition to this, two of the characteristics were discarded from the model based on a factor analysis of the findings. Consequently, the model was updated to consist of 17 technical, 6 economic and 4 organizational characteristics in 3 dimensions.

To validate and further refine the assessment model, qualitative case study research was undertaken, investigating 10 companies, grouped as four different case studies. This phase of the research led to the final CCEAM consisting of 4 dimensions, 24 technical, 9 economic, 7 organizational and 2 external characteristics.

Finally; confirmatory case studies were carried out in five companies from four different categories to validate the finalized CCEAM as stated in the answer of "How can the proposed model be validated" question at the beginning of this section.

Details of the intermediate stages of the model, stated in the research process as literature survey, draft model, initial cloud effectiveness assessment model, and updated model, have been documented in [27].

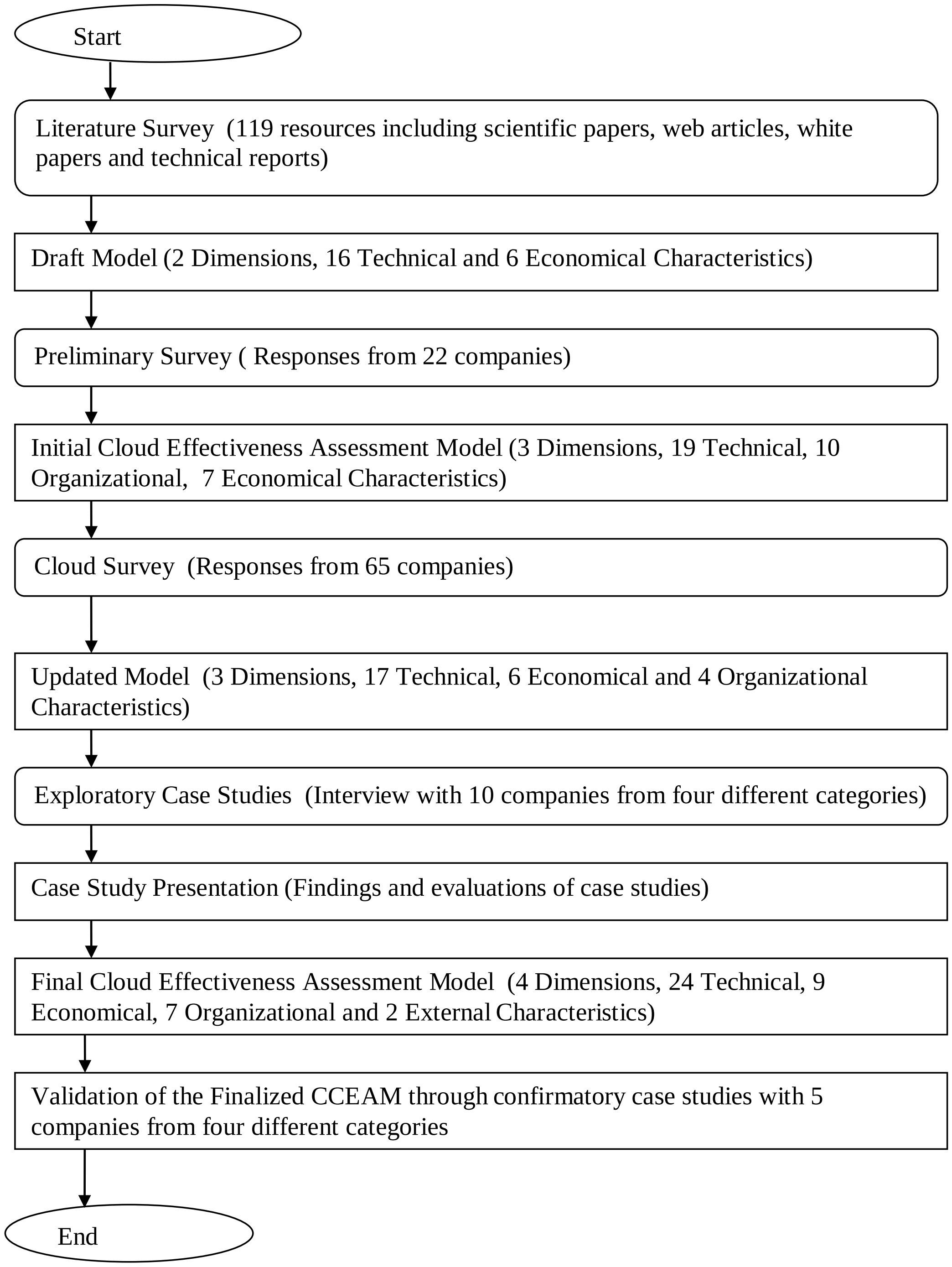

Figure 1. Research Flow Chart

1.4. Major Contributions

The main contribution of this study and its corollaries can be outlined as follows:

- An effectiveness assessment model for cloud computing consisting of the technical, economic, organizational and external dimensions is proposed. The model includes 42 characteristics with a total of 142 measures.
- A list of measures, defined in a concrete and objective manner has been compiled.
- Applicability and validity of the model has been shown in the context of cloud computing service providers, service provider/receivers, solution providers, and users. Confirmatory case studies have been applied in five companies from these four different categories.
- The ability to benchmark and compare different organizations in terms of their cloud computing effectiveness also leads to a starting point for process and infrastructure improvements.

1.5. Layout of the Dissertation

This dissertation is structured in 6 chapters.

After this first chapter which consists of an overview of the fundamental concepts, a brief review of the background and motivation for the study, in Chapter 2, an extensive review of the literature on which the draft model was based, is presented. After that, in Chapter 3, the case studies which constituted an essential phase of exploration of the major contribution and its corollaries are discussed.

The proposed CCEAM is presented in its final form with its characteristics and measures in Chapter 4. Detailed references to the literature supporting the elements and relationships that constitute CCEAM have been provided in that chapter together with brief justification of the decisions that led to the final model. In Chapter 5, case studies for validation of CCEAM are discussed.

Chapter 6 concludes the thesis with a review of the main results, summary of findings, an outline of the fundamental contribution of the study and its corollaries, considerations of the limitations and shortcomings of the study and suggestions for future work.

CHAPTER 2

LITERATURE REVIEW

In this study, first of all, a draft model was constructed based on an extensive literature review. In terms of cloud computing, economic challenges and technology related issues have long been under focus [14], [25]-[26]. We also categorized factors and characteristics at this stage in two broad categories as technical and economic. The resources investigated in the scope of literature review associated with these two categories are listed in the following table with their reference numbers in brackets.

Table 2.1: Literature Review Resources

Characteristic Category	Reference Numbers of The Resources
Technical	[5], [31], [34]-[38], [41]-[46], [50], [55], [67], [70]-[71], [73], [75], [79], [239]-[241], [244]-[245], [246], [247]-[252], [253], [254], [256]-[257], [259]-[260], [262], [263]-[264], [265], [266]-[268], [270], [271], [272], [273]-[274], [275]-[277], [278], [279], [280]-[285], [286]-[287], [288], [290], [291], [292], [293], [295], [296]-[298], [299]-[300], [301]-[302], [303], [304]-[306], [307], [308], [309]-[310], [311]-[312], [314], [315], [317], [318], [319], [320], [321], [322]-[323], [324], [325], [327]-[328], [329]
Economic	[12], [18], [50], [53], [66], [68], [71], [76], [81], [243], [244]-[245], [249], [254], [255], [258], [261], [268], [269], [281], [289], [294], [300], [309], [312], [313], [316], [324], [326], [329]

Resource types and their reference numbers are listed in Table 2.2:

Table 2.2: Resource Types for Extensive Literature Review

Resource Type	**Reference Numbers of the Related Resources**
Journal Articles	[5], [12], [18], [31], [35], [44], [55], [66], [71], [76], [79], [242], [245], [247], [254], [255], [258], [260], [262], [266], [268], [269]-[270], [272], [273], [275]-[277], [280]-[281], [283], [288]-[289], [291], [293], [294], [295], [296]-[297], [300], [302], [308], [312], [313], [314], [315], [316]-[317], [319], [325]
Articles of IT Related Magazines	[257], [278], [305], [310], [320]
Technical Reports	[36], [240], [251], [256]
White Papers, Working Paper, Position Paper & Discussion Paper	[45], [50], [243], [263], [306], [322], [324], [329]
Book & Book Chapters	[265], [267], [323], [326]
Internet Resources (Blog, Website Articles, electronic dictionary etc.)	[34], [37]-[38], [41]-[43], [46], [53], [241], [244], [287], [292]
Conference Papers/ Panel Papers/ Workshop Papers/ Symposium Proceeding	[67]-[68], [70], [73], [75], [78], [81], [239], [246], [248]-[250], [252], [253], [259], [261], [264], [271], [274], [279], [282], [284]-[285], [286], [290], [297], [299], [301], [303], [304], [307], [309], [311], [318], [321], [327]-[328]

Articles from 36 journals were investigated in the scope of extensive literature review. Journals and the reference numbers of articles in these journals are listed in Table 2.3.

Table 2.3: Journals and Reference Numbers

Journal Name	Reference Numbers
ABA (American Bankers Association) Banking Journal	[275]
ACM Queue	[268]
ACM SIGCOMM Computer Communication Review	[18], [288], [312], [315]
Business & Information Systems	[262]
Business Review	[76]
Cluster Computing	[66]
Communications of the ACM	[44], [281], [289]
Cutter IT Journal	[258]
Decision Support Systems	[71]
Engineering & Technology	[260]
Eui-nam Huh Annales des Télécommunications	[247]
Future Generation Computer Systems	[293]
IEEE Computer	[12], [31], [273]
IEEE Security & Privacy	[283]
IEEE Transactions on Knowledge & Data Engineering	[300]
IEEE Transactions on Parallel and Distributed Systems	[79]
Intellectual Property & Technology Law Journal	[325]
International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering	[297]
International Journal of Advanced Research in Engineering & Technology	[308]
International Journal of Cloud Applications and Computing (IJCAC)	[313], [319]
International Journal of Computer Applications	[276], [295]
International Journal of Database Management Systems	[316]
IS Management	[280], [314]
IT Professional	[255], [291], [317]
Journal of Economic Computation and Economic Cybernetics	[277]
Journal of Financial Planning	[245]
Journal of Information Technology Management	[35]
Journal of Internet Law	[269], [272], [302]
Journal of Internet Services and Applications	[270]
Journal of Object Technology	[55]
Material Handling & Logistics	[254]
MIS Quarterly	[294]
New Generation Computer	[266]
Quarterly Journal of Economics	[242]
Software System Model	[5]
WSEAS Transactions on Computers	[296]

The characteristics included in the draft model and the reference numbers of their resources are given in Table 2.4.

Table 2.4: Characteristics in the Draft Model and related reference numbers

Characteristic Name	Reference Numbers
Agility	[5], [37], [73], [246], [253], [262], [265], [277], [290], [304], [310], [312], [317]
Availability	[18], [38], [53], [73], [260], [262], [274], [275], [297], [321]
CAPEX (Capital Expenditure)	[12], [18], [66], [68], [76], [268], [294]
Cloud deployment type	[18], [55], [71], [73], [254], [262], [273], [281]-[282], [299], [305]-[306], [319]
Cloud migration cost	[18], [[244], [249], [313], [316]
Cloud performance	[75], [79], [251], [263], [276], [279], [298], [311], [318]
Cloud Security	[250], [259], [264], [267], [269], [272], [275], [278], [282], [291], [301]-[302], [308]
Concurrency	[18], [71], [73], [240]-[241], [245], [266], [270]
Data locality	[44], [71], [256], [265], [266], [292]
Data replication cost	[12], [68], [243], [245], [249], [261], [313]
Distance	[18], [35], [50], [71], [73], [262], [265], [266], [292], [296]
Isolation failure	[18], [46], [71], [73], [262], [266], [285]
Manageability	[18], [36]-[37], [71], [73], [245], [252], [271], [280], [293], [295], [300], [309], [314], [327]-[328]
Network virtualization	[31], [34], [67], [71], [73], [253], [262], [267]-[268], [287], [298], [315], [322], [328]
Operational efficiency	[18], [43], [73], [260], [262], [320], [324], [329]
Outage duration cost	[12], [18], [53], [68], [255], [281]
Resilience (fault tolerance)	[18], [45], [73], [262], [275], [279], [284], [286], [315]
Scalability	[18], [41]-[42], [70], [247], [260], [270], [288], [303], [307], [321]
Switching cost	[12], [68], [242], [258], [289]
Total cost of ownership (TCO)	[18], [81], [244]-[245], [326],
Upgradeability	[18], [71], [73], [239], [262], [265], [266], [292], [323]
Vendor lock in degree	[18], [35], [73], [244]-[245], [248]-[249], [257], [262], [275]

2.1. Discussion on Characteristics with their Related Resources

Agility

As stated in [5], cloud services should be flexible enough to be modified according to the changing requirements of cloud customers, which is called as agility. In [37], agility is defined as "the capability of organizations to adapt themselves to the changes". Agility may be achieved through virtualized resources, which allow the usage of hardware and software components of cloud computing in a highly efficient manner, and dynamic scalability, where the amount of service can be adjusted according to the demand of customers [37]. In terms of cloud computing; agility means meeting the demands of cloud customers as fast as possible [246], [290]. Developing flexible architectures, which help companies to cope with rapidly evolving business requirements, can be carried out through the agility characteristic of cloud computing. One of the most important possibility provided by cloud computing through its agility characteristic is the ability to elastically provision new resources in response to changes in demand [246], [265], [290], [317]. Agility characteristic of cloud computing also provides to develop automated control mechanisms for cloud computing resources which provides to understand the demand changes continuously. The new products and services can also be deployed through the faster on-demand infrastructure of cloud computing, which also states the agility characteristic of cloud computing [253] and [310]. Agility in cloud provides to expand the IT infrastructures of companies quickly to meet the demand of their customers. Besides, agility in cloud offers the ability of supporting on-demand provisioning and configuration of integrated virtual systems with the aim of meeting the demands of cloud customers [73] and [262]. [277] stated that integration of cloud business intelligence solutions into the companies provides them advantages originated from agility. Through the integration of cloud business intelligence solutions, the companies aim to improve agility as well as reducing costs. In other words, increased agility at low cost is the aim of these cloud business intelligence solutions and increased agility is accepted as one of the intangible advantage of a cloud business intelligence solution [277]. Cloud service providers try to realize agility requirements in their cloud services by using Service Oriented Architecture (SOA) and cloud computing concurrently. In this sense, cloud computing supports SOA with its platform and storage service in order to increase the efforts of SOA [304]. [312] stated that increase on agility can cause decrease on the unit cost of data centers. In this manner, agility in cloud provides to grow cloud computing resources to meet the demands and to take these resources from the most optimal network location [312].

Availability

High availability is one of the important characteristics of cloud computing [321]. According to [321]; "availability refers to the continuity of cloud computing services although some of the nodes cause failures and faults in the cloud computing system". Cloud focused on high availability for Quality of Services guarantees. The critical certain value determined for high availability is generally 99.9% infrastructure uptime. The cloud storage systems are adjusted to meet the requirements for high availability [18], [260], and [274]. High and increased availability can be provided through virtualization, for that reason, cloud computing adopts virtualization. Quick recovery ability of virtualization decreases the effects of unplanned outages and the amount of interruption in services is decreased by backing up the virtual environments, so availability is increased [73] and [262]. As stated in [38], if some of the cloud services of company was not accessible for only some of their users, it is also accepted as an availability issue for the cloud service provider company. Cloud computing does not accept the thought of replicating everything for providing high availability. Rather than this, it proposes to make plan associated with software and data center and provide high availability of these components by obeying the plan [53]. [275] stipulates that if cloud service provider has service interruptions frequently, this situation is defined as loss of availability. Availability level can be also understood by investigating the question of whether the internal operations of cloud computing system are always available to customers and clients [275]. [297] argues how mobile cloud computing integrates cloud computing into the mobile environment and how it solves the availability related issues.

CAPEX (Capital Expenditure)

Cloud computing moves CAPEX to OPEX (Operational Expense), by adjusting the expenses according to the resource usage level. In other words, it can be stated that "Pay as you Go" model is provided by Cloud Computing. The capital expenses are reduced and fixed through cloud computing, on the other hand, operating expenses are increased and varied. By converting CAPEX to OPEX, the saved capital can be used for the other required areas of the company. Through CAPEX to OPEX conversion mechanism, the cost of deploying the new services is much lower and the companies do not need to make high investment for dedicated infrastructure. In other words, upfront investment is not included in the scope of OPEX. OPEX allows cloud users to pay on a specific time period basis (year/month/day/hour). Rather than making investment on the peak capacity for physical infrastructure, cloud users pay only the services that they use according to their service usage and resource consumption level [12], [18], [66], [68], [76], [268], [294].

Cloud deployment type

Four major deployment types are: public, private, community and hybrid clouds. Public cloud is used by the general public and requires high amount of investment. It is elastic and provides service based usage to the customers. Private cloud is managed within the organization and used by one organization. Besides, it offers greater control over the cloud infrastructure. A community cloud is a cloud controlled by a group of organizations that share common interests and that is developed for their specific aims and requirements. In addition to these, hybrid cloud can also be considered as the combination of private and public cloud. According to the rules of hybrid structure, non-critical information is kept in public cloud, on the other hand, critical information is managed and control within the organization [18], [71], [73], [262], [305] and [306]. As stated in [282] and [299]; cloud customers try to determine the most suitable cloud deployment type for them. Cloud service providers also tries to determine the most suitable cloud deployment type for their customers by investigating the business requirements of their customers. For this aim, they conduct simple questionnaires and mini case studies for their customers [282] and [299]. In [273] and [281], public and private clouds are compared in terms of the security perspective. Generally, it is considered that public clouds have weaker security, because it is used by the general public. On the other hand, private cloud is more secure because the network, hardware and data storage are designed to guarantee the high levels of security that the other organizations can not reach the private cloud of this organization [273] and [281]. [55] and

[254] declared that companies have begun to use hybrid and private clouds in the recent years although they include availability and security issues. The most important issue in hybrid cloud is related with the data security because data is stored with multiple locations and by multiple cloud service providers [55] and [254]. The usage of free software for elastic web hosting on a private cloud is discussed in [319] with an example. Through this usage, companies can build their own private cloud on top of their local infrastructure and so they benefit from the advantages provided by cloud computing structure [319]. Consequently, public cloud includes two major problems: Lack of control over cloud computing infrastructure and vendor-lock in [71], [73], [305], [319].

Cloud migration cost

There are three important questions to be answered by companies before cloud migration decision. First of all, the applications that should be migrated to cloud should be determined. Secondly, the order of the applications that will be migrated is determined. After that, the cloud service provider should be selected according to the performance and reliability requirements. After these three steps, cost of migration should be calculated because cost is as important as performance and reliability requirements in the migration process. Cloud migration costs includes three main components as setup costs, migration costs and ongoing costs as defined in section 2.3. Only the applications that will be selected for migration by the company according to its business requirements and priorities are taken into consideration while calculating the cloud migration cost [18], [244], [249], [313] and [316].

Cloud performance

[75], [276], [279] and [298] discussed why the cloud performance measurement is required for cloud computing systems and stated network performance, application performance and data center performance metrics for measuring cloud performance. To measure the application performance, which is one of the component of cloud performance, application response time is proposed as a metric. Application response time states the time in which a cloud application will reply to the clients for their requests. If this time is low, this means that the client will get the services without waiting more time. Network performance is also very important because networks are generally the bottleneck that prevents cloud computing from supporting high performance applications. For instance, if the network bandwidth is low, the performance will be low since the expectations of cloud customers will not be met on time. Storage, disk and buffer capacity may have effect on cloud performance. If buffer capacity is not high, most of the requests by the customers can not be replied, so the performance will be low. Data center metrics include the number of users of the related data center and the distance of the data center from the location of cloud customers. If the number of users in a data center exceed the capacity, the cloud performance will decrease because the services will be provided to the customers in a long period. On the other hand, long distance from data center of cloud service provider may cause delays in responses to requests. Workload, throughput, average processing time and percentage of Central Processing Unit (CPU) utilization are the other metrics that can be considered while measuring cloud performance [79], [251], [263], [311], [318].

Cloud Security

[301] and [308] agree that the list of security issues include data protection, operational integrity, vulnerability management, business continuity, disaster recovery, and identity management. Besides, [267] and [291] present the various security issues faced inside cloud computing environment with various practical examples and with various security scenarios. [267] and [291] also state that security in cloud also may bring some benefits to its users especially in terms of data security. For instance, by maintaining the data on cloud, the amount of information that could be lost is decreased because of the strong access control mechanism offered by cloud. Some of the other benefits of cloud computing is that centralized data is provided through cloud, cloud service providers offer more efficient security software to their customers, and security testing is carried out with lower costs. Cloud security includes not only data security but also people security. This means that the security of cloud staff is as important as data security. To control the security level of cloud companies, security review processes are developed, customized security plans are adjusted and external and internal security audits are realized in the companies [267] and [291].

[259] explains how to integrate security into a cloud-based virtual environment with the usage of a specific channel encryption mechanism. [250] and [264] discussed the negative and positive consequences of cloud computing in terms of risks of cloud and cloud security. More specifically, a security policy model is proposed in [250]. This security policy model can be used as a guide by the companies because it offers the security requirements that have to be paid attention to by the company before deploying secure business processes on the cloud. In other words, this model generates specific security policies for each of the companies that uses this model [250].

[269] and [302] identify the emerging legal issues associated with security "originated from the increase on both the number and the coverage of various cloud computing services". Legal uncertainties associated with copyright and data protection on cloud, privacy and security concerns are the most important current legal issues to be solved. Besides, the content of the legal liability and rights of cloud service providers have to be determined and updated when necessary [269] and [302].

According to [272], [275] and [278], cloud security is a data-oriented issue since the sensitive and significance data of companies are controlled and governed by cloud service providers and so the cloud customers can lose control over their data. In [283], cloud security methods that have to be implemented inside cloud computing in cloud sector are discussed. To ensure data security, strong access controls to prevent unauthorized access to data, scheduled backup data and secure data storage should be provided [283].

Concurrency

As stated in [240]-[241], it is defined as "a situation of cloud computing systems where the tasks of performing computations as well as making these computations interacted with each other are realized concurrently". It is also accepted as a characteristic that increases the system performance by distributing the work to various computers which can be seen by the related user as a single computer. Cloud computing system can serve various requests from a client simultaneously thanks to concurrency. Communication thread is one of the threads which is used to support concurrency in cloud. Besides, it is used to start service instances inside cloud computing system. Concurrency allows each thread to run and communicate with the other threads simultaneously [18], [71], [73], [262], [266] and [270].

Data locality

In [44], data locality is defined as “the gathering of data locations referenced in a short span of time in a computer that executes its operations and includes predictable clusters”. [256] supports the definition stated in [44]. Data locality has impact on the speed of Internet access. For instance, local web caches, which are also named as edge servers, speed up internet access and reduce network traffic at sources. Data locality is a characteristic stated with the same value or related storage locations being frequently accessed by the users. It has two basic types named as temporal and spatial locality. Temporal locality states the reuse of specific data within a small time period. On the other hand, spatial locality states the use of data elements within the nearest locations. High data locality can be used for speed and performance optimization. Exploiting and increasing data locality provides speed and performance optimization. Data locality is also related with network optimization. For instance, if data locality can be coupled with routing algorithms, applications can run more faster inside cloud computing environment. To exploit data locality efficiently, either the amount of data movement inside cloud computing system is decreased or the schedulers are improved to be aware of data and data locality information when scheduling the cloud computing tasks. Compared to cloud computing, data locality can not be easily carried out in grid computing because data storage generally depends on shared file systems in grid computing [71], [265], [266] and [292].

Data replication cost

It refers to the cost of sharing data in order to ensure consistency between redundant resources [243]. Data replication technologies are required especially to protect the cloud computing infrastructure from disaster. Data replication includes creating duplicate copies of data. If the outage prevents to access to the data, the backup copy of this data created through data replication is used in the related applications of the company. Data replication cost is associated with data loss. If there is zero tolerance for data loss, then the replication cost is high. Besides, the methods used to provide zero data loss, such as synchronous replication, cause slower application response time, and so application performance decreases. Support costs for data replication are reduced if there is a close integration between storage and replication platforms. If the number of servers used in data replication increase, data replication costs increase. Bandwidth costs can also be reduced through the usage of data compression techniques for data replication. But, the network cost can not be strictly equal to zero because there is some expense for network cost for data replication even with very high data compression ratios [12], [68], [245], [249], [261], [313].

Distance

As stated in [50], distance is the relative location of the system of a cloud customer to the cloud service provider compared to the average distance of the other cloud customers to this service provider. The distance has impact on network latency. To solve the latency issue originated from the distance, the companies make investments on new technologies to accelerate their end-to-end network performance [18], [73] and [262]. A small amount of latency can reduce the download speeds significantly, for that reason, cloud services should be planned strategically so as to reduce distances [50] and [296]. To eliminate latency originated from distance, advanced network services such as dedicated connection can be used [35] and [71]. If the distance between the data center of cloud service provider and the system of cloud customer is high, this distance may cause slow file transfers and inefficient application performance. Distance has also impact on price of cloud computing services. If the distance is high, cloud customer can access and download the file in a long period, so the cloud customer will pay for the cloud services for more time interval and so the price of associated cloud service will be increased [265], [266] and [292].

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[35] agrees that distance is associated with cloud adoption. Main characteristics of distance in terms of cloud computing are discussed in [71] and [266]. [265] and [292] explain the specific strategies that have to be used for decreasing the distance between the systems of cloud customers and systems of cloud service providers.

Isolation failure

In [46], it is defined as the "the failure of methods in carrying out the task of separating the data and computing resources of different cloud customers involved in the same cloud computing system from each other". [285] supports the definition stated in [46] and also [285] declares that cloud service providers should have their own isolated cloud monitoring strategy to prevent isolation failure. Isolation failure is originated from multitenancy which causes gap between tenants as the cloud computing resources are shared [71] and [266]. Isolation failure is a threat for public cloud services, but not for private cloud ones. In public clouds, attacks directed to the resources and sensitive information of multiple cloud customers can be occurred in case of isolation failure. Besides, isolation failure can cause unauthorised access of the cloud customers into the resources of other cloud customers in the cloud. Besides, isolation failure causes misconfiguration of cloud computing resources and faults on resource isolation [18], [73] and [262].

Manageability

According to [37], manageability is defined as the ability of "visibility and control over cloud computing services and their usage". Manageability is important for cloud computing because IT becomes increasingly automated and manageability causes decrease on costs [18], [36], [37] and [252]. Manageability in cloud has the main dimensions as resource management and automation. Resource management is mainly related with resource scheduling, resource assignment, availability and performance. On the other hand, automation deals mainly with configuration, deployment, provisioning and monitoring. As inferred from [252] and [280], cloud data management can also be considered in the scope of manageability. Data management is important for cloud computing because of the increase on data-intensive applications [71], [73] and [309]. Manageability also includes the management of services in clouds [293], [327], [328]. Cloud computing contributes to the manageability of cloud services by offering the efficient sharing of cloud resources [245], [271], [295]. Cloud service management should absolutely include automation feature because the cloud customers nowadays demand automation functionality for each of the cloud services [314], [327] and [328]. Cloud service management also deals with providing the cloud services to the multiple users with suitable prices [300].

Network Virtualization

Network virtualization supports cloud computing by providing variable network topologies to offer cloud services. It provides separation of physical network resource from isolated logical network. It also can mitigate hardware restrictions [71], and [328]. [253] and [315] all agree that the advances in network virtualization have caused to meet the demands of cloud customers in a cloud computing environment in a dynamic and quicker way.

Network virtualization provides the required abstraction such that the network resources can be unified as a pool of resources and provides better manageability and isolation. Grid computing does not use network virtualization as much as cloud computing [73] and [262]. [31] and [34] state that network virtualization provides to isolate "multiple software stacks in their own virtual machines".

[267] and [268] discuss and propose various network virtualization options faced inside cloud computing with various real-life examples. [268] shows that optimal use of network virtualization decreases costs of data centers. [67] and [267] stress that network virtualization is a prerequisite for cloud computing because it can help effective use of network resources by enhancing the utilization of a physical resource. Network virtualization also provides the advantages of isolation, elasticity. It provides the preparation of resources according to the demand of cloud customers, which is called as its elasticity benefit. It isolates the reserved resources from the other resources, which is named as its isolation benefit [67], [267] and [268].

Management of network virtualization is discussed in [287] and [298]. [287] suggests that prior experience on virtualization technology is not necessary in order to take advantage of network virtualization in cloud computing. [298] states that "cloud computing networking services are decoupled from their network infrastructures by the usage of network virtualization". [322] is a guide for network virtualization planning, which describes various network virtualization options with their specifications, advantages, disadvantages and with their limitations.

Operational efficiency

In [43], operational efficiency is defined as "the capability of delivering cloud services to customers in the optimal cost manner as well as protecting their quality". [324] and [329] support the definition stated in [43]. Resource usage and resource allocation problems should be solved by cloud service providers to obtain the highest operational efficiency. There must be an equilibrium between the amount of resource allocated and the amount of resource used. This means that the amount of resource allocated should not exceed the amount of resource used because this may cause the cost and budget oriented problems for the company [260] and [320]. Automation of cloud computing services can bring increases on operational efficiency [324] and [329]. If the automation occurs, repetitive and time-consuming tasks of cloud computing services are eliminated and so operational efficiency increases [324] and [329]. Cloud computing provides virtualization, automated service management and self-service resource allocation techniques to the cloud customers and customers can select the suitable platform according to their specific requirements (either private or public cloud), so it can be stated that cloud computing may cause increase on operational efficiency [18], [73] and [262].

Outage duration cost

Outage is one of the quality of service issues for cloud computing [12], [68]. Outage duration is defined as the period of time the cloud computing system fails to perform its primary function [18], [255]. Outage duration cost means the cost of inaccessibility of data originated from the failures occurred in the main functions of cloud computing system [53]. The cost here can also be considered as the lost cloud services transaction/operation revenue [18], [53] and [281].

The most important findings of [53] and [68] associated with outage duration cost are stated as follows:

- Outage duration cost is a significant expense for cloud-based companies.
- Outage duration cost is associated with data center size.
- Outage duration cost is mostly originated from cloud equipment failure. Accidental faults are less expensive compared to them.

Resilience (fault tolerance)

As stated in [45], resilience is "the feature which provides the cloud computing system to continue executing its operations smoothly although some of its components have failures and cause some faults". This means that cloud computing removes single points of failure [45], [262]. The failure of this node of the cloud computing system does not have impact on execution of its operations [45], [262]. The most optimal solution to ensure resilience is to provide "multiple highly resilient data centers" with strong network links between them[275], [279], [284] and [286]. Migration of virtual machines also improves the resilience of cloud computing systems [18], [73]. Resource pooling, which refers to "making a collection of networked resources behave as though they make up a single pooled resource" is accepted as one of the important way to achieve resilience at an optimal cost [315]. [315] shows that network designers have developed local technical mechanisms inside the cloud computing system for providing resilience.

Scalability

According to [321], "scalability refers to the ability of increasing the number of nodes as required". On the other hand, according to [70], "scalability is the requested feature of cloud computing system". [288] accepts scalability as an "advanced outsourcing solution" that can be applied through cloud computing. [247] argues that scalability is an important issue for cloud computing and this problem can be solved by constructing a collaboration platform among cloud service providers. As stated in [270], if "the network structure must be able to scale to a large number of servers and allow for incremental expansion," then the conditions of scalability are realized.

Cloud computing provides scalability by automatic resizing of virtualized hardware resources. It can be stated that dynamic configuration is required for scalability. This means that cloud computing system should be reconfigured automatically as it scaled. Scalability is easy in a single administrative domain, but difficult with multiple administrative domains. Grid computing has nodes and sites scalability. On the other hand, cloud computing has nodes, sites and hardware scalability. Hardware level scalability in cloud computing provides to use virtualized hardware resources efficiently, but grid computing does not gain this advantage because it does not have hardware scalability [18], [41], [260].

Cloud computing provides on-demand scalability of resources [303], [307]. [42], [303] and [307] show that while dynamically scaling applications, minimizing costs simultaneously should be the other aim of companies and the resource control mechanism should be located into cloud computing system in order to scale applications and resources in a dynamic and effective way. Besides [42], [303] and [307] agree that scalable modelling with cloud resources is an important topic for researchers nowadays.

Switching cost

Switching cost states the financial expenses spent for switching from one cloud service provider to the other one in terms of cloud products and services [242]. The amount of switching cost in cloud computing is mainly affected by two different situations. In the first situation, the switching cost states the cost of moving a business service of cloud customer from one cloud platform to another. If the cloud customer company is on a specific platform, it should buy required services compatible with current platform. On the other hand, in the second situation, the cloud technologies may become embedded within organizational tasks and processes, the switching cost here is more compared to the first situation because adapting the organizational processes into the new cloud services is more costly [12], [68]. Cloud service providers generally try to reduce the switching costs for the key and global players of information technology sector [68], [258]. In grid computing, switching cost is low due to the standardization of gridified applications, whereas, it is high in cloud computing due to the incompatibilities in cloud applications and services [12], [289].

Total cost of ownership (TCO)

Total cost of ownership is the sum of purchase, usage, ownership and maintenance costs of a cloud computing product and/or services [18]. Since up-front investment and long-term operating costs are lower in cloud computing compared to traditional systems, TCO is lower in cloud computing [81]. Since cloud computing provides subscription-based usage of cloud services, total cost of subscribing to a particular cloud service or product is also accepted as TCO. Cloud network management costs and the cost of cloud services are the most important and specific cost components of TCO for cloud computing [244], [326]. Since cloud service delivery and cloud service management are the most important tasks that have to be offered by cloud computing, they are important cost components for TCO [245], [326].

Upgradeability

According to [239], it is defined as “the ability of adjusting the cloud computing network structure with the purpose of enhancing the performance”. In the software-as-a-service model, cloud service provider carries out the software and hardware updates for its customers, and so significant workload is removed from the in-house IT department of cloud customers, this is called upgradeability [18], [71], [73], [323]. Besides, the code base of a cloud computing application must be easy to upgrade and update, which is also required for the upgradeability characteristic [262] , [266], [292]. Upgradeability is also defined as “the ability of cloud computing system to extend its functionality over time through the integration of new modules”[265].

Vendor lock in degree

[275] defines vendor lock in degree as "the dependency of cloud customers on cloud service providers in terms of cloud computing services and products". Vendor-lock in occurs when a cloud customer company becomes dependent on a single cloud service provider for many of the cloud computing products and/or services [18], [73], [262]. Vendor-lock in degree changes according to the company type. Vendor-lock in degree is higher for small and medium sized companies compared to global and big companies because vendor-lock in creates monopolies for cloud service providers with certain cloud customers [35], [244]. Vendor-lock in also may originate from the proprietary technologies that are incompatible with the services of other competitor cloud service providers. The contract constraints in Service Level Agreements (SLA) may also cause the vendor-lock in because cloud customers can not change the service provider because of these constraints [245], [248]. To overcome the vendor lock-in issue, cloud customers should choose the providers by comparing the policies and services of each of the cloud service providers [249], [257]. Some of the companies also demand vendor-lock in by themselves, for instance, they purchase as many applications as possible from one cloud service provider in order to demand higher discounts, although not all of its solutions are optimal [73], [245]. Vendor-lock in degree also depends on the cloud deployment type and application programming interfaces [248], [257]. Consequently, it can be stated that cloud service providers will aim to lock in their customers by providing proprietary technologies, on the other hand, cloud customers will try to eliminate lock-in situations.

Within the context of the draft model, considering the related literature outlined above, technical characteristics were defined as the characteristics of cloud computing in a company in terms of:

- their ability to adapt cloud computing,
- the sufficiency level of cloud-based solutions they have adopted,
- the significance of risks originating from cloud computing,
- the feasibility of their cloud computing system,
- the levels of their computing resources,
- their cloud computing system continuity,
- the sufficiency of the level of agreement about meeting their expectations for the cloud computing system.

On the other hand, economic characteristics consist of measures of cloud computing stated in terms of:

- the costs accruing for cloud computing usage,
- savings and benefits being achieved through cloud computing,
- the level of cloud-based revenue,
- their potential to invest on cloud infrastructure for future and the level of this investment.

The draft model consisted 16 technical and 6 economic characteristics in these two dimensions. The technical characteristics and economic characteristics have been identified in the following sections, respectively.

2.2. Definitions of Technical Characteristics

Agility refers to the ability to rapidly change the cloud applications to meet user requirements [37].

Availability is defined as the percentage of time the cloud computing system is available for use via possibly multiple cloud computing providers [14], [38]-[39].

Cloud deployment type refers to the ownership and operational categorization of the computing infrastructure. Four major deployment types are: public, private, community and hybrid clouds [35].

Cloud performance is determined by various metrics named as network performance, application performance and data center performance, respectively. These three performance components are affected by all software and hardware infrastructures. Network performance is measured mainly by throughput and latency metrics [47]-[48].

Cloud infrastructure performance, on the other hand, can be evaluated with such metrics as CPU (Central Processing Unit) utilization and application traffic [49].

Cloud security states the policies and rules used for cloud computing with the purpose of protecting the data and resources of cloud computing stakeholders. Cloud security also includes data protection, identity management, physical and personnel security, application security and privacy [30].

Concurrency is a situation of cloud computing systems where the tasks of performing computations as well as making these computations interacted with each other are realized concurrently [240]-[241].

Data locality is the gathering of data locations referenced in a short span of time in a computer that executes its operations and includes predictable clusters [44].

Distance is the relative location of the cloud customer to the cloud providers and the other cloud customers [50].

Isolation failure refers to the failure of methods in carrying out the task of separating the data and computing resources of different cloud customers involved in the same cloud computing system from each other [46].

Manageability refers to "the collective processes of administration, configuration, deployment and optimization in the course of lifecycle of cloud computing systems and services". Related metrics proposed are "checklist of manageability functions, number of steps to manage towards desired state, time to manage, documentability, elasticity of management, availability and continuity of management and ease of use" [36].

Another alternative definition of **manageability** states the importance of having the ability of control and visibility over cloud computing services and usage through the usage of self-service provisioning feature and web-oriented management capabilities of cloud [37].

Network virtualization refers to the capability of dividing the bandwidth into channels with the purpose of assembling the computing resources in a cloud network. Possible levels of virtualization have been described, in increasing levels, as para-virtualization, hardware-assisted virtualization, live-migration, and Pause-Resume [31]-[34].

Operational efficiency is the capability of delivering cloud services to customers in the optimal cost manner as well as protecting their quality [43].

Resilience (fault tolerance) refers to the feature which provides the cloud computing system to continue executing its operations smoothly although some of its components have failures and cause some faults [45].

Scalability refers to the ability of increasing the number of cloud users supported by the system and the number of transactions performed as required [40]-[42].

Upgradeability refers to the ability of adjusting the cloud computing network structure with the purpose of enhancing the performance [239].

Vendor lock in degree states the level of the customer dependency on cloud service providers for cloud products and services [2], [14].

2.3. Definitions of Economic Characteristics

Capital expenditure (CAPEX) includes the cost of entire data center infrastructure, including servers, storage arrays, software licenses, routers, and load-balancers [2].

Cloud migration cost is the cost of carrying all applications from the current computing environment to cloud environment. It can be defined mathematically as follows [2], [54]:

Cloud migration cost=Setup costs + Migration costs + Ongoing costs (2.1)
Setup costs+ migration costs= The costs of moving application and business moving to the cloud (2.2)
Ongoing costs= f (CPU time, GB of RAM, terabyte of storage) (2.3)

Data replication cost refers to the cost of sharing data in order to ensure consistency between redundant resources. Licensing fees, network bandwidth, heterogenous storage are the most important factors that have impact on data replication cost [243].

Outage duration cost is mainly calculated by multiplying the length of outage duration period with the number of users cloud services offered. If available, a fixed customer outage duration cost is added to the result of this multiplication operation [52].

Total cost of outages= f (duration of outage, size of data center, business disruption, lost revenues, IT equipment failure, accidental/human error) (2.4)
where,
Duration of outage= f (length of outage duration, the number of customers served, fixed customer outage duration cost) (2.5)

Outage duration cost refers to the cost of inaccessibility of data originated from the failures occurred in the main functions of cloud computing system. Outage duration cost can also be calculated by multiplying outage duration hours with amount of money lost per hour [52]-[53].

Switching cost means the financial expenses spent for switching from one cloud provider to another cloud provider in terms of cloud services and products [242].

Total cost of ownership (TCO) can be defined arithmetically as [2], [51]:

TCO= (Network management expenses+ the expenses of services)/ (number of customers of service providers) (2.6)

or,

TCO= (Network costs+ Router/switch costs+personnel costs + training costs + hardware costs + software costs + endpoint costs+ energy costs+ facilities costs) / (number of customers of service providers) (2.7)

CHAPTER 3

EXPLORATORY CASE STUDIES

The case studies carried out to refine and finalize the CCEAM are presented below in conformance with the structure proposed in widely cited texts on qualitative research (e.g. [28], [231]-[237]). Validity of the results of these studies is also discussed explicitly, considering possible threats and mitigation approaches.

3.1. Problem Statement and Research Objectives for the Case Studies

The literature consistently leads to the observation that cloud computing effectiveness assessment has to consider at least the technical and economic dimensions. On the other hand, the cloud survey results indicated three dimensions, including the organizational dimension. For that reason, whether these three dimensions and their constituent characteristics are valid and sufficient to investigate the effectiveness assessment of cloud computing had to be determined in practical organizational settings.

The first aim in the case studies was to determine whether the sub-characteristics associated with the 27 characteristics of the updated model were suitable for effectiveness assessment or not. The sub-characteristics determined to be valid in the scope of the case studies were adopted and later named as measures. The second aim was to determine the new characteristics to be added to the model.

Another aim was to determine whether the three dimensions of the model were valid and sufficient.

3.2. Context

The context of our case studies consists of the companies from the following four categories:
(i) cloud service providers (CSP),
(ii) companies that provide as well as receive cloud computing service (CPR),
(iii) solution providers for cloud service providers (SPCSP), and
(iv) cloud users (CU).
All companies were located in Turkey, where this research was undertaken. The companies who participated in the case studies are briefly described in Table 3.1. Their names are witheld due to reasons of corporate privacy.

3.3. Selection of case and subjects

We undertook case studies in 10 firms collectively covering all four categories of companies stated above as service providers, service provider/receivers, solution providers, and users. These four categories were determined, based on the review of literature, prior to case study applications. After that, most suitable and commercial organizations for each of the category were determined by investigating the cloud services, products they offered and/ or received according to the search on web. In the first step, 32 companies were selected as suitable for study. We made a first contact with these companies by e-mail and when necessary through phone. The results of this first contact indicated that 16 companies would be sufficient to cover the four categories in answering the open-ended interview questions. Out of these 16 companies, 10 firms accepted to participate in case studies. Hence the firms were selected according to their suitability through the preselection process and their willingness to participate.

The size of companies and their turnover were not considered for categorization of companies because the content of cloud work offered and/or received by an organization was considered to be more important rather than its size and turnover in the cloud sector. For instance, a solution provider for a cloud service provider does not generate a higher turnover than the other solution providers because the maximum turnover value of them is determined by according to the demands of cloud service providers in the cloud sector so none of them can have the opportunity of exceeding this turnover value. For that reason, for this category, it is not necassary to classify firms according to their turnover. Another example is for cloud service providers. Especially, being a key player in the IT sector is a prerequisite to be a cloud service provider. This means that only big companies in the IT sector can serve as cloud service providers. Besides, there is not a big turnover differentiation among cloud service providers in the sector, so categorization is not necessary also for them.

3.4. Methodology

A qualitative research methodology [28, 231-237] based on case studies was preferred because cloud computing involves many different parameters and obtaining the new parameters and creating a final model with quantitative studies is statistically infeasible.

Cloud computing is still a relatively new topic, so terminology problems abound. This is another reason for our preference for qualitative research. Since we have tried to support similar as well as contradictory results while constructing the effectiveness assessment model, a multiple-case design was needed.

We prepared open-ended questions to start interviews for each case. These questions were formulated based on our updated model. They included 20 major questions with numerous subordinate ones. The open-ended interview questions are available in Appendix A.

Table 3.1: Participants in the Exploratory Case Study

Company name	Category	Number of employees	The sectors the company operates in	Contacted company staff	Marketplace of the company	Turnover for year 2012 (Million $)
A	CSP	700	• Finance • Telecom • Manufacturing and Services • Automotive	Senior Solutions Architect	Global	80
B	CU	50-100	• IT	General Manager	Domestic	2
C	SPCSP	50	• IT • Communication	Business Service Management Consultant & System Administrator	Domestic	5
D	CPR	11-50	• Mobile Operators • Media and Entertainment • Education	Cloud Team Leader & Senior Software Architect	Domestic	2
E	CPR	11-50	• IT and Services	Managing Director	Domestic	1-2
F	CPR	51-200	• Computer Software • Manufacturing • Automotive • Food • Chemicals • Construction • Retail • Textile • Tourism	Vice President of the Software Company	Domestic	22
G	CPR	51-200	• IT	Data Center Services Manager	Domestic	50
H	CPR	51-200	• IT	General Manager	Domestic	2
I	CSP	10001	• IT and Services	Cloud Computing Expert & Sales Leader	Global	3,000
J	SPCSP	51-200	• IT and Services	IT Manager	Domestic	6

3.5. Data collection procedure

We performed face-to-face interviews and had e-mail contacts with the companies to collect data. The transcipt of interviews (provided in [230]) and the answers sent through e-mail by the companies were combined and analyzed in order to construct the CCEAM.

3.6. Analysis procedure

In the first step, we evaluated the suitability of 27 characteristics constituting the updated model. If the suitability of a characteristic was supported according to the results of an open-ended interview question by most of the companies participating in the case studies, the related characteristic was incorporated in the final model. The sub-characteristics to be added and to be eliminated from the model were also determined in the same manner.

The new characteristics to be added to the model were determined according to the inferences upon analyzing the interview transcripts.

Besides, the suitability of model dimensions was ascertained. If most of the organizations participating in the case study supported the suitability of the three dimensions of the updated model, they would be accepted as the dimensions of the final CCEAM.

Finally, the new dimension(s) to be added to the model were determined by evaluating all proposals regarding different dimensions of the assessment model. If a new dimension proposed by different companies implied the same concept in different terms, the related dimension was added to the model under a commonly acceptable name.

3.7. Description of cases

Category 1: Cloud service providers

We selected Company A and I as they are among the most influential cloud service providers in the IT sector.

Company A provides cloud services to their customers; they do not receive any cloud service because they had built their IT infrastructure before cloud computing was as popular as it has recently become. They provide such cloud services as cloud installation, cloud migration, application development (preparing applications for cloud or transforming applications for cloud compatibility), and cloud hosting. Besides, they provide SaaS (Software as a Service) solutions to the public sector as well as IaaS (Infrastructure as a Service) solutions to both private and public sectors.

On the other hand, Company I offers services in each of the cloud layers (IaaS-PaaS (Platform as a Service)-SaaS-BPaaS (Business Process as a Service)) and in each of the service models (public, private and hybrid). They construct solutions according to customers' requests.

Category 2: Companies that provide as well as receive cloud computing service

Company D offers SaaS and PaaS (Platform as a Service) solutions. They provide SaaS solutions with the support of large scale enterprises. For IaaS and PaaS, they make use of virtualization manager solutions, virtualization platforms and services. They provide SaaS for mobile devices on which their own operating systems are installed. All of the assets of Company E are located on the cloud. Mainly, commercial packages are used for the following cloud services by them:

- CRM (Customer Relationship Management)
- Project Management
- Integration
- Collaboration
- File hosting and content management
- Social Media (Network) Tracking

Except project management, the services stated above are also offered by Company E. They realize implementations for organizations. This means they deal with the organizational side of cloud.

Company F has virtualized some of their servers. They manage all of their applications (including the operating systems of the virtualization servers) by themselves. They also offer corporate commercial applications to SME (Small and Medium Enterprises) with a renting model on the cloud.

Company G offers IaaS to their customers. In the scope of this service, they use the existing infrastructures of the other service providers. Then, they add their own management services (operating system management, database management, etc.) to this service.

Company H provides IaaS. They provide this AWS (Amazon Web Services)-like service to their customers in accordance with the pay per use model with scalable, agile and flexible server resources. The customers of Company H can create a Company H account online. By using this account, they have the ability of using CPU (Central Processing Unit), disk, bandwidth, and operating system resources through a web control panel, API (Application Programming Interface) and a mobile operating system in any combination as needed. In addition to server resources, they also provide the opportunity of using value added services such as storage, DNS (Domain Name System) and load balancing through web control panel, API and a mobile operating system.

Category 3: Solution providers for cloud service providers

Company C offers cloud computing life cycle management solution as a business partner of a large global company. Through this solution, cloud service provider firms can manage their cloud infrastructure over the cloud.

Company J deals with virtualization, IT infrastructure and desktop virtualization. They offer services for the public sector.

Category 4: Cloud user

Company B uses the cloud together with their business partner companies on different projects. Their main aim is to reach a wider customer base. In their projects, they use an enterprise resource planning tool on the cloud. The benefit for their organization is the usage of cloud as a new technology in a data-intensive environment.

3.8. Case study findings

The main findings of the case studies can be classified as general and external dimension-based findings.

The general findings and achievements of the case studies were:

- The list of characteristics and their measures were finalized. Organizational, economic and technical dimensions proposed in the model were validated.
- Level of business ethics, legal environment of cloud computing, social and geographical factors, agility, and computer literacy rate had to be added to the CCEAM as new characteristics.

The external dimension-based findings are:

- An external dimension had to be added to the model as the fourth dimension with the characteristics: legal environment and social factors.
- Since computer literacy rate is associated with social factors, it had to be considered as a sub-characteristic of the social factor.

The detailed explanations about the case study findings and interview transcripts are available in [230].

3.9. Limitations of the case studies

Feasibility assessment for full or partial migration to cloud is not possible with our model because potential users considering to migrate their operations fully or partially to the cloud were not included in the case studies. The model was finalized by studying cases from the four categories of companies stated in the subsection on selection of case and subjects. Future work will have to focus on potential cloud users and possibly other categories of companies that can be analyzed in the scope of cloud computing effectiveness assessment.

3.10. Validity of the case study results

The validity of a case study can be evaluated from two perspectives. First of all, to what extent the results are true must be evaluated. Secondly, the effects of subjective biases of researchers on the results of case studies must be assessed. The generally accepted categories of validity threats to case studies [28, 231-232, 234-235] are discussed below together with our respective mitigation remedies:

- **Construct validity**: The characteristics that we investigated in the scope of the case studies were determined and defined within the framework of both the literature and cloud surveys. As such, they were suitable for the problems tackled in this study. The interpretation of the interview questions were mostly identical between the researcher and interviewed persons. 9 companies understood all the interview questions correctly. Only one company interpreted the cloud interoperability related question in a different way from us. We made the necessary explanations about this question. Besides, due to the novelty of the area, in some of the interviews we observed that some interviewees interpreted some individual terms differently. To tackle with this threat, we explained these sub-characteristics with sample short cases including these sub-characteristics and their effects. Since we investigated four different categories of companies in the scope of this study, these short cases were adjusted and prepared specifically for the category of related company. So, the problem of interpreting some of the terms differently was solved. Besides, this enabled us to reach a common understanding on problematic terms.
- **Internal validity:** In our model, some of the characteristics may have dependencies on and relationships with some other characteristics. To overcome this issue, operational definitions of each of the measures were formulated to ensure strict independence from the other measures. For instance, there may be a relationship between locality of reference to data and data integrity. But, in our model, locality of reference to data is measured with the measure "level of hit rate of cache". On the other hand, data integrity is assessed with the seven separate measures as listed in Table 4.2. Hence, strictly different measures are used to evaluate these two characteristics. The relationship between scalability and cloud performance can be considered as an other example. As shown in Table 4.5 and 4.8, their measures are also different. Another example is the relationship between hardware virtualization and network virtualization. To assess network virtualization, the measures of data confidentiality level, sensitivity of data and deployment situation inside network are investigated. On the other hand, two different mathematical ratios are evaluated for hardware virtualization. Thus these two characteristics are also evaluated with distinct measures. Consequently, in CCEAM, each of the characteristics have separate measures and so it is ensured that evaluations of different characteristics do not effect each other. Another issue is associated with the deficiency of experts having both comprehensive technical and business knowledge on cloud computing. To overcome this issue, we selected interviewees based on several factors. The first factor was to determine whether the related interviewee has experience on cloud computing in terms of both technical and business aspects. The second factor was to determine whether the related staff has both technical and business education background. All of the interviewees who participated in the research had both engineering undergraduate and business administration graduate degrees. In our study, we gathered information from various sources to enhance the validity of findings by means of triangulation. For instance, we conducted a preliminary survey in Cloud Expo Europe 2012 conference. In addition to this, papers, interviews and presentations in Cloud Expo Europe 2012 and CLOSER2012 were studied. By combining all of these findings, the components of the initial model were defined. We adopted this mechanism in each of the phases of our research. The constructed model was updated after

each phase as necessary. Consequently, to limit subjectivity biases and to render the findings more trustworthy, triangulation was extensively applied while updating the model.

- **External validity:** The common characteristic of the firms selected from the described four categories was that they were all important players in the IT sector and in the cloud computing field in Turkey. The literature survey and the earlier phases of the research involved direct contacts with and investigation of international firms. Hence, even though the case studies were carried out exclusively in Turkey, the national characteristics of the participants were neither relevant, nor evaluated. The combined results of these four different cases can thus be used by different researchers as a wide coverage was achieved in terms of mode of participation in cloud computing. On the other hand, as with any instance of qualitative research, full generalizability is neither achieved, nor claimed.
- **Reliability:** In the scope of this research, a sequence of complementary phases were carried out, consisting of literature survey, a preliminary survey and a second focused survey, followed by direct qualitative study in 10 firms. The constructed model was updated after each phase as necessary. The questionnaires and interview questions applied in these steps were all clear and prepared in advance, based on the findings of the earlier phases, taking firms from a number of different countries as well as multi- and trans-national corporations into consideration. In the long-term, since major changes in all dimensions of cloud computing and IT sector are inevitable, it is only to be expected that applicability of our findings will be reduced in time. But, in the short term, the adopted scope of the study as well as the applied steps and objective operational definitions of all measures have ensured repeatability of findings among different researchers.

CHAPTER 4

CCEAM

In this chapter we present the final model, CCEAM, as formulated after the exploratory case studies described in the preceding chapter.

This final model consists of a set of dimensions and characteristics to be used in cloud computing effectiveness assessment for (i) cloud service providers (CSP), (ii) companies that provide as well as receive cloud computing service (CPR), (iii) solution providers for cloud service providers (SPCSP), and (iv) cloud users (CU) (Table 4.12). The characteristics and their measures are presented in Tables 4.2 to 4.11 in the next section. Table 4.1 presents a list of all characteristics of CCEAM.

4.1. Structure of CCEAM

CCEAM consists of the technical, organizational, economic and external dimensions. In these four dimensions, it consists of 24 technical, 9 economic, 7 organizational and 2 external characteristics and a total of 142 measures. The number of measures for technical, organizational, economic and external dimensions are 80, 31, 29 and 2, respectively.

4.2. Measures

This section presents the measures to be used in assessing characteristics in the technical, economic, organizational and external dimensions.

Ten separate tables have been constructed for measures. Seven of them focus on the technical dimension as the characteristics of this dimension are categorized into seven major categories: cloud adoption, technical cloud solutions, risk based issues, system technical feasibility, technical resources, cloud system continuity, technical agreement. The last three tables present the characteristics of the economic, external and organizational dimensions, respectively.

In our model, the measures are capable of independently measuring the same characteristic. For instance, level of architectural compatibility of applications with cloud, level of average usage period of cloud based desktop applications, satisfaction level about cloud friendly components and level of cloud applications support represent four separate measures to assess the same characteristic of cloud applications. As seen from the names of these four measures, this characteristic is assessed in terms of the four separate perspectives of architectural compatibility, average usage period, satisfaction level and support. Similar to this, cloud security is assessed with seven separate measures. Cloud security can be

Table 4.1: Characteristics of CCEAM

Technical dimension	Organizational dimension	Economic dimension	External dimension
1. Agility 2. Application Integration 3. Availability 4. Computing Capacity 5. Cloud Applications 6. Cloud Application Migration 7. Cloud Delivery Models 8. Cloud Deployment Type 9. Cloud Interoperability 10. Cloud Performance 11. Cloud Response Time 12. Cloud Security 13. Data Integrity 14. Distance 15. Hardware Virtualization 16. Isolation Failure 17. Locality of Reference to Data 18. Multiplicity 19. Network Virtualization 20. Reliability 21. Resilience 22. Scalability 23. Service Level Agreement as a Technical Dimension 24. Technical Flexibility	1. Administration 2. Cloud Strategy 3. Cloud Supplier Selection 4. Innovation 5. Level of Business Ethics 6. Manageability 7. Vendor Lock-in Degree	1. Cost-Benefit Analysis 2. Cloud Application Migration Cost 3. Economic Flexibility 4. Future Major Cloud Infrastructure Cost 5. Operational Efficiency 6. Outage Duration Cost 7. Revenue 8. Service Level Agreement as an Economic Dimension 9. Total cost of application ownership	1. Legal Environment of Cloud Computing 2. Social Factor

considered as another example. It is assessed with eight separate measures. Similar examples from our model can be increased and discussed here, but the important thing to be emphasized is that the separate measures assess the same characteristic independently and each of these measures represent different perspectives, which enhances the independence, consistency and completeness of measures in CCEAM.

In Tables 4.2 through 4.11, the measures for the four dimensions are presented together with their denotations used in the footprint diagrams. In these ten tables, the description, explanations where necessary, and Likert scale assignment rules / ratio formula for each of the measures are also presented. The references to bibliography indicate fundamental sources related to individual characteristics and their relationships to cloud computing effectiveness.

Table 4.2: Technical dimension measures-category1-cloud adoption

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Cloud Adoption	Agility [37], [223].	Effects of archival strategy **(Ag1)**	Archival strategy provides a guideline to the organizations so that they can archive the correct data correctly [145]-[149].	**High:** The archival strategy is adjusted according to the retrieval requirements of cloud customer, and includes the amount of data to be archived, the period of archived data to be maintained, the information about how to access to the archived data.	The impacts of the archival strategy adopted by the company should be investigated. This strategy should be selected according to archive retrieval requirements of the company.
				Medium: Between one and three of the four conditions stipulated for the "high" evaluation are not valid.	
				Low: The organization does not have a defined archival strategy.	
		Ratio of data stored outside cloud **(Ag2)**	Database size of cloud customer refers to the total size of all objects in the database. To evaluate this measure, ratio of data stored outside cloud is calculated [145]-[149].	**Ratio of data stored outside cloud**= 1 - (Capacity reserved for cloud customer data by cloud service provider(s)) / (Cloud customer database size)	If the ratio of data stored outside cloud is low, this means that high amount of data of cloud customer is included inside cloud system. This situation causes the decrease on the transaction speed inside the system. For that reason, in this case, this ratio should be reduced.

Table 4.2 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Cloud Adoption	Agility [37], [223].	The effects of the type of interfaces the cloud system supports (**Ag3**)	It is used to determine whether the cloud computing system offered by cloud service provider supports an external interface which allows to integrate with other applications without causing negative consequences on the cloud customer company [145]-[149].	**High:** All of the three types of interfaces in the list in the comment part are supported by cloud service provider	The following types of interfaces must be supported in the scope of cloud computing: 1. Interfaces between cloud applications 2. Interfaces between cloud computing systems 3. External interfaces to integrate the cloud applications with other applications
				Medium: Two of them are supported	
				Low: Only one of them is supported	
		Infrastructure utilization **(Ag4)**	It measures the adaptation level of cloud infrastructure to the changes, such as in workloads [145]-[149].	**High:** Cloud computing infrastructure and resources increase rate> Workloads increase rate	Only the changes on workloads are evaluated in the scope of this measure.
				Medium: Cloud computing infrastructure and resources increase rate=Workloads increase rate	
				Low: Cloud computing infrastructure and resources increase rate< Workloads increase rate	

Table 4.2 (continued)

Major Category	**Characteristic Name**	**Measure Name**	**Description**	**Likert scale assignment rules / Ratio formula**	**Comment/ Explanation**
Cloud Adoption	Agility [37], [223].	Level of services reuse **(Ag5)**	It is used to determine whether cloud customer reuses the cloud services in an optimal way so that it can adapt itself to the changes on services easily [145]-[149].	**High:** New cloud services can be created by composing current cloud services by cloud service provider **Medium:** A problem of current cloud service is solved by reusing one of the other current cloud services without composing them **Low:** They can be created by neither reusing nor composing current cloud services	
	Application Integration	Level of Service Oriented Architecture **(Aint1)**	It measures whether the cloud service provider has an architecture through which they can change and/ or modify their one of the cloud computing services without causing problems and/or changes on other cloud computing services [108]-[110].	**High:** Any cloud computing service is both replaceable & modifiable without causing problems on other services. **Medium:** Any cloud computing service is either replaceable or modifiable without causing problems on other services. **Low:** It is neither replaceable nor modifiable without causing problems on other services.	Assessment of whether the cloud service provider has the ability of deploying its cloud services in a Service Oriented Architecture (SOA) structure.

Table 4.2 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Cloud Adoption	Cloud Application Migration [56]-[57].	Bandwidth level **(Clam1)**	It refers to the level of bandwidth provided by cloud service provider for cloud computing applications [134]-[140].	**High:** Bandwidth provided by cloud service provider > the bandwidth requested by the applications	
				Medium: Bandwidth provided by cloud service provider = Bandwidth requested by the applications	
				Low: Bandwidth provided by cloud service provider < the bandwidth requested by the applications	
		Wide area network latency success **(Clam2)**	Wide area network latency refers to network latency (round trip time) to transmit data from cloud computing system to cloud customer system; or from cloud customer system to cloud computing system [134]-[140]. Wide Area Network Latency Success Ratio (WANLSR) is used for this measure and it is calculated with the following formula: WANLSR= (Latency determined by cloud service provider and customer in SLA (Service Level Agreement)) / (Wide area network latency)	**High:** WANLSR>1	
				Medium: WANLSR=1	
				Low: WANLSR<1	

Table 4.2 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Cloud Adoption	Cloud Application Migration [56]-[57].	Level of synchronization ability (**Clam3)**	It is used to evaluate whether both process and data synchronization are provided to cloud customer by cloud service provider in case of migrating its applications to cloud [134]-[140].	**High:** Cloud service provider provides both process and data synchronization to cloud customers **Medium:** It provides either process or data synchronization **Low:** It provides neither process nor data synchronization	
		Level of mass conversion **(Clam4)**	Mass conversion refers to converting multiple program files of the system to the cloud computing system with the usage of file converter option provided by cloud service provider inside cloud computing system. Through this file converter option, files in bulk are converted and so program files are migrated to the cloud computing system [134]-[140].	**Very High:** All of the tasks in the list in the comment part are carried out by cloud service provider **High:** Four of the tasks in the list are carried out **Medium:** Three of them are carried out **Low:** Two of them are carried out **Very Low:** Only one of them is carried out	In the scope of mass conversion, the following tasks are carried out: 1. Manage the process of conversion 2. Configure application libraries 3. Run application libraries 4. Catalog application libraries 5. Test all of the applications after conversion

Table 4.2 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Cloud Adoption	Cloud Application Migration [56]-[57].	Level of back up ability (**Clam5)**	Backup means backing up data to a cloud based server. It also refers to the ability of copying and archiving data of the organization inside the cloud computing system provided by cloud service provider [134]-[140].	**Very High:** All of the tasks in the list in the comment part are carried out by cloud service provider	Backup includes the following tasks: 1. Storing the data 2. Copying the data 3. Archiving the data 4. Providing opportunities in case of disaster recovery 5. Restoring the data when requested and/or necessary
				High: Four of the tasks in the list are carried out	
				Medium: Three of them are carried out	
				Low: Two of them are carried out	
				Very Low: Only one of them is carried out	
		Level of cultural readiness to cloud system inside the company **(Clam6)**	Cultural readiness means behaviors, beliefs and organizational traditions that causes the acceptance of cloud application migration thought within the organization [134]-[140].	**High:** The percentage of the information technology staff of the company that has positive attitude on cloud application migration thought >50% & new technologies systematically adopted by company when considered necessary.	
				Medium: Either the percentage of the information technology staff of the company that has positive attitude on cloud application migration thought <50% OR the company does not prefer to migrate to the new technologies as stated in its previous experiences.	
				Low: The percentage of the information technology staff of the company that has positive attitude on cloud application migration thought <50% & the company does not prefer to migrate to the new technologies as stated in its previous experiences.	

Table 4.2 (continued)

Major Category	**Characteristic Name**	**Measure Name**	**Description**	**Likert scale assignment rules / Ratio formula**	**Comment/ Explanation**
Cloud Adoption	Cloud Application Migration [56]-[57].	Strategic importance level of cloud application migration for organization **(Clam7)**	Strategic importance refers to the effects the cloud application migration has on the competitive positioning of the organization [134]-[140].	**High:** Number of customers of organization after cloud application migration > Number of customers of organization before cloud application migration	Whether the cloud application migration is a compulsory situation for the company to survive in the information technology sector.
				Medium: Number of customers of organization after cloud application migration = Number of customers of organization before cloud application migration	
				Low: Number of customers of organization after cloud application migration < Number of customers of organization before cloud application migration	
	Cloud Applications	Level of architectural compatibility of applications with cloud (**Cla1**)	It measures whether the applications of cloud customer company are compatible with the cloud computing system in terms of the architecture features and design characteristics of the system [82], [86].	Very High: AVERAGE(CRAF, CRDC) > 0.75	Compatibility ratio for architecture features (CRAF) = (Number of compatible architecture features of cloud customer applications) / (Total number of architecture features of cloud computing system). Compatibility ratio for design characteristics (CRDC) = (Number of compatible design characteristics of cloud customer applications) / (The total number of design characteristics of cloud computing system)
				High: 0.55 < AVERAGE(CRAF, CRDC) < 0.75	
				Medium: 0.45 < AVERAGE(CRAF, CRDC) < 0.55	
				Low: 0.25 < AVERAGE(CRAF, CRDC) < 0.45	
				Very Low: AVERAGE(CRAF, CRDC) < 0.25	

Table 4.2 (continued)

Major Category	**Characteristic Name**	**Measure Name**	**Description**	**Likert scale assignment rules / Ratio formula**	**Comment/ Explanation**
Cloud Adoption	Cloud applications	Level of average usage period of cloud based desktop-applications (**Cla2**)	The ratio is calculated by dividing the total usage hours of cloud based applications for all of the staff in company by total number of working hours in a month for all of the staff [82], [86].	Average usage period of cloud based desktop applications $= \frac{\sum_{i=1}^{n} T_i}{(Number\ of\ \ working\ hours)*n}$	According to the result of this calculation, average usage period of cloud based desktop applications for a staff per working hour is obtained. T_i: It denotes the total usage hours of cloud based desktop applications for the related staff i: 1,2,…,n where i denotes staff members.
		Satisfaction level about cloud friendly components **(Cla3)**	It measures whether the cloud computing components provided with cloud applications to cloud customers help them for carrying out their tasks inside their company in an effective way [82], [86].	**High:** The average time to complete tasks through cloud friendly components < the average time to complete the tasks without using them **Medium:** The average time to complete tasks through cloud friendly components is = the average time to complete the tasks without using them **Low:** The average time to complete tasks through cloud friendly components is > the average time to complete the tasks without using them	

Table 4.2 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Cloud Adoption	Cloud Applications	Level of cloud applications support **(Cla4)**	It measures whether the cloud service providers offer sufficient level of support to solve the issues of their customers when they faced problems associated with cloud applications [82], [86].	**Very High:** All of the components in the list in the comment part are provided **High:** Four of the components in the list are provided **Medium:** Three of them are provided **Low:** Two of them are provided **Very Low:** Only one of them is provided	The level of support must be determined according to the following components: 1. The cloud service provider can support for applications 24 hours in 7 days. 2. They may offer detailed reports about each of the cloud applications to their customer. 3. They may send their technical staff to the cloud customer companies to give information about the usage of applications. 4. They may ask to the cloud customers within defined time intervals whether they face problems related with cloud applications. 5. They can also offer the alternative solutions for the problems associated with cloud applications.
	Cloud Interoperability [62].	Variety of ready-made integrated solutions **(Cli1)**	It is used to determine whether cloud service providers offer to their customers various ready-made integrated applications and solutions [153]-[155].	**Very High:** Cloud service provider offers all of the five alternatives stated in the list in the comment part **High:** It offers four of the alternatives in the list **Medium:** It offers three of them **Low:** It offers two of them **Very Low:** It offers only one of them	Cloud service providers must offer the following alternatives for ready-made integrated applications and solutions: 1. Cheap ready-made integrated applications and solutions for small and medium sized organizations 2. Cheap ready-made integrated applications and solutions for only a department of an organization 3. Medium priced ready-made integrated applications and solutions for more than one department of an organization 4. Medium priced ready-made integrated applications and solutions for only a department of an organization 5. Expensive applications and solutions for entire organization

Table 4.2 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Cloud Adoption	Cloud Interoperability [62].	Level of possibility of programming applications in the cloud environment **(Cli2)**	It is used to determine whether cloud service providers offer the service of programming the applications of cloud customer for cloud environment [153]-[155].	**High:** Cloud service provider offers all of the three alternatives stated in the list in the comment part **Medium:** It offers two of them **Low:** It offers only one of them	The cloud service providers must provide programming alternatives for the following application types: 1. Complex 2. Medium-sized 3. Small/simple
		Level of applicability of different application usage scenarios (**Cli3)**	It measures whether the different application usage scenarios are applicable in the cloud computing system provided by cloud service provider and/or through solutions provided by solution provider [153]-[155].	**Very High:** All of the five scenarios in the list in the comment part occur in the cloud computing system provided by cloud service provider and/or solution provider **High:** Four of them occur **Medium:** Three of them occur **Low:** Two of them occur **Very Low:** Only one of them occurs	The main application usage scenarios that can be realized in the cloud computing system are : 1. Applications on cloud can be used for business tasks. 2. They can be developed on cloud. 3. They can be tested on cloud. 4. They can be deployed on cloud. 5. They can be managed on cloud
		Level of heterogeneity of data produced in the cloud environment **(Cli4)**	It refers to the level of differences in data of cloud customer in terms of data type and data formats in the cloud environment [153]-[155].	**High:** Data with both various format and content is available in cloud environment **Medium:** Data with either various format or content is available in cloud environment **Low:** Various format and content of data is not available in cloud environment	There are three possible situations in the cloud environment associated with this measure: Situation1: Various data contents provided on a common data format in the cloud environment Situation2: Single data content provided on a common data format in the cloud environment Situation3: Various data contents provided with the various data formats in the cloud environment

Table 4.2 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Cloud Adoption	Cloud Interoperability [62].	Data replication ability level in cloud **(Cli5)**	It refers to keep multiple copies of data of cloud customer in order to prevent data loss by storing the data at various locations in cloud computing system [153]-[155].	**High:** Multiple copies of data are stored at different locations. **Medium:** Single copy of data is distributed to various locations OR Multiple copies of data are stored at a single location. **Low:** Single copy of data is stored at a single location.	The impact of data replication on the elimination of data loss.
		Ability level of moving data inside cloud correctly (**Cli6)**	It is used to determine whether the data can be moved from the locations to locations correctly inside the cloud computing system [153]-[155].	**Success ratio for moving data inside cloud correctly**= 100- Percentage of number of error messages	The value of this measure is determined with the percentage of number of error messages occurred in a month while carrying out data move operations. This percentage is calculated as follows: **Percentage of number of error messages=** (The number of error messages faced with while moving data inside the cloud computing system in a month) / (the number of data move operation carried out inside this system in a month) *100 After that, the success ratio for moving data inside cloud correctly is calculated.

Table 4.2 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Cloud Adoption	Cloud Interoperability [62].	Possibility level of managing workflows and distributed databases inside cloud **(Cli7)**	It provides us to understand whether the cloud computing system provided by cloud service provider offers the capabilities of managing workflows and distributed databases inside cloud computing system [153]-[155].	**Very High:** Cloud computing system carries out all of the five tasks emphasized in the list in the comment part **High:** It carries out four of the tasks **Medium:** It carries out three of them **Low:** It carries out two of them **Very Low:** It carries out only one of them	The following tasks are carried out while managing workflows and distributed databases: 1. The workflow processes of organization are identified. 2. Workflows are automated. 3. Workflows are controlled. 4. Changes on distributed databases inside cloud are monitored. 5. The changes originating from the updates on distributed databases inside cloud are tracked.
	Data integrity	Level of control easiness in the scope of access rights **(Di1)**	It is used to determine whether the cloud service provider has easiness while controlling the access rights of users in order to prevent unauthorized users from accessing the data of companies included in the cloud computing system [102]-[104].	**Very High:** RAU > 0.75 **High:** 0.55 < RAU < 0.75 **Medium:** 0.45 < RAU <0.55 **Low:** 0.25<RAU<0.45 **Very Low:** RAU<0.25	The ratio of authorized users (RAU) is calculated to evaluate this measure. The ratio of authorized users (RAU)= 1- [(The number of unauthorized users accessing the cloud service provider’s system) / (The number of total users accessing the system)]

Table 4.2 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Cloud Adoption	Data integrity	Riskless level of integrity for cloud customer company **(Di2)**	It measures whether the cloud customer company faced with the risks of failure in terms of integrating its data due to the misalignment of data, and involving multiple heterogeneous data sources [102]-[104].	**High:** Cloud customer has neither misalignment of data nor multiple heterogeneous data sources **Medium:** It has either misalignment of data or multiple heterogeneous data sources **Low:** Cloud customer has both misalignment of data and multiple heterogeneous data sources	The situations of misalignment of data and multiple heterogeneous data sources are evaluated for cloud customer company. Misalignment of data occurs in the following situations: 1) Cloud computing solutions cannot obtain the required data of their customers whenever they want and so cannot provide them to their customers 2) It cannot be quaranteed by the cloud service provider that the data inside the cloud system is accurate 3) Cloud customers obtain more or less data than what they requested when they access to the cloud computing system
		Data quality of the integrated applications **(Di3)**	It provides to determine the situation of the data of the integrated applications whether they have sufficient in the features of data quality so as to use the data in making decisions for the purposes of company [102]-[104].	**Very High:** All of the five features of data quality as stated in the list in the comment part are provided **High:** Four of the features in the list are provided **Medium:** Three of them are provided **Low:** Two of them are provided **Very Low:** Only one of them is provided	The features of data quality evaluated in the scope of this measure are stated as follows: 1. Completeness 2. Validity 3. Consistency 4. Timeliness 5. Accuracy

Table 4.2 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Cloud Adoption	Data integrity	Sufficiency level of technical infrastructure of the integrated applications **(Di4)**	It measures whether the integrated applications have sufficient technical infrastructure in terms of supporting their operations and functions [102]-[104].	**High:** The technical infrastructure supports both the operations and functions of integrated applications	
				Medium: It supports either operations or functions of them	
				Low: It supports neither of them	
		Level of data management provided by cloud service provider **(Di5)**	It measures whether the cloud service provider offers enough support to the cloud customer company in terms of management of its data [102]-[104].	**Very High:** Cloud service provider carries out all of the five tasks stated in the comment part for the data of cloud customer	The tasks carried out in the scope of data management are stated as follows: 1. Acquiring 2. Storing 3. Maintaining 4. Protecting 5. Processing
				High: It carries out four of the tasks.	
				Medium: It carries out three of them	
				Low: It carries out two of them	
				Very Low: Only one of them is carried out by cloud service provider	

Table 4.2 (continued)

Major Category	**Characteristic Name**	**Measure Name**	**Description**	**Likert scale assignment rules / Ratio formula**	**Comment/ Explanation**
Cloud Adoption	Data integrity	Data speed level (**Di6**)	It is used to determine how fast data is transmitted from the cloud computing system [102]-[104].	**High:** Data transmission rate > Average requested data transmission rate according to the requirements of companies **Medium:** Data transmission rate = Average requested data transmission rate according to the requirements of companies **Low:** Data transmission rate < Average requested data transmission rate according to the requirements of companies	
		Ease of deployment **(Di7)**	It is used to determine whether the cloud service providers provide effort advantage to the cloud customers in terms of deployment by moving the clients to the cloud computing services without the usage of additional equipments. Besides, it is used to determine whether the cloud service provider is sufficient in eliminating the implementation based issues faced during deployment [102]-[104].	**High:** Cloud service provider carries out the task of both eliminating the implementation based issues faced during deployment and moving the clients to cloud computing system without using additional equipments. **Medium:** Either implementation based issues faced during deployment eliminated or clients migrated to cloud computing system without using additional equipments. **Low:** Neither of the tasks is carried out.	

Table 4.2 (continued)

Major Category	**Characteristic Name**	**Measure Name**	**Description**	**Likert scale assignment rules / Ratio formula**	**Comment/ Explanation**
Cloud Adoption	Technical Flexibility	Level of flexible application architectures **(Tfl1)**	It is used to determine whether the cloud service provider offers an application architecture to its customers which can be changed and adjusted according to the demands of cloud customers in a dynamic way [14], [72], [82], [120]-[121].	**Very High:** The application architecture provided by cloud service provider offers all of the opportunities stated in list in the comment part	The application architecture provided by cloud service provider must offer the following opportunities: 1. Creating new applications 2. Configuring cloud services according to the customer demands 3. Adding new capabilities to cloud services 4. Creating new cloud services 5. Management of network
				High: Four of the opportunities are offered	
				Medium: Three of them are offered	
				Low: Two of them are offered	
				Very Low: Only one of them is offered	

Table 4.3: Technical dimension measures-category2-cloud system continuity

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula
Cloud System Continuity	Availability [14], [38]-[39].	Level of accessibility ratio for cloud system and applications **(Av1)**	Uptime is here defined as the time cloud computing system has been working and available. On the other hand, downtime refers to periods when system is unavailable [122]-[125].	**Accessibility ratio for cloud system and applications=**(Uptime) / (Uptime+downtime)
		Accessibility level of back-up infrastructure from every environment **(Av2)**	It is used to determine whether the cloud back-up infrastructure offered by cloud service provider is accessible from every computing environment to its customers and to its cloud staff [122]-[125].	**High:** Cloud service provider has two separate private monitoring networks to provide both its customers and its cloud staff to access the cloud backup infrastructure from every computing environment.
				Medium: It has only one private monitoring network for access to backup.
				Low: It does not have any private monitoring networks for backup infrastructure.
	Resilience (Fault tolerance) [45], [226].	Level of buffering capacity **(Rs1)**	Buffering capacity is here defined as the amount of information the cloud computing system can store [117]-[121].	**High:** Cloud service provider's buffering capacity > Total amount of information of its cloud customers
				Medium: Cloud service provider's buffering capacity = Total amount of information of its cloud customers
				Low: Cloud service provider's buffering capacity < Total amount of information of its cloud customers
		Level of connection success **(Rs2)**	It is measured with the connection loss period, which is acceptable to cloud customer requirements [117]-[121].	**High:** Connection loss period of cloud computing system < Average connection loss period of all customers of service provider
				Medium: Connection loss period of cloud computing system = Average connection loss period of all customers of service provider
				Low: Connection loss period of cloud computing system >Average connection loss period of all customers of service provider

Table 4.4: Technical dimension measures-category3-risk-based issues

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Risk-based issues	Cloud security [18], [30], [56].	The level of preservation on technical functions in the cloud system in terms of security **(Cs1)**	It is used to determine whether cloud customer company faced with security issues due to the changes on technical functions of their applications [30], [111]-[112].	**Preservation ratio for cloud security=** 1- (Number of applications for which technical functions can not be preserved inside cloud system) / (Total number of applications of cloud customer inside the cloud system)	If this ratio is low, encryption-based techniques may be used to increase it.
		The level of noninfringements that have originated from the cloud system **(Cs2)**	It is used to evaluate the level of nonviolation of law in terms of intellectual property, copyright, trademark and patent infringements faced with migrating to the cloud computing system [30], [111]-[112].	**Noninfringement ratio=** 1- (Number of intellectual property, copyright, trademark and patent infringements originating from migration to cloud system) / (Total number of infringements for the company)	If the value of this ratio is low, infringements can be accepted as a big issue of the company in terms of cloud security.
		The effects of availability of security certifications **(Cs3)**	It is used to determine whether the company has specific cloud security certifications and apply the security rules, regulations and carry out the security tasks to be compatible with these certificates continuously [30], [111]-[112].	**Compatibility ratio for security=** (Number of statements included in security certificates that were applied by the company] / (Total number of statements included in these security certificates)	.

Table 4.4 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Risk-based issues	Cloud security [18], [30], [56].	Acceptability of frequency of client access to the system **(Cs4)**	It is used to determine the level of client access to system resources [30], [111]-[112]. The acceptability of frequency of clients access to the system ratio (AFCASR) is used for this measure and calculated with the following formula: AFCASR=(Threshold value for clients access frequency determined by both cloud service providers and cloud customer) / (Client access frequency)	**High:** AFCASR>1 **Medium:** AFCASR=1 **Low:** AFCASR<1	Client access frequency refers to number of times cloud computing resources are accessed in a definite time period by clients.
		The level of usage ability of data isolation methods for cloud security **(Cs5)**	It is used to determine whether the cloud service provider uses data isolation methods to protect the data of cloud customers from security issues [30], [111]-[112].	**Very High:** All of the methods in the list in the comment part are used by cloud service provider **High:** Four of the methods are used **Medium:** Three of them are used **Low:** Two of them are used **Very Low:** Only one of them is used	The following methods must be used for isolation of cloud computing: 1. Off-site operating system virtualization 2. Sandboxing 3. Virtual machine oriented isolation 4. Hardware oriented isolation 5. Operating system oriented isolation

Table 4.4 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Risk-based issues	Cloud security [18], [30], [56].	Security level of cloud staff, cloud partner company and hosting environment **(Cs6)**	It provides to understand whether the hosting environment of cloud customer on where the applications and data of cloud customers are hosted, and the cloud partner companies with which they conducted cloud computing projects, and its IT staff and cloud experts are secure or not [30], [111]-[112].	**Combined security ratio of cloud staff, cloud partner company and hosting environment=** ([(Number of hosting requirements met by cloud service provider) / (Total number of hosting requirements requested by cloud customer)] + [(Number of security rules obeyed by all of the Cloud Partner Companies) / (Number of Cloud Partner Company * Total Number of Security Rules)] + [(Number of security procedures carried out by all cloud staff) / (Number of Cloud Staff * Total Number of Security Procedures)]) / 3	The combined security ratio includes three component as follows: 1) Ratio of hosting requirements met by cloud service provider 2) Ratio of security rules obeyed by cloud partner companies 3) Ratio of security procedures carried out by Cloud Staff After calculating this three separate components, the combined value of them are obtained by taking the average of their values.
		Ability level of applying security audits **(Cs7)**	It is used to determine whether both cloud customers and cloud service providers apply security audits inside their organizations [30], [111]-[112].	**High:** Both internal audit and external audit are applied in the company **Medium:** Either internal audit or external audit is applied in the company **Low:** Neither internal audit nor external audit is applied in the company	

Table 4.4 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Risk-based issues	Cloud security [18], [30], [56].	Level of data security **(Cs8)**	It refers to the sufficiency of cloud service provider in terms of "protecting the data of its cloud customers from destructive forces and the unwanted actions of unauthorized users" [30], [111]-[112].	**Very High:** All of the five tasks in the list in the comment part are carried out **High:** Four of the tasks are carried out **Medium:** Three of them are carried out **Low:** Two of them are carried out **Very Low:** Only one of them is carried out	The following tasks must be carried out by cloud service provider for providing data security: 1. Access of clients to the cloud computing system must be adjusted with authentication mechanisms. 2. Network should be isolated and security controls must be applied for operations and transactions. 3. Access to the operating system and databases must be restricted with the usage of firewalls and intrusion detection system. 4. Physical security of data must be provided with specific cloud tracking and management systems. 5. Access level permission for the cloud computing system must be adjusted according to the permission level of cloud users.
	Isolation failure [46].	Level of financial gain originated from data retention and protection **(Isf1)**	It measures the financial gain against the financial losses due to the data loss that occurs with isolation failure [84], [126]-[130].	**Ratio of financial gain originated from data retention and protection**= 1- [(Total monetary loss due to cloud customer data loss with isolation failure) / (The price of data hosting service of the cloud customer data determined by both cloud service provider and customer)]	While calculating this ratio, the value of numerator and denominator will be converted into same currency if they are different.

Table 4.4 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Risk-based issues	Isolation failure [46].	Non-impact rate of data loss on commercial results **(Isf2)**	It measures the consequences of data loss for cloud service providers and cloud customers in terms of prestige and competitive power [84], [126]-[130].	**High:** RCRDLCSP>1 & RCRDLCC>1 **Medium:** RCRDLCSP=1 & RCRDLCC=1 **Low:** RCRDLCSP<1 & RCRDLCC<1	To evaluate this measure, the following ratios are calculated for cloud service providers and customers, respectively: **Ratio of commercial results of data loss for cloud service provider (RCRDLCSP)**= (Average number of cloud projects/businesses/ services carried out by cloud service provider after data loss per week/month/year/season) / ((Average number of cloud projects/businesses/ services carried out by cloud service provider before data loss per week/month/year/season) **Ratio of commercial results of data loss for cloud customer (RCRDLCC)=** (Average number of businesses/works carried out by cloud customer after data loss per week/month/year/season) / (Average number of businesses/ works carried out by cloud customer before data loss per week/month/year/season)
		Level of legal results excluding isolation failure **(Isf3)**	It measures the number of legal results originated from isolation failure against the total number of legal actions [84], [126]-[130].	**Ratio of legal results except isolation failure**= 1 - [(Number of legal actions (penal charges) originating from isolation failure for the cloud service provider) / (Total number of legal actions (penal charges) faced by the cloud service provider)]	

Table 4.4 (continued)

Major Category	**Characteristic Name**	**Measure Name**	**Description**	**Likert scale assignment rules / Ratio formula**	**Comment/ Explanation**
Risk-based issues	Reliability [62].	Protection level of corporate identity of cloud customer company **(Re1)**	The cloud service provider provides unique and more effective solutions to its customers about its core businesses to add value to their customers [96]-[98].	**High:** Cloud service provider offers unique solutions to its customers for their core businesses	.
				Medium: It offers non-unique solutions for customers' core businesses.	
				Low: It offers solutions for customers' secondary activities.	
		Preparation ability of cloud service provider for disaster scenarios **(Re2)**	It is used to determine whether the cloud service provider has a mature and detailed disaster recovery plan [96]-[98].	**Very High:** all of the components in the list in the comment part is included in the plan	A detailed disaster recovery plan for cloud computing must include the following components: 1. Details about how to protect system security in case of disaster situations 2. Methods about how to decrease amount of data loss in case of disaster situations 3. Backup strategy 4. Backup template including the steps followed for taking backup 5. Restoring and recovery procedures
				High: Four of the components are included	
				Medium: Three of them are included	
				Low: Two of them are included	
				Very Low: Only one of them is included	
		Effectiveness of backup and recovery facilitated by redundancy **(Re3)**	It is used to determine whether the cloud service provider and /or solution provider accomplishes recovery through redundancy [96]-[98].	**Redundancy rate for reliability=** (Number of duplicated critical functions of cloud computing system) / (Total number of critical functions of cloud computing system)	Redundancy is defined here as "duplication of critical functions of the cloud computing system in order to enhance the reliability of the system".

Table 4.5: Technical dimension measures-category4-system technical feasibility

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
System Technical Feasibility	Cloud performance [47]-[49], [61], [65].	Speed of internet connections **(Cp1)**	It refers to the data transfer rate from cloud computing system to cloud customer company computer for the cloud services offered over internet [78], [79], [90].	**High:** Current maximum data transfer rate of cloud service provider or solution provider for cloud services > the minimum data transfer rate requested by cloud customer	
				Medium: Current maximum data transfer rate of cloud service provider or solution provider for cloud services = the minimum data transfer rate requested by cloud customer	
				Low: Current maximum data transfer rate of cloud service provider or solution provider for cloud services < the minimum data transfer rate requested by cloud customer	
		Speed of external applications **(Cp2)**	The speed of an application refers to how fast the application can perform a task. External application refers to applications that can be used out of the system [78], [79], [90]. Speed is defined here as the number of transactions performed by an application per second.	**High:** Average speed of external applications >average speed of internal applications of company	For instance, companies may use external applications for financial services. The companies can depend on the external applications to start using these cloud computing services. In this case, if the speed of external applications are low, then the company will access to the cloud computing services slowly, which causes the decrease on cloud performance.
				Medium: Average speed of external applications of company = Average speed of internal applications of company	
				Low: Average speed of external applications of company < Average speed of internal applications of company	

Table 4.5 (continued)

Major Category	**Characteristic Name**	**Measure Name**	**Description**	**Likert scale assignment rules / Ratio formula**	**Comment/ Explanation**
System Technical Feasibility	Cloud performance [47]-[49], [61], [65].	Independency level on external applications for cloud customer company **(Cp3)**	It measures the independency level of cloud customer on external applications [78], [79], [90].	**High:** The number of external applications of cloud customer company < the number of internal applications of the company **Medium:** The number of external applications of cloud customer company = the number of internal applications of company **Low:** The number of external applications of cloud customer company > the number of internal applications of company	The low independency may cause reduction in cloud performance indirectly.
		Efficiency of cloud computing arrays, indexes and algorithms used for developing cloud applications and system **(Cp4)**	It is used to determine whether cloud service providers used efficient algorithms for developing cloud computing applications and system [78], [79], [90].	**High:** 0 < The execution time of algorithms (EXTAL) − the estimated execution time of algorithms (ESEXTAL) < 0.00001 second AND 0 < the working memory space necessary for algorithms (WMSAL) − the estimated space necessary for algorithms (ESWMSAL) < 0.01 Gigabyte **Medium:** 0.00001 < EXTAL–ESEXTAL < 0.1 AND 0.01 <WMSAL–ESWMSAL<0.1 **Low:** EXTAL–ESEXTAL > 0.1 AND WMSAL–ESWMSAL > 0.1	

Table 4.5 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula
System Technical Feasibility	Cloud performance [47]-[49], [61], [65].	Data accuracy control and maintenance ability **(Cp5)**	Data accuracy refers to correctness and consistency of data [79], [80], [91]. This measure is used to determine whether cloud system provides checking and maintaining data correctness and data consistency. .	**High:** The cloud system checks and maintains both data correctness and data consistency. **Medium:** The cloud system checks and maintains either data correctness or data consistency. **Low:** The cloud system checks and maintains neither data correctness nor data consistency.
	Cloud response time [59], [225].	Level of system connection quality **(Crt1)**	The connection quality of cloud computing system is determined by a composite of factors of speed, accessibility and reliability of system [50], [59], [141]-[144]. Speed is defined here as the data transfer rate from the cloud system to the system of cloud customers. Accessibility is defined here as the availability percentage of cloud system. Besides, reliability is measured here with Mean Time Between Failures (MTBF), which denotes the amount of average time cloud system operates without any faults.	**High:** The value of all of speed, accessibility and reliability of the cloud system are at least equal to the value of these three parameters requested by cloud customer **Medium:** The value of two of these parameters are at least equal to the value of two of these parameters requested by cloud customer **Low:** Only value one of them is at least equal to the one of these parameters requested by cloud customer
		Shortness of cloud service lead time **(Crt2)**	Cloud service lead time refers to the time determined by cloud service provider and cloud customer to complete a cloud computing service [50], [59], [141]-[144].	**High:** Time spent to complete a cloud computing service < Expected lead time of this service **Medium:** Time spent to complete it = Expected lead time of this service **Low:** Time spent to complete a cloud computing service > Expected lead time of this service

Table 4.5 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula
System Technical Feasibility	Locality of Reference to Data [44], [224].	Level of hit rate of cache **(Dl1)**	The miss rate of cache is the fraction of cache misses among the total number of requests [73], [105]-[107]. Hit rate of cache is calculated by subtracting miss rate of cache from 1 [73], [105]-[107]. If the hit rate of cache is lower, the appropriate methods should be searched for to increase it and applied.	**Hit rate of cache=** 1- miss rate of cache **Miss rate of cache=** [Number of cache misses] / [Number of accesses] **Hit rate of cache=** 1- [(Number of cache misses) / (Number of accesses)]
	Distance [50].	Relative proximity of the system of cloud customer to system of cloud service provider **(Dis1)**	It is used to determine the relative locations of cloud customers to cloud computing system [25], [68], [113].	**High:** Customer to service provider distance < the average of the distance of the other customers of the cloud service provider to the cloud service provider system **Medium:** Customer to service provider distance = the average of the distance of the other customers of the cloud service provider to the cloud service provider system **Low:** Customer to service provider distance > the average of the distance of the other customers of the cloud service provider to the cloud service provider system
	Multiplicity	The effects of multiplicity in cloud environment **(Mul1)**	It is used to determine whether the cloud computing system provided by cloud service provider offers parallelization of tasks feature inside cloud computing environment [2], [99]-[101].	**High:** The total time spent to complete all tasks inside the company after multiplicity < the total time to spent to complete them before multiplicity **Medium:** The total time spent to complete all tasks inside the company after multiplicity = the total time spent to complete them before multiplicity **Low:** The total time spent to complete all tasks inside the company after multiplicity > the total time spent to complete them before multiplicity

Table 4.6: Technical dimension measures-category5-technical agreement

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Technical Agreement	SLA as a technical dimension [60].	Level (amount) of availability and uptime measures definitions in the agreement **(Slt1)**	This measure is used to determine whether definitions associated with availability and uptime are at a sufficient level in SLA [150]-[152].	**Sufficiency ratio of availability and uptime measures in SLA**= (Number of statements associated with availability and uptime measures per SLA) / (NTSPS) NTSPS=Number of total statements per SLA	
		Frequency of realistic targets included in the specifications **(Slt2)**	It measures the number of realistic targets defined in SLA with concrete technical measures [150]-[152].	**Ratio of realistic targets in SLA=** (The number of statements associated with committed cloud services per SLA) / (NTSPS)	
		Differentiation of service levels **(Slt3)**	It is used to determine whether each of the separate service levels were defined in SLA in an acceptable level of detail [150]-[152].	**High:** The service levels are defined in SLA for the three types of customers stated in the list in the comment part **Medium:** They are defined for two types of customers. **Low:** They are defined for only one type of customers.	Service levels must be adjusted for three types of customer organizations: 1. Corporate 2. Small and medium sized 3. Individual and end users

Table 4.6 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula
Technical Agreement	SLA as a technical dimension [60].	Level of precautions established for continuity of performance criteria stated in SLA **(Slt4)**	It refers to the number of definite and concrete statements including penal sanctions associated with cloud performance in SLA [150]-[152].	**Ratio of precautions for performance criteria in SLA=** (Number of statements per SLA including penal sanctions associated with cloud performance) / (NTSPS)
		Level of methods followed for continuity of performance criteria stated in SLA **(Slt5)**	It refers to the number of statements associated with the methods followed for continuity of cloud performance in SLA [150]-[152].	**Ratio of methods for performance criteria in SLA=** (Number of statements associated with the methods followed for continuity of cloud performance per SLA) / (Total number of statements associated with cloud performance per SLA)

Table 4.7: Technical dimension measures-category6-technical cloud solutions

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Technical Cloud Solutions	Cloud Delivery Models	The effects of back-up data (**Cdm1**)	Through this measure, we can determine whether it is necessary for the cloud service provider to offer remote backup service to its customers through its cloud delivery models [91]-[93].	**Very High:** Remote backup service provided by cloud service provider carries out all of the tasks stated in the bulleted list in the comment part	In the scope of remote backup service, the following tasks are carried out: 1. Configuring the back-up data 2. Managing the back-up processes 3. Informing with simultaneous alerts in case of backup failures 4. Recovery and restore operations for data 5. Storing data
				High: Four of the tasks in the list are carried out	
				Medium: Three of the tasks are carried out	
				Low: Two of them are carried out	
				Very Low: Only one of them is carried out	
		Level of data migration ability (**Cdm2**)	It refers to the level of data migration provided by cloud service provider through the usage of its cloud delivery models [91]-[93].	**High:** Time spent for migrating all of the data through the usage of data migration program < Migration time calculated by applying migration tests to a sample set of data	
				Medium: Time spent for migrating all of the data through the usage of data migration program = Migration time calculated by applying migration tests to a sample set of data	
				Low: Time spent for migrating all of the data through the usage of data migration program > Migration time calculated by applying migration tests to a sample set of data	

Table 4.7 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Technical Cloud Solutions	Cloud Delivery Models	Level of Performance gains as a monetary value compared to Total Price of solutions (**Cdm3**)	It is calculated by comparing the total price of solutions offered through cloud delivery models to performance gains of cloud customer company obtained through these solutions [91]-[93].	**High:** Monetary gains through performance increase > the total price of solutions **Medium:** Monetary gains through performance increase = the total price of solutions **Low:** Monetary gains through performance increase < the total price of solutions	Performance gains are measured with the increase on the percentage of number of tasks carried out in a unit of time through using these solutions. Then, this increase is converted into monetary value. The comparison here is used to determine whether the cloud customer gains expected benefits from the cloud solutions offered through cloud delivery models.
		Level of compatibility with consumer rights (**Cdm4**)	This measure is used to determine whether the cloud service providers and/or solution provider obey the consumer rights while offering solutions through their cloud delivery models [91]-[93].	**Very High:** Cloud service provider and/or solution provider provides all of the consumer rights stated in the list in the comment part **High:** Four of the consumer rights are provided **Medium:** Three of them are provided **Low:** Two of them are provided **Very Low:** Only one of them is provided	The major consumer rights that must be provided by cloud service providers and /or solution providers are: 1. Inform customers about the technical limitations and specifications of the services that they will provide. 2. Inform customers about the processes that they will use for security. 3. Inform customers about the updates and changes associated with the services. 4. Provide to the customers the ability of controlling and tracing their data. 5. Explain their responsibilities to the cloud customers about obeying the legal rules associated with the cloud services.

Table 4.7 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Technical Cloud Solutions	Cloud deployment type [35].	Satisfactory level of the cloud deployment type (private/public/hybrid/community) used as a solution in the cloud customer company **(Cdt1)**	It measures the satisfaction level of cloud customers about the solutions associated with cloud deployment type [1], [131]-[133].	**Very High:** The cloud deployment type have all of the five features in the list in the comment part **High:** Four of the features are available **Medium:** Three of them are available **Low:** Two of them are available **Very Low:** Only one of them is available	For customer satisfaction, a cloud deployment type must at least: 1. Be provided with a low level of startup cost. 2. Guarantee the reliability, security, speed and performance conditions requested by customers. 3. Enable scaling down and up the cloud computing resources according to the expectations of cloud customers. 4. Enable disaster recovery and precautions taken in case of contingency situations. 5. Enable adjusting and configuring the cloud computing resources according to the business strategy, core business and expectations of cloud customer.

Table 4.7 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula
Technical Cloud Solutions	Hardware Virtualization [31]-[34].	Virtualization Percentage for Hardware **(Hv1)**	It measures the virtualization percentage in terms of hardware [156]**-**[157].	**Virtualization percentage:** [(Number of Physical Servers/NOVH)]*100 NOVH=Number of Virtual Hosts
		Percentage of Virtual Machines **(Hv2)**	It measures the usage level of virtual machines in the company [156]**-**[157].	**Percentage of Virtual Machines:** [(Number of Virtual Operating Systems / NOVH)]* 100
	Network Virtualization [31]-[34].	Data confidentiality Level **(Nv1)**	It means limiting information access to authorized users as well as preventing access to unauthorized ones [87]**-**[89].	**High:** The cloud computing system provides both limited information access to authorized users and preventing access of unauthorized ones to system
				Medium: It provides either limited information access to authorized users or preventing access of unauthorized ones to system
				Low: It provides neither limited information access to authorized users nor preventing access of unauthorized ones to system

Table 4.7 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Technical Cloud Solutions	Network Virtualization [31]-[34].	Insensitivity of data (**Nv2)**	It refers to the need to protect data from unauthorized modification and/or disclosures [87]-[89].	**High:** Cloud customer not impacted by the disclosure of unauthorized users.	The data of the cloud customer presented in its web site is publicly available to everyone, for that reason, this type of data can be considered as low sensitive. On the other hand, the customer data of cloud customer company can be stated as high sensitive. Organizational chart is an example for the medium level.
				Medium: Relatively small risks are incurred through disclosure of unauthorized users, such as small amount of economic losses.	
				Low: The modification and disclosure of unauthorized users cause the major risks such as high amount of economic losses for cloud customer company.	
		Ease of deployment of cloud applications **(Nv3)**	It is used to determine whether the cloud service providers provide effort advantage to the cloud customers in terms of deployment by moving the clients to their cloud computing applications without the usage of additional equipments [87]-[89].	**High:** The deployment process of cloud service provider both monitors and automates the cloud applications.	
				Medium: The deployment process of cloud service provider either monitors or automates the cloud applications	
				Low: The deployment process of cloud service provider neither monitors nor automates the cloud applications	

Table 4.8: Technical dimension measures-category7-technical resources

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Technical Resources	Computing capacity	Level of the improbabilities of occurrence of bottleneck, contention and congestion situations inside the cloud system **(Cc1)**	Bottleneck refers to a situation by which the performance or capacity of the cloud computing system is limited by a single component or some of the resources. Contention refers to conflicts over resources in a shared network. It is also named as resource contention. Network congestion refers to the situation where demand on a network exceeds capacity, so the network cannot provide all users with maximum speeds [114]-[119].	**High:** The probabilities of occurrence of bottleneck, contention and congestion inside the cloud system are lower than the predetermined upper bound values for these probabilities. **Medium:** Two of these probabilities are lower than the respective predetermined upper bounds. **Low:** One such probability is lower.	
		Sufficiency level of the growth plan of cloud service provider for computing capacity **(Cc2)**	This measure is used to determine whether the cloud service provider has a mature and an advanced growth plan for computing capacity [114]-[119].	**High:** Computing capacity growth plan of cloud service provider includes all of the three components stated in the list in the comment part **Medium:** Two of them are included in the plan **Low:** Only one of them is available in the plan	A growth plan for computing capacity must include the following components: 1. Prediction of long-term capacity requests of each of the cloud customers 2. Prediction of medium-term capacity requests of each of them 3. The growth phases and trends of the capacity requests of each of them

Table 4.8 (continued)

Major Category	Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula
Technical Resources	Computing capacity	Level of installed capacity **(Cc3)**	For our study, installed capacity describes the maximum capacity the cloud computing system is designed to run at. Level of installed capacity can be determined by calculating the amount of CPU, RAM, and disk size [114]-[119].	**High:** CPU, RAM, and disk sizes are at least equal to the value of these three parameters estimated by cloud service provider.
				Medium: Two of these parameters are at least equal to the estimates.
				Low: At most one value is greater or equal to the estimate.
		Level of expandable capacity **(Cc4)**	It means the additional capacity made available by cloud service provider to meet the requests of cloud customers [114]-[119].	**High:** Additional capacity of cloud service provider > Total capacity requests of customers
				Medium: Additional capacity of cloud service provider = Total capacity requests of customers
				Low: Additional capacity of cloud service provider < Total capacity requests of customers
	Scalability [14], [40]-[42], [70].	Level of capacity increase in terms of transactions per request **(Sc1)**	It refers to the scale-up capability of cloud service providers and/or solution providers according to the requests of cloud customers [1], [67], [69], [75], [94]-[95].	**High:** Number of transactions > Number of customer requests
				Medium: Number of transactions = Number of customer requests
				Low: Number of transactions < Number of customer requests

Table 4.9: Economic dimension measures

Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Cloud application migration cost [2], [54].	Ratio of the non-electricity expenses **(CLAMIGCOS1)**	It measures the ratio of non-electricity expenses in total investment for cloud application migration compared to electricity expenses in total investment [77], [80], [81], [187].	**The ratio of non-electricity expenses for cloud application migration=** 1- [(Total electricity expenses for cloud application migration) / (TINVCAP)] TINVCAP=Total Investment Capital	
	Ratio of innovation turnover by migrating one application or some of the applications of company to cloud **(CLAMIGCOS2)**	Innovation turnover is here defined as the sum of turnover attributed to new or significantly improved services associated with their core businesses [77], [80], [81], [187].	**Innovation turnover ratio**= (Turnover obtained through migrating some applications of company to cloud) / (Total turnover of the company)	When a company migrates some of its applications to cloud, one of its services, such as logistics services, can be improved at a substantial level. The turnover originated from the improvement on logistics services is accepted as innovation turnover [221].
	Ratio of Return on Investment (ROI) through migrating one application and/ or some of the applications of company to the cloud **(CLAMIGCOS3)**	ROI calculation here depends on the situation of migrating some of the applications to the cloud [77], [80], [81], [187].	**ROI through migrating some applications to cloud=** Max (1, (Increase in profit + Reduction in cost - cost of migrated applications) /(cost of migrated applications))	

Table 4.9 (continued)

Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula
Cost-benefit analysis [59].	Percentage of non-deployment based costs **(CBA1)**	Deployment cost is here defined as the sum of hardware, licensing, network and software costs [66], [192]-[194].	**Percentage of non-deployment based costs**= 100 - [(Total deployment cost) / (TCCP+TCCS)]*100 TCCP=Total cost of cloud products TCCS= Total cost of cloud services
	Percentage of non-virtualization based costs **(CBA2)**	Virtualization cost includes the components of hardware costs associated with server virtualization, software costs associated with server virtualization, and maintenance, implementation and management costs, and network virtualization cost [66], [192]-[194].	**Percentage of non-virtualization based costs**= 100 - [(Total virtualization cost) / (TCCP +TCCS)]*100
	Percentage of non-service based costs **(CBA3)**	Service cost refers to the total cost of cloud services [66], [192]-[194].	**Percentage of non-service based costs**= 100 - [(TCCS) /(TCCP +TCCS)]*100
	Percentage of non-total cost of ownership of the complete cloud computing system **(CBA4)**	Total cost of ownership is calculated here for the complete cloud computing system [66], [192]-[194].	**Percentage of non-total cost of ownership of the complete cloud computing system=** 100 - [(Total cost of ownership of the complete cloud computing system) /(TINVCAP)]*100

Table 4.9 (continued)

Characteristic Name	**Measure Name**	**Description**	**Likert scale assignment rules / Ratio formula**
Cost-benefit analysis [59].	Percentage of non-initial investment for cloud system **(CBA5)**	Total initial investment here refers to the startup capital that is reserved for cloud computing system by the company [66], [192]-[194], [222].	**Percentage of non-initial investment for cloud system=** 100 **-** [(Startup capital for cloud computing system) /(TINVCAP)]*100
	Percentage of net present value of cloud system **(CBA6)**	Net present value of cloud computing system is calculated with the following formula[66], [192]-[194], [222]: $NPV=\frac{CSFL_1}{(1+DISCR)}+\frac{CSFL_2}{(1+DISCR)^2}+...+\frac{CSFL_t}{(1+DISCR)^t}$ -Initial Investment CSFL=Cash Flow DISCR= Discount rate t= Time	**Percentage of NPV (Net Present Value)=** [(NPV) / (TINVCAP)]*100
	Percentage of average annual ROI for company through the complete cloud computing system **(CBA7)**	Average Annual ROI= [(Gain from the complete cloud computing system **-** cost of complete cloud computing system)] / (cost of complete cloud computing system) [66], [192]-[194].	**Percentage of average annual ROI=** ([(Gain from the complete cloud computing system **-** cost of complete cloud computing system) / (cost of complete cloud computing system)] /[(ANOPCAP)]) *100
	Percentage of hardware savings through cloud per year **(CBA8)**	The hardware savings may be originated from the decrease on the number of servers through migrating into the cloud computing system [66], [192]-[194].	**Hardware savings (%)=**100**-** ([(COHARDW)**-** (Reduction in server depreciation cost+ Reduction in energy cost)]/[(COHARDW]) *100 COHARDW= cost of hardware

Table 4.9 (continued)

Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula
Cost-benefit analysis [59].	Percentage of software savings through cloud per year **(CBA9)**	The software savings are originated from the decrease in terms of operating system licenses thanks to migrating into the cloud computing system [66], [192]-[194].	**Software savings (%)=** 100- ([(COSOFT)-(Reduction in virtualization software cost + Reduction in cloud management software cost)]/[(COSOFT)]) * 100] COSOFT=cost of software
	Percentage of system administration cost savings through cloud per year **(CBA10)**	The saving may be originated from the increased productivity of the cloud computing administration staff thanks to migrating into the cloud computing system [66], [192]-[194].	**System administration savings (%)=** 100- ([(cost of system administration)-(Reduction in support and administration cost)]/[(COSOFT)]) *100
	Percentage of testing and productivity savings through cloud per year **(CBA11)**	The saving may be originated from the decreased response time for the services through the cloud computing system [66], [192]-[194].	**Testing and productivity savings (%)=** 100- [(cost of testing and productivity)-(total reduction in cost of testing and productivity)]/[(COSOFT)] *100)]
	Percentage of provisioning cost savings through cloud per year **(CBA12)**	The saving may be originated from the decreased time for each of the provisioning tasks thanks to cloud computing system [66], [192]-[194].	**Provisioning savings (%)=** 100- [(cost of provisioning)-(total reduction in cost of provisioning)]/[(COSOFT)] *100)]

Table 4.9 (continued)

Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Economic flexibility	The qualitative value of cloud application and system **(EFL1)**	It refers to the strategic importance level of cloud application and/or system for the core business of company [188]-[191].	**High:** The company uses the cloud application and system for its core business & the usage leads to increase of total sales and revenues.	Two main criteria are used to evaluate this measure: • Impact of system on core business of company • Impact of system on total sales and revenues of company
			Medium: The company uses the cloud application and system for its core business but it does not lead to increase of total sales and revenues.	
			Low: The company uses the cloud application and system for the secondary businesses and tasks of the company	
	Variety of pricing and billing mechanisms **(EFL2)**	It is used to determine whether various pricing and billing mechanisms are provided for the different service levels by the cloud service providers [188]-[191].	**High:** The cloud service provider offers all of the three options in the list in the explanations part	The major pricing and billing mechanisms must be categorized into three groups as follows: 1. Subscription-based 2. According to consumption levels 3. According to the average cloud sector price of the associated service
			Medium: It offers two of the options in the list	
			Low: It offers only one of the options in the list	
Future major cloud infrastructure cost [63].	The ratio of future major cloud infrastructure cost **(FMCICOS1)**	Future major cloud infrastructure cost is the sum of hardware, electricity, data center, security, support, staff, storage, network, localization, bandwidth, opportunity, hosting, infrastructure deployment, construction costs [50], [59], [74], [207]-[210].	**The ratio of future major cloud infrastructure cost=** (Investment in major cloud infrastructure of company per year) / (ANOPCAP) ANOPCAP=Annual Operating Capital	

Table 4.9 (continued)

Characteristic Name	**Measure Name**	**Description**	**Likert scale assignment rules / Ratio formula**	**Comment/ Explanation**
Operational efficiency [43].	Cost suitability of cloud applications **(OEF1)**	It measures whether the price of applications in the company are lower compared to the market price of them.	**High:** Application prices in the company < Market prices	The cost level of cloud applications are shaped by the interactions between the cloud customer demand and cloud service provider supply for cloud applications.
			Medium: Application prices in the company =Market prices	
			Low: Application prices in the company > Market prices	
	Quality level of applications **(OEF2)**	This measure is used to determine the sufficiency of functionality, features and capabilities of cloud applications [12], [202]-[203].	**High:** Both the features and capabilities of cloud applications are matching with the requirements of cloud customers one by one AND these applications also include the additional features and capabilities besides the requirements of its customers	Three criteria stated as functionality, capability and features are used to evaluate the effectiveness of this measure.
			Medium: The number of features and capabilities of cloud applications are approximately equal to the number of features and capabilities requested by customers AND they all are matching with the requirements one by one	
			Low: The number of features and capabilities of cloud applications are lower compared to the requirements of its customers	

Table 4.9 (continued)

Characteristic Name	**Measure Name**	**Description**	**Likert scale assignment rules / Ratio formula**
Outage duration cost [14], [52]-[53], [83].	Percentage of length of non-outage duration hours **(ODC1)**	Outage duration time refers to the time period between when cloud computing services and applications are unavailable and when they are usable and in operating state again [204]-[206].	**Percentage of length of non-outage duration hours=** 1 **-** [(Outage duration hours per month] / (Total number of working hours of cloud computing system for a month)]
	Percentage of amount of money lost per hour excluding outage situation **(ODC2)**	Outages of cloud services cause money and revenue losses for companies [204]**-**[206].	**Percentage of amount of money loss per hour excluding outage situation=** 1 **-** [(Amount of money lost per hour in case of outage duration) / (Total amount of loss of company per hour)]
Revenue	Level of amount of cloud product and/or services sold **(REV1)**	It refers to the sale amount of each of the cloud products and services [25], [195]-[198].	**High:** Actual average sales amount of cloud products and services per year > Estimated average sales amount per year
			Medium: The actual average sale =the estimated sale
			Low: The actual average sale<the estimated sale
	Level of unit price of each of the cloud product and/or services sold **(REV2)**	Unit price here refers to the price for a single unit of measure of a cloud product and/or service sold [25], [195]-[198].	**High:** Unit price of cloud product and services of the company > Unit prices in the sector
			Medium: Unit price of cloud product and services of the company = Unit prices in the sector
			Low: Unit price of cloud product and services of the company < Unit prices in the sector

Table 4.9 (continued)

Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula
SLA as an economic dimension [60].	Percentage of amount of penalties in SLA **(SLAEC1)**	It is used to determine whether penalties because of not obeying the commitments associated with cloud services are defined at a sufficient level in SLA [211]-[212].	**Percentage of amount of penalties in SLA=** [(Total number of statements in SLA associated with penalties) / (TNSIS)]*100 TNSIS= Total number of statements in SLA
	Percentage of amount of investment for SLA **(SLAEC2)**	It is used to determine the amount of investment reserved for SLA monitoring and reporting tools [211]-[212].	**Percentage of amount of investment for SLA=** [(The amount of investment reserved for SLA monitoring and reporting tools) / (TINVCAP)] *100
	The effects of operating costs **(SLAEC3)**	It is used to determine whether the operating cost of system, targets and definitions associated with this cost are included in SLA [211]-[212].	**High:** The operating cost of the cloud system, targets of the system and definitions for the operating cost components are included in SLA
			Medium: Operating cost and targets of the system are included in SLA
			Low: Only the value of operating cost is stated in SLA
	Sufficiency level of definitions about variety of service charges **(SLAEC4)**	It is used to determine whether service charges are defined for each of the services separately in a detailed way in SLA [211]-[212].	**Sufficiency ratio of definitions of service charges in SLA=** **(**Total number of statements in SLA associated with service charges) / (TNSIS)
Total cost of application ownership [2], [51].	Ratio of non-total cost of ownership of applications **(TCAO1)**	Total cost of application ownership is here defined as the sum of storage, network, infrastructure, backup, disaster, maintenance, support, infrastructure management software, archive, platform and server costs [85], [199]-[201].	**Ratio of the non-total cost of ownership of applications=** 1- (The total cost of ownership of applications) /(TINVCAP)

Table 4.10: External dimension measures

Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Legal environment of cloud computing	The level of maturity of cloud-specific legislation **(LEGENV1)**	It measures the maturity level of cloud customer and cloud service provider companies in terms of obeying the regulations and laws associated with cloud-specific legislation [213]-[217].	**High:** The company obeys the rules of private copying, legislation for data location and data protection **Medium:** The company obeys two of the rules stated in the high criteria. **Low:** The company obeys only one of the rules stated in the high criteria.	Compatibility of company with cloud computing legislation is evaluated through this measure.
Social factor	Level of computer literacy rate inside the cloud-related company **(SOCF1)**	It refers to the computer literacy rate inside the cloud customer and cloud service provider companies [218]-[219].	**Computer literacy rate= (**Number of computer literate staff in the company) / (Total number of company staff)	In terms of cloud service provider companies, very high computer literacy rate states that the company can build effective cloud solutions with a high level of IT experience. On the other hand, for cloud customers, the same rate means that they can use the cloud solutions and adapt them to their businesses easily.

Table 4.11: Organizational dimension measures

Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Administration [56]-[57], [61].	Level of automated resource management through cloud **(ADM1)**	It is used to determine the level of automated resource management through cloud computing system. If the cloud computing system offers this mechanism, resource demands of cloud customers will be realized more quickly [158]-[160].	**High:** All of three features stated in the list in the comment part are offered through cloud computing system	An automated resource management structure in the scope of cloud computing must mainly offer the following features: 1. Dynamic and automated allocation of cloud computing resources 2. Automated load balancing 3. Providing the usage of idle cloud computing resources automatically when there were no other resources available
			Medium: Two of them are offered	
			Low: Only one of them is offered	
	Ability level of adjusting the schedule of administrative tasks through cloud **(ADM2)**	This measure is used to evaluate whether the timelines and deadlines for administrative tasks specific to cloud customer company can be adjusted and programmed through cloud computing [158]-[160].	**High:** All of three components in the list in the comment part are provided by the system	Cloud computing system must include the following components for the schedule of administrative tasks: 1. Timelines and deadlines for each of the administrative tasks 2. Job/duty definition of each of the administrative staff and definition of administrative tasks 3. Order of tasks by charts
			Medium: Two of them are provided	
			Low: Only one of them is provided	

Table 4.11 (continued)

Characteristic Name	**Measure Name**	**Description**	**Likert scale assignment rules / Ratio formula**	**Comment/ Explanation**
Administration [56]-[57], [61].	The functionality of cloud administration tools **(ADM3)**	It refers to the features, functionality and capability of cloud administration tools provided by cloud service providers [158]-[160].	**High:** Both the features and capabilities of cloud administration tools are matching with the requirements of cloud customers one by one AND these tools also include the additional features and capabilities except the requirements of its customers	
			Medium: The number of features and capabilities of cloud administration tools are approximately equal to the number of features and capabilities requested by customers AND they all are matching with the requirements one by one	
			Low: The number of features and capabilities of cloud administration tools are lower compared to the requirements of its customers	
	Variety of regular reports about each of the cloud services **(ADM4)**	It is used to observe whether cloud computing system offers detailed, regular and separate reports for each of the cloud services [158]-[160].	**Very High:** All of the type of the reports stated in the list in the comment part are offered by the cloud computing system of the cloud service provider	Cloud computing system must offer the following type of the reports for each of the cloud services: 1. Daily 2. Weekly 3. Monthly 4. Seasonal/periodical 5. Annual
			High: Four of them are provided by the system	
			Medium: Three of them are provided	
			Low: Two of them are provided	
			Very Low: Only one of them is provided	

Table 4.11 (continued)

Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula
Administration [56]-[57], [61].	Level of detail on service interruptions **(ADM5)**	It refers to the information level offered by cloud computing system to the cloud customers about frequency of service interruptions in a definite time interval and service interruption durations [158]-[160].	**High:** Cloud computing system provides both the information of the frequency of service interruptions and service interruption durations
			Medium: The system provides either the information of the frequency of service interruptions or service interruption durations
			Low: Neither the frequency of service interruptions nor service interruption durations is offered by the system
	Level of detail on solution durations **(ADM6)**	It refers to the information level offered by cloud computing system to the cloud customers about each of the cloud service based issue types and average time spent for solving each of them [158]-[160].	**High:** Cloud computing system provides both the information of the cloud service based issue types and average time spent for solving each of them
			Medium: The system provides either the information of the cloud service based issue types or average time spent for solving each of them
			Low: Neither the information of the cloud service based issue types nor average time spent for solving each of them is offered by the system

Table 4.11 (continued)

Characteristic Name	**Measure Name**	**Description**	**Likert scale assignment rules / Ratio formula**
Administration [56]-[57], [61].	Level of detail on interventions to services **(ADM7)**	It refers to the information level offered by cloud computing system about the number of interventions to services by cloud administrators in a definite time interval [158]-[160].	**High:** Cloud computing system provides both the information of the number of interventions to services and intervention period for each of the services
			Medium: The system provides either the information of the number of interventions to services or intervention period for each of the services
			Low: Neither the information of the number of interventions to services nor intervention period for each of the services is offered by the system
	Level of detail on data accessibility statistics of cloud customers **(ADM8)**	It refers to the information level offered by cloud computing system about the number of accesses to the cloud computing system in a definite time interval for each of the customers, and the number of transactions associated with the cloud computing resources such as upload and /or download operations carried out by them [158]-[160].	**High:** Cloud computing system provides both the information of the number of accesses to the cloud computing system for each of the customers and the number of transactions associated with cloud computing resources carried out by them
			Medium: The system provides either the information of the number of accesses to the cloud computing system for each of the customers or the number of transactions associated with cloud computing resources carried out by them
			Low: Neither the information of the number of accesses to the cloud computing system for each of the customers nor the number of transactions associated with cloud computing resources carried out by them is offered by the system

Table 4.11 (continued)

Characteristic Name	**Measure Name**	**Description**	**Likert scale assignment rules / Ratio formula**
Administration [56]-[57], [61].	Level of detail on data migration (data move) **(ADM9)**	It refers to the information level offered by cloud computing system about the frequency of data migration (data move) between different cloud computing environments [158]-[160].	**High:** Cloud computing system provides both the location information of data after each move (migration) and the frequency of data migration (data move) between different cloud computing environment
			Medium: The system provides either the location information of data after each move (migration) or the frequency of data migration (data move) between different cloud computing environments
			Low: Neither the location information of data after each move (migration) nor the frequency of data migration (data move) between different cloud computing environments is offered by the system

Table 4.11 (continued)

Characteristic Name	**Measure Name**	**Description**	**Likert scale assignment rules / Ratio formula**	**Comment/ Explanation**
Cloud strategy [64].	The level of effects of cloud strategies **(CLSTR1)**	In the scope of this measure, the impact of the cloud strategy on the core businesses of company shall be investigated [71], [76], [136], [168]-[171].	**High:** The company has a definite cloud strategy & the cloud products and solutions are developed based on the specifications in the strategy.	
			Medium: It has a definite cloud strategy and the core businesses of it were not conducted based on this strategy.	
			Low: The content of cloud computing were included as a subpart under IT strategy of company.	
Cloud supplier selection [64].	Level of the number of reference customers of cloud supplier **(CLSUPSEL1)**	This measure is used to select the optimal cloud supplier for the related cloud customer company [47], [172]-[173].	**Reference customer ratio of cloud supplier=** (Number of reference customers of cloud supplier) / (Total number of customers of cloud supplier)	
Innovation [58].	The level of effects of availability of sub-strategies of the innovative product **(INV1)**	It measures whether the sub-strategies of the innovative cloud product are compatible with the corporate IT strategy of the company [161]-[167].	**High:** Cloud service providers are using specific strategies for each of the innovative cloud products & these strategies are compatible with the corporate IT strategy of company in terms of aims, scope and purposes.	
			Medium: Innovative cloud products are designed and developed by using the corporate IT strategy of company instead of defining specific sub-strategies for them.	
			Low: Definite strategies are not used while designing and developing the innovative cloud products by company.	

Table 4.11 (continued)

Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula
Innovation [58].	The frequency of reference customers of cloud service providers that will develop the innovative cloud product **(INV2)**	It refers to the number of reference customers of the related cloud service providers [161]-[167].	**Reference customer ratio of cloud service provider**= (Number of reference customers of cloud service provider that will develop innovative cloud products) / (Total number of customers of cloud service provider)
	Accessibility level of innovative cloud product in different architectures **(INV3)**	It measures whether the innovative cloud product can be accessible in different architectures [161]-[167].	**High:** Cloud service provider has two separate private networks to provide both its customers and its cloud staff to access innovative cloud products in different architectures.
			Medium: It has only one private network to provide its cloud staff to access innovative cloud products.
			Low: It does not have a private network.

Table 4.11 (continued)

Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Innovation [58].	Level of readiness for disaster recovery in terms of innovative product **(INV4)**	It measures whether the cloud service provider has a disaster recovery plan specific to innovative cloud products [161]-[167].	**Very High:** All of the components in the list are included in the plan **High:** Four of the components in the list are included **Medium:** Three of them are included **Low:** Two of them are included **Very Low:** Only one of them is included	A detailed disaster recovery plan specific to innovative cloud products must include the following components: 1. Details about how to protect the security of innovative cloud products in case of disaster situations 2. Methods about how to decrease amount of data loss associated with innovative cloud products in case of disaster situations 3. Backup strategy adopted for innovative cloud products 4. Backup template including the steps followed for taking backup 5. Restoring and recovery procedures for each of the innovative cloud products
	Normal (usual) state frequency of innovative cloud product **(INV5)**	It measures the ratio of normal (usual) situations associated with innovative cloud product in a definite time interval. It is calculated by subtracting contingency ratio of innovative cloud product from 1 [161]-[167].	**Contingency ratio of innovative cloud product (CRICP)**= [(Number of contingency situations occurring in the company in a definite time interval originating from innovative cloud products) / (Total number of contingency situations occurring in the company in a specific time interval)] **Normal (usual) state ratio of innovative cloud product=** 1-CRICP	Contingency is here defined as an unexpected failure of the innovative cloud product. This measure also provides to understand whether a contingency plan should be adjusted or, if available, revised for this product.
	Cloud-based automatization level of business processes **(INV6)**	It measures whether process innovation is realized for the business processes of cloud customer through cloud system [161]-[167].	**Cloud business process automatization ratio=** (Number of automated business processes developed through cloud computing) / (Total number of business processes of cloud customer)	

Table 4.11 (continued)

Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Level of business ethics	The satisfaction level about the behavior of cloud vendor and provider firm in product and service quality **(LOBETH1)**	Product and service quality are evaluated in terms of ethical perspective through this measure [181]-[183].	**High:** The cloud service provider carries out all of the three tasks stated in the list in the explanations part	In the scope of product and service quality, the following tasks must be carried out by cloud service providers: 1. Guarantee functionality with minimum amount of faults and errors within the subscription period of cloud users 2. Uninterrupted maintenance and recovery 3. Preservation of acceptable risk levels for both customer and cloud service provider
			Medium: It carries out two of the tasks in the list	
			Low: It carries out only one of tasks in the list	
	The satisfaction level about the behavior of cloud vendor and provider firm in treatment of customers **(LOBETH2)**	Treatment of customers are evaluated in terms of ethical context [181]-[183].	**High:** The cloud service provider gives right information to its customers about the price of its services & it develops the cloud products by quaranteeing the security and reliability conditions of them	
			Medium: The cloud service provider either gives right information to its customers about the price of its services OR develops the cloud products by quaranteeing the security and reliability conditions of them	
			Low: The cloud service provider neither gives right information to its customers about the price of its services nor develops the cloud products by quaranteeing the security and reliability conditions of them	

Table 4.11 (continued)

Characteristic Name	**Measure Name**	**Description**	**Likert scale assignment rules / Ratio formula**	**Comment/ Explanation**
Level of business ethics	The satisfaction level about the behavior of cloud vendor and provider firm in fair market practices **(LOBETH3)**	Availability of fair market practices in the service provider company is evaluated in terms of ethical perspective through this measure [181]**-**[183].	**High:** The cloud service provider carries out all of the three tasks stated in the list in the explanations part	In the scope of fair market practices; the cloud service provider must carry out the following tasks: 1. Obey the delivery rules of cloud products and services as agreed on with customers 2. Develop the cloud products and services by being compatible with ethical, quality standarts and agreements with customers 3. Provide the cloud services and products at fair prices even in case of being monopoly in terms of the associated cloud services and products
			Medium: It carries out two of the tasks in the list	
			Low: It carries out only one of tasks in the list	
	The satisfaction level about the behavior of cloud vendor and provider firm in terms of community responsibility **(LOBETH4)**	Community responsibility of cloud service providers is evaluated in terms ethical context through this measure [181]-[183].	**High:** The cloud service provider carries out all of the three tasks stated in the list in the explanations part	In the scope of community responsibility; the service provider must carry out the following tasks for cloud computing: 1. Provide training 2. Publish guidance documents 3. Arrange public conferences
			Medium: It carries out two of the tasks in the list	
			Low: It carries out only one of tasks in the list	

Table 4.11 (continued)

Characteristic Name	**Measure Name**	**Description**	**Likert scale assignment rules / Ratio formula**
Manageability [36]-[37], [227]-[228].	The level of detail of checklist of manageability functions adjusted for cloud environment **(MNG1)**	It measures whether manageability functions checklist for cloud include the information about the tasks that have to be carried out by cloud administrators, cloud experts and associated IT staff and the definitions of the responsibilites of each of these staff [174]-[180].	**High:** The checklist of manageability for cloud environment include both explanations about tasks and definitions of the responsibilities of each of the cloud staff for these tasks
			Medium: The checklist includes only the explanations about the tasks
			Low: Neither tasks nor responsibilities are included in the checklist
	Success level of activity management inside cloud computing system **(MNG2)**	It measures the total number of steps to manage each of the activities in the cloud environment compared to the total number of steps without using cloud [174]-[180].	**High:** Total number of steps of operation in cloud environment < the total number of steps without the usage of cloud computing system
			Medium: Total number of steps of operation in cloud environment = the total number of steps without the usage of cloud computing system
			Low: Total number of steps of operation in cloud environment > the total number of steps without the usage of cloud computing system
	Success level of task management inside cloud computing system **(MNG3)**	It measures the total time spent for managing all of the tasks in the cloud environment compared to the total time spent for managing them without using cloud [174]-[180].	**High:** Total time spent for managing all tasks in cloud environment < total time spent for managing them without the usage of cloud computing system
			Medium: Total time spent for managing all tasks in cloud environment = total time spent for managing them without the usage of cloud computing system
			Low: Total time spent for managing all tasks in cloud environment > total time spent for managing them without the usage of cloud computing system

Table 4.11 (continued)

Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Manageability [36]-[37], [227]-[228].	Documentability level **(MNG4)**	It refers to the ability of using code analyzers which provides to obtain template texts through the implementation of them. These texts can be used for cloud manageability documentation [174]-[180].	**High:** Actual number of lines of cloud manageability documentation > Estimated number of lines **Medium:** Actual number of lines of cloud manageability documentation= Estimated number of lines **Low:** Actual number of lines of cloud manageability documentation < Estimated number of lines	Documentability level is evaluated with the lines of management code. Number of lines of management code denotes the complexity of cloud management tasks [220].
	Elasticity of management **(MNG5)**	It refers to the modifying or development of cloud management automation features to manage cloud computing at scale by taking the requirements of cloud customers into consideration [174]-[180].	**High:** The cloud computing system of company allows both modifying and development of cloud management automation functions when necessary **Medium:** The system allows only to modify these functions when necessary **Low:** The system allows neither to modify nor to develop these functions	
	Availability and continuity of management **(MNG6)**	It measures whether the cloud management is continuously available inside cloud computing system. It also measures whether the procedures, regulations and definitions defined inside cloud management are working and being applied properly [174]-[180].	**High:** The accessibility ratio of cloud management functions inside cloud computing system≥ %99.9 & all of the procedures defined inside cloud management are working and applied in the company **Medium:** Either Accessibility ratio to the management functions ≥ %99.9 OR all of the procedures defined inside cloud management are working and applied in the company **Low:** Accessibility ratio to the management functions < %99.9 & at least one of the procedure defined inside cloud management is not working and applied in the company	

Table 4.11 (continued)

Characteristic Name	**Measure Name**	**Description**	**Likert scale assignment rules / Ratio formula**
Manageability [36]-[37], [227]-[228].	Ease of use in cloud computing systems and services **(MNG7)**	It measures whether cloud users have ease of use in cloud computing systems and services by applying the cloud management functions inside cloud computing system [174]-[180].	**High:** Actual average time of cloud users to learn cloud management functions < Estimated time
			Medium: The actual time =the estimated time
			Low: The actual time >the estimated time
	Level of ability to have visibility and control over cloud services and cloud usage **(MNG8)**	It measures whether cloud administrators can manage cloud computing systems and services easily by adapting the cloud management structure into cloud computing system and services [174]-[180].	**High:** The visualization tools and analytics are used for managing cloud services by cloud administrators & graphical user interfaces specifically designed for each of the cloud customers are available
			Medium: Either Visualization tools and analytics OR specific graphical user interfaces are used by cloud administrators
			Low: Neither visualization tools and analytics nor specific graphical user interfaces are used by cloud administrators

Table 4.11 (continued)

Characteristic Name	Measure Name	Description	Likert scale assignment rules / Ratio formula	Comment/ Explanation
Vendor lock-in degree [2], [14].	Level of the number of cloud vendor and/or cloud service providers that the cloud customer takes the services and/or products from **(VLID1)**	This measure is used to analyze the vendor-lock-in degree in terms of number of cloud service providers perspective [184]-[186].	**High:** The cloud customer obtains each of the cloud services from at least 2 separate companies **Medium:** Each cloud service obtained from a different company **Low:** It obtains all cloud services from only one company	Medium value defined only if number of services obtained $\neq$ 1.
	Independency ratio of usage period of the cloud product and/or service **(VLID2)**	This measure is used to analyze the vendor-lock-in degree in terms of usage period perspective [184]-[186].	**Usage period independency ratio of a cloud service for a customer=** 1**- [**(Usage period of a cloud service from a vendor) / (Total usage period of this service from all vendors)]	

In Table 4.12, measures, associated company categories and four model dimensions are presented. In this table explicit reference to the characteristics with which each measure is associated with are omitted for the sake of brevity, however, as the abbreviated denotations of measures include characteristic name denotations, alphabetical ordering of measures preserves proximity of measures associated with the same characteristic.

Table 4.12: Measures according to Company Categories and Model Dimensions

	Dimensions of Measures			
Company Category	**Technical**	**External**	**Organizational**	**Economic**
CSP	• Ag1, Ag3-4 • Aint1 • Av1-2 • Cc1-4 • Cdm1-4 • Cla4 • Clam1-5 • Cli1-7 • Cp1, Cp4-5 • Crt1-2 • Cs3, Cs5-8 • Di1, Di5-7 • Dl1 • Hv1-2 • Isf2-3 • Mul1 • Nv1-3 • Re1-3 • Rs1-2 • Sc1 • Slt1-5 • Tfl1	All.	• ADM1-9 • CLSTR1 • INV1-6	• EFL2 • FMCICOS1 • ODC1 • OEF1-2 • REV1-2 • SLAEC1-4
CPR	All.	All.	All.	All.
SPCSP	• Cdm3-4 • Cli3-4 • Cp1, Cp5 • Crt1-2 • Nv1-2 • Re3 • Sc1	All.	• ADM1-8 • LOBETH3	• EFL2 • REV1-2
CU	• Ag2, Ag5 • Cdt1 • Cla1-3 • Clam6-7 • Cp2-3 • Cs1-2, Cs4, Cs6-7 • Di2-4 • Dis1 • Isf1-2 • Slt1-3	All.	• CLSUPSEL1 • LOBETH1-4 • MNG1-8 • VLID1-2	• CBA1-12 • CLAMIGCOS1-3 • EFL1 • ODC2 • SLAEC1-4 • TCAO1

We present assessment results in the form of footprint diagrams [29], considered appropriate especially for comparative and improvement studies. A normalization process is applied for the values of measures. In our study, the values of measures are categorized into three groups: 5-point Likert scale values, 3-point Likert scale values and Percentages.

Since, according to the results of exploratory case studies, 5-point Likert scale definitions have been determined to be appropriate for some of the measures and 3-point definitions for some others, a common Likert scale was not constructed, but 3-point values have been mapped into the 5-point scale for normalization.

To evaluate all of the measures on a common basis, the following normalization process has to be followed:

STEP1: Conversion of 3-point Likert scale values into 5-point values:
3-point Likert scores are mapped to 5-point scores via the mapping:
$Y = x^3 - 6x^2 + 13x - 7 \qquad 1 \leq x \leq 3 \quad 1 \leq Y \leq 5$
where x and Y denote the 3- and 5-point Likert values, respectively. This ensures that when only a single respondent has evaluated a certain characteristic according to the 3-point scale, the possible values of 1, 2 and 3 are mapped directly to 1, 3 and 5, respectively. In case of multiple responses, a 3-point average is then mapped to the 5-point range accordingly.

STEP2: Normalizing measures as percentages:
Each measure is normalized with respect to its maximum possible value.

Normalized values of measures obtained in the case studies are presented in footprint diagrams (Figures 2 through 16) in the next chapter.

CHAPTER 5

CASE STUDIES FOR VALIDATION OF THE FINALIZED CCEAM

As described before, we carried out confirmatory case studies in four different categories of companies with the aim of validating the finalized CCEAM. Footprint diagrams are drawn for each of the four dimensions according to the normalized values of measures obtained by applying the normalization process stated in the previous chapter.

Similar to the exploratory case studies, the confirmatory case studies in this chapter are also presented in conformance with the structure proposed in the literature [28, 231-238] for documenting qualitative research.

5.1. Relation of Case Study Results to CCEAM

Measures used by each of the four categories of companies are different, except those in the external dimension. Hence, the measures that will be used in effectiveness assessment will be selected according to the company category as shown in Table 3.12.

5.2. Participants of Confirmatory Case Study

Five companies from four different categories participated in the confirmatory case studies. Four of these companies are different from the companies that participated in the exploratory case studies. Only Company B participated in exploratory as well as confirmatory case studies.

The participants of the confirmatory case studies are briefly described in Table 5.1. Since information about Company B is available in Table 3.1, it is not repeated in Table 5.1.

Table 5.1: Participants of Confirmatory Case Study

Company name	Category	Number of employees	The sectors the company operates in	Contacted company staff	Marketplace of the company	Turnover for year 2012 (Million$)
K	CPR	350	IT and Services	National Technology Officer & Business Development Manager	Global	250
L	CPR	30000	1. IT and Services 2. Communication	1) Senior Solutions Architech 2) Data center architecture and planning manager	Global	6000
M	CSP	1001-5000	Communication	1) Head of Cloud Business 2) Product Marketing Manager 3) Expert Solution Designer	Global	5200
N	SPCSP	11-50	IT	IT Manager	Domestic	11

5.3. Normalized Values of Measures

Normalized values of measures obtained through the case study applications in these five companies from four categories are denoted in Tables 5.2 to 5.5. They are presented according to model dimension categorization; economic, organizational, external, technical, respectively. In the tables, NS abbreviation denotes that the related measure is not suitable for the related company category, whereas NA states that the related measure is not available in the company although it is relevant for its category.

Table 5.2: Normalized Values of Measures for Economic Dimension

	Companies				
Measure	**Company B**	**Company K**	**Company L**	**Company M**	**Company N**
CBA1	0,7	0,3	0,75	NS	NS
CBA2	0,6	0,35	0,65	NS	NS
CBA3	0,7	0,35	0,6	NS	NS
CBA4	0,38	0,4	0,4	NS	NS
CBA5	0,22	0,24	0,22	NS	NS
CBA6	0,55	0,6	0,3	NS	NS
CBA7	0,03	0,04	0,02	NS	NS
CBA8	0,16	0,18	0,12	NS	NS
CBA9	0,17	0,13	0,13	NS	NS
CBA10	0,14	0,16	0,07	NS	NS
CBA11	0,06	0,04	0,07	NS	NS
CBA12	0,08	0,07	0,15	NS	NS
CLAMIGCOS1	0,89	0,97	0,88	NS	NS
CLAMIGCOS2	0,07	NA	0,09	NS	NS
CLAMIGCOS3	0,6	0,75	0,55	NS	NS
EFL1	1	0,6	0,6	NS	NS
EFL2	NS	0,6	1	0,6	1
FMCICOS1	NS	0,25	0,28	0,7	NS
ODC1	NS	0,925	0,96	0,975	NS
ODC2	0,91	0,98	0,97	NS	NS
OEF1	NS	0,6	0,6	0,6	NS
OEF2	NS	1	0,6	1	NS
REV1	NS	0,6	0,6	1	1
REV2	NS	0,6	0,6	0,6	0,6
SLAEC1	0,15	0,1	0,1	0,45	NS
SLAEC2	0,19	0,15	0,1	0,4	NS
SLAEC3	0,6	0,6	0,2	0,6	NS
SLAEC4	0,18	0,12	0,15	0,5	NS
TCAO1	0,92	0,96	0,92	NS	NS

Table 5.3: Normalized Values of Measures for Organizational Dimension

	Companies				
Measure	**Company B**	**Company K**	**Company L**	**Company M**	**Company N**
ADM1	NS	1	0,2	1	1
ADM2	NS	1	0,2	1	1
ADM3	NS	1	0,6	1	NA
ADM4	NS	0,8	0,6	0,8	0,8
ADM5	NS	1	0,6	1	1
ADM6	NS	1	0,6	1	1
ADM7	NS	1	0,6	1	1
ADM8	NS	1	0,2	1	0,6
ADM9	NS	0,6	0,2	1	NS
CLSTR1	NS	1	0,2	1	NS
CLSUPSEL1	0,85	0,8	0,8	NS	NS
INV1	NS	1	0,6	0,79	NS
INV2	NS	0,55	0,45	0,85	NS
INV3	NS	1	0,2	1	NS
INV4	NS	0,8	0,2	1	NS
INV5	NS	0,25	0,9	0,95	NS
INV6	NS	0,8	0,35	0,9	NS
LOBETH1	1	1	1	NS	NS
LOBETH2	1	1	1	NS	NS
LOBETH3	1	1	0,6	NS	1
LOBETH4	1	1	0,2	NS	NS
MNG1	0,6	1	1	NS	NS
MNG2	0,6	0,2	0,6	NS	NS
MNG3	0,6	0,2	0,6	NS	NS
MNG4	1	0,6	0,2	NS	NS
MNG5	1	1	0,6	NS	NS
MNG6	1	1	0,6	NS	NS
MNG7	1	1	1	NS	NS
MNG8	0,6	1	0,6	NS	NS
VLID1	0,2	1	0,6	NS	NS
VLID2	0,3	0,15	0,1	NS	NS

Table 5.4: Normalized Values of Measures for External Dimension

	Companies				
Measure	**Company B**	**Company K**	**Company L**	**Company M**	**Company N**
LEGENV1	0,2	0,6	0,6	1	0,4
SOCF1	0,75	0,98	0,99	0,98	0,89

Table 5.5: Normalized Values of Measures for Technical Dimension

	Companies				
Measure	**Company B**	**Company K**	**Company L**	**Company M**	**Company N**
Ag1	NS	1	0,2	1	NS
Ag2	0,7	0,85	0,9	NS	NS
Ag3	NS	1	0,6	1	NS
Ag4	NS	1	0,6	1	NS
Ag5	0,6	1	0,2	NS	NS
Aint1	NS	1	0,6	1	NS
Av1	NS	0,95	0,99	0,999	NS
Av2	NS	1	0,2	1	NS
Cc1	NS	0,2	0,6	NA	NS
Cc2	NS	1	0,2	1	NS
Cc3	NS	1	1	0,6	NS
Cc4	NS	1	0,6	1	NS
Cdm1	NS	0,8	0,6	1	NS
Cdm2	NS	1	0,2	1	NS
Cdm3	NS	1	0,6	1	1
Cdm4	NS	0,8	0,4	1	1
Cdt1	1	0,8	1	NS	NS
Cla1	0,8	1	0,8	NS	NS
Cla2	0,7	0,93	0,65	NS	NS
Cla3	0,6	1	1	NS	NS
Cla4	NS	1	0,6	0,8	NS
Clam1	NS	1	0,73	1	NS
Clam2	NS	0,2	1	0,2	NS
Clam3	NS	1	1	1	NS
Clam4	NS	0,8	0,4	NA	NS
Clam5	NS	0,8	0,6	1	NS
Clam6	1	1	0,2	NS	NS
Clam7	1	1	0,6	NS	NS
Cli1	NS	0,8	0,8	0,8	NS
Cli2	NS	0,6	0,2	1	NS
Cli3	NS	0,8	0,4	0,8	1
Cli4	NS	1	0,2	1	1
Cli5	NS	1	0,2	1	NS
Cli6	NS	0,83	0,65	0,99	NS
Cli7	NS	0,8	0,4	0,8	NS
Cp1	NS	1	1	1	1
Cp2	1	1	0,2	NS	NS
Cp3	0,6	0,2	1	NS	NS
Cp4	NS	1	0,6	1	NS
Cp5	NS	1	0,2	1	1
Crt1	NS	1	0,73	0,79	1
Crt2	NS	0,2	1	0,2	0,2
Cs1	0,9	NA	0,9	NS	NS
Cs2	0,95	0,78	0,9	NS	NS
Cs3	NS	0,85	0,45	0,92	NS
Cs4	1	0,2	1	NS	NS
Cs5	NS	0,8	1	1	NS
Cs6	0,99	0,85	0,95	0,98	NS
Cs7	1	1	0,2	1	NS

Table 5.5 (continued)

	Companies				
Measure	**Company B**	**Company K**	**Company L**	**Company M**	**Company N**
Cs8	NS	0,8	0,8	1	NS
Di1	NS	0,8	0,6	0,8	NS
Di2	0,6	0,2	0,6	NS	NS
Di3	1	0,8	0,4	NS	NS
Di4	1	1	0,6	NS	NS
Di5	NS	0,8	0,4	0,6	NS
Di6	NS	1	1	1	NS
Di7	NS	1	0,2	1	NS
Dis1	1	0,2	1	NS	NS
Dl1	NS	0,3	0,85	0,97	NS
Hv1	NS	0,84	0,3	0,8	NS
Hv2	NS	0,75	0,45	0,8	NS
Isf1	0,95	0,85	0,9	NS	NS
Isf2	1	1	0,2	NA	NS
Isf3	NS	0,95	0,2	NA	NS
Mul1	NS	1	0,6	1	NS
Nv1	NS	1	1	1	1
Nv2	NS	1	1	0,79	1
Nv3	NS	1	0,2	1	NS
Re1	NS	1	0,73	0,67	NS
Re2	NS	0,8	0,8	1	NS
Re3	NS	0,8	0,85	0,96	0,9
Rs1	NS	1	0,6	1	NS
Rs2	NS	1	0,6	1	NS
Sc1	NS	1	1	1	1
Slt1	0,9	0,85	0,85	0,91	NS
Slt2	0,95	0,9	0,95	0,95	NS
Slt3	1	1	0,2	1	NS
Slt4	NS	0,8	0,65	0,85	NS
Slt5	NS	0,8	0,85	0,82	NS
Tfl1	NS	0,8	0,4	0,8	NS

5.4. Case Study1: Cloud Service Providers (Company M)

Technical, organizational and economic footprints of Company M are presented in Figures 2, 3 and 4, respectively. Whereas some characteristics are irrelevant for this specific firm, some others, e.g. "dependence on external systems" are not relevant for any service provider.
Upon inspection of the footprints of the technical dimension for CompanyM, the following observations can be made:

- Cloud computing system of Company M has a high wide are network latency problem.
- Company M completes cloud computing services in a higher period compared to the customer expectations although its cloud computing system connection quality is high.
- Most of the technical characteristics evaluated for Company M indicate either high or very high effectiveness.

In the scope of the effectiveness assessment of the organizational dimension of a cloud service provider company, the characteristics cloud supplier selection, vendor lock-in degree, level of business ethics and manageability are not relevant because they are associated with cloud customer /user companies.

Inspecting the footprint of the organizational dimension of Company M, the following observations can be made:

- The effects of cloud strategy on Company M are very high because they have a service portfolio strategy specific to cloud.
- The innovation characteristic is effective for Company M because they develop many innovative products specific to cloud. They also declared that they will continue developing cloud based innovative products in the near future.

In the effectiveness assessment of the economic dimension of a cloud service provider company, the measures of cloud application migration cost, cost and benefit analysis and total cost of application ownership are excluded because they are associated with cloud customer companies.

Assessment of the economic characteristics for Company M lead to the following inferences:

- The company will increase their investment on cloud infrastructure in the future because they expect increased earnings from cloud computing.
- The company has the ability of selling a high amount of cloud products and services with medium prices.
- They do not provide a subscription based pricing and billing mechanism, which is most usable in the cloud sector.

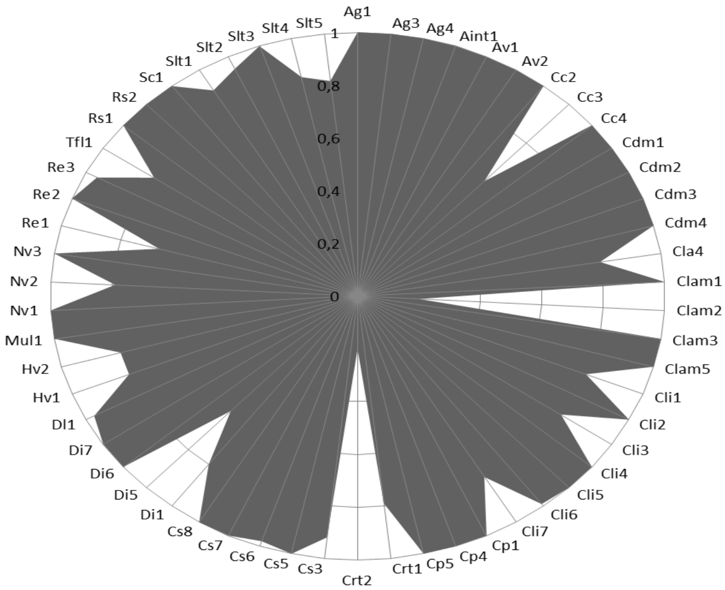

Figure 2. Technical dimension footprint of Company M

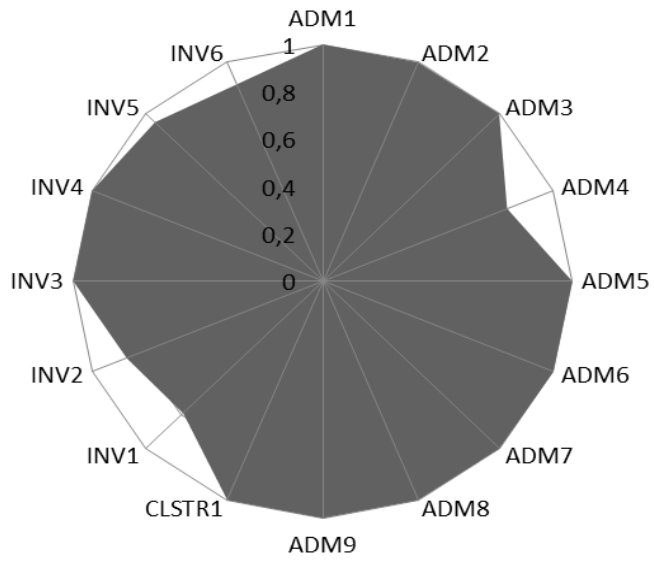

Figure 3. Organizational dimension footprint of Company M

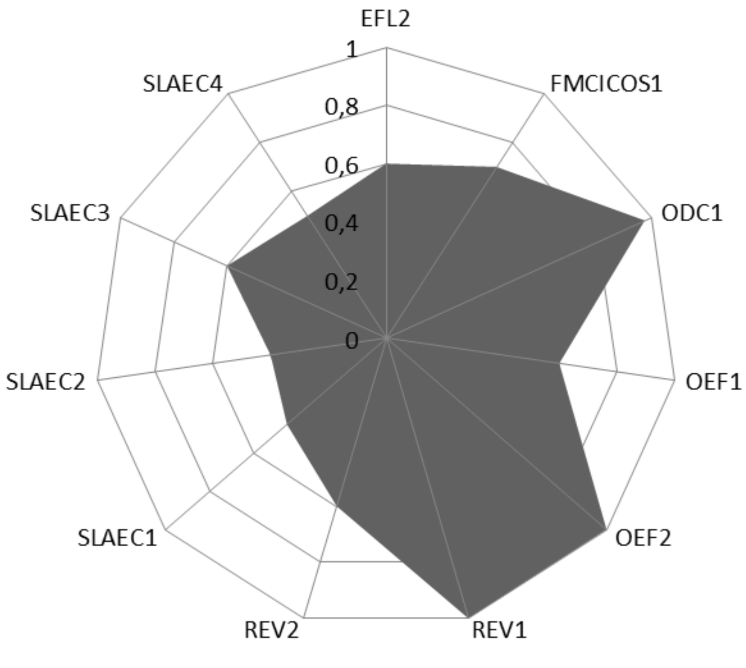

Figure 4. Economic dimension footprint of Company M

5.5. Case Study2: Cloud User (CompanyB)

Technical, organizational and economic footprints of Company B are provided in Figures 5, 6 and 7.

Slt1, Slt2 and Slt3 are the common measures that apply both to cloud service providers and to users. There are not any other common measures for these two categories of companies. The following observations can be made:

- They are satisfied with the private cloud provided to them by their cloud service providers.
- They have medium level of dependency on external systems since the numbers of their external applications are equal to the number of their internal applications.

Assessment of the organizational dimension of Company B indicates that:

- Company B generally uses cloud services from only one company in a definite period. After this definite period, they can select another cloud service provider for cloud services. But they do not take cloud services from more than one provider at the same time. Besides, they use the cloud services with long periods from the same provider, which is stated with VLID2 value in Table 5.3. This means that vendor-lock in degree is an important issue for them.
- Suppliers of Company B boast a large number of reference customers stated with the value of 0,85 for reference customer ratio of cloud supplier, indicating their overall reliability.

According to the economic dimension evaluation results of Company B, it is observed that Company B obtains most savings in software savings among all of the savings through cloud computing.

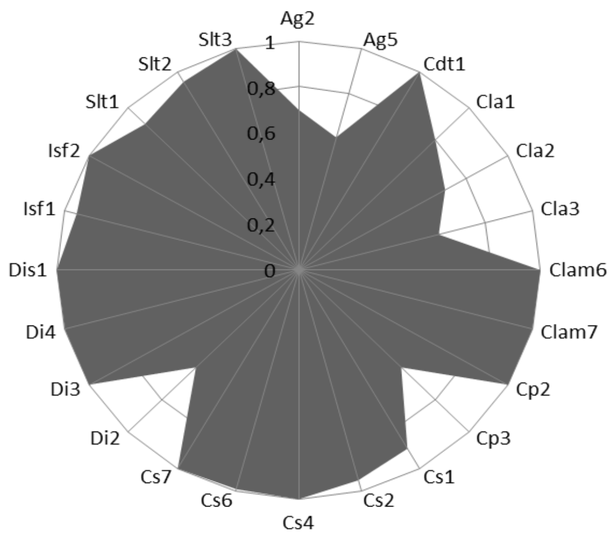

Figure 5. Technical dimension footprint of Company B

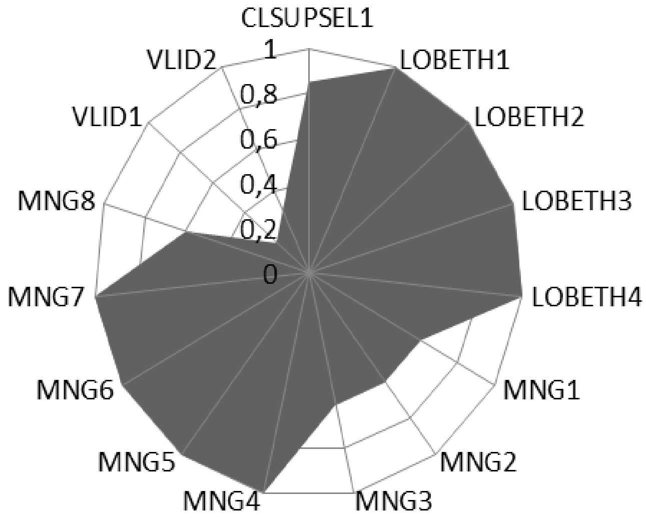

Figure 6. Organizational dimension footprint of Company B

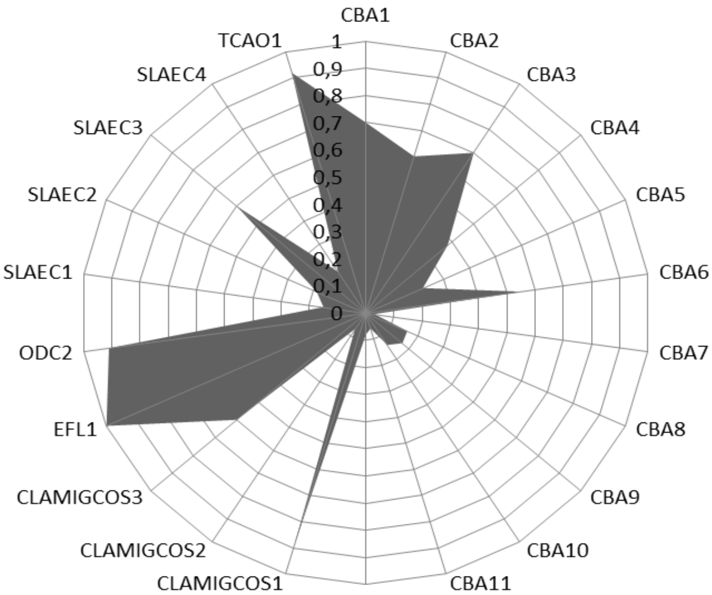

Figure 7. Economic dimension footprint of Company B

5.6. Case Study3: Solution Provider for Cloud Service Providers (CompanyN)

Technical, organizational and economic footprints of Company N are given in Figures 8, 9 and 10. The following observations are made:

- Cloud response time is not satisfactory for Company N. The level of system connection quality is very high, but the level of cloud service lead time is also high. For that reason, cloud response time seems to be problematic.
- Company N has a high value of redundancy rate for reliability, stated as 0.9 in Table 5.5. This denotes that they are highly effective in using the redundancy mechanism for reliability.

The assessment results associated with the economic dimension for Company N are as follows:

- They supply a high volume of cloud solutions with medium level of unit prices to cloud service providers. Company N provides solutions to the key and big cloud service providers in the sector. Since these service providers can access many competing solution providers, prices are determined competitively.
- Company N provides a high variety of pricing and billing mechanisms to the service providers, which helps them to increase their market potential.

According to the organizational dimension evaluation results of Company N, it is observed that they obey all of the rules of fair market practices while offering their solutions.

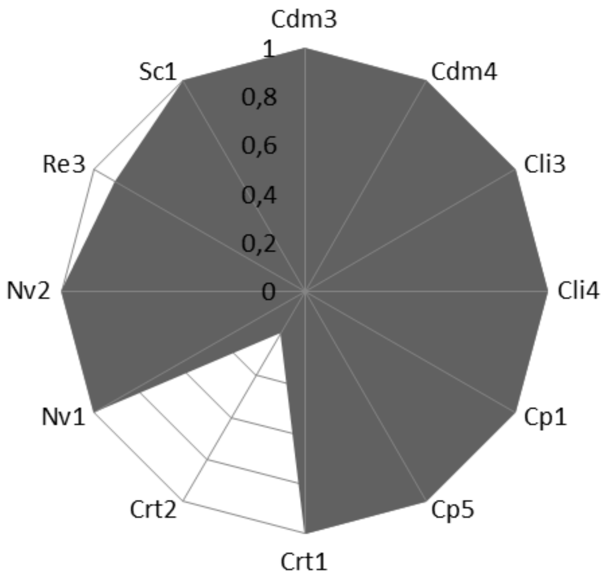

Figure 8. Technical dimension footprint of Company N

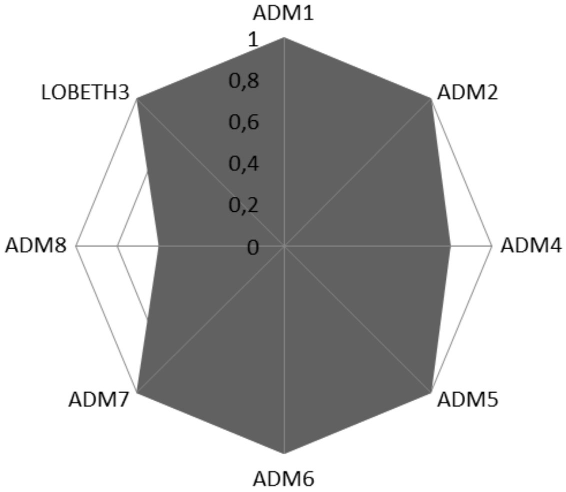

Figure 9. Organizational dimension footprint of Company N

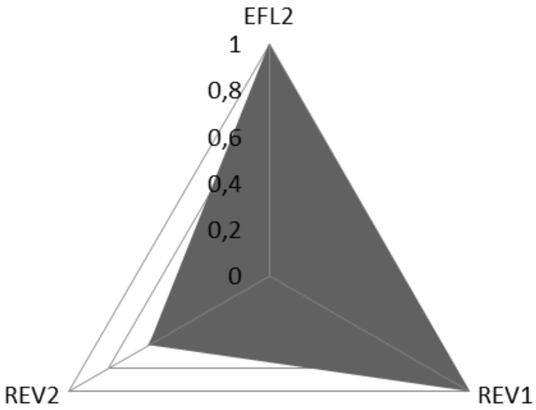

Figure 10. Economic dimension footprint of Company N

5.7. Case Study4: Cloud User and Service Provider (Company K and L)

Technical, organizational and economic footprints of Company K are given in Figures 11, 12 and 13. The following inferences are made according to the technical, economic and organizational footprints of Company K:

- They sell medium amount of cloud product and services with their average prices in the cloud sector.
- They do not provide a pricing and billing mechanism based on the consumption level of the cloud services for their customers.

- The ratio of future major cloud infrastructure cost for Company K is 0,25. This ratio denotes that they do not make high investment on cloud infrastructure.
- Percentage of non-deployment cost is 0,3 for Company K. For that reason, the deployment based cost can be considered as approximately high for them. They declared that they will decrease deployment based cost by developing a centralized deployment management structure in the long term.
- Cloud service lead time for Company K is very high. They stated that they will increase the shortness of cloud service lead time through dynamic provisioning.
- The level of hit rate of cache is 0,3 for Company K. They declared that they will increase level of hit rate of cache by increasing the size of blocks.

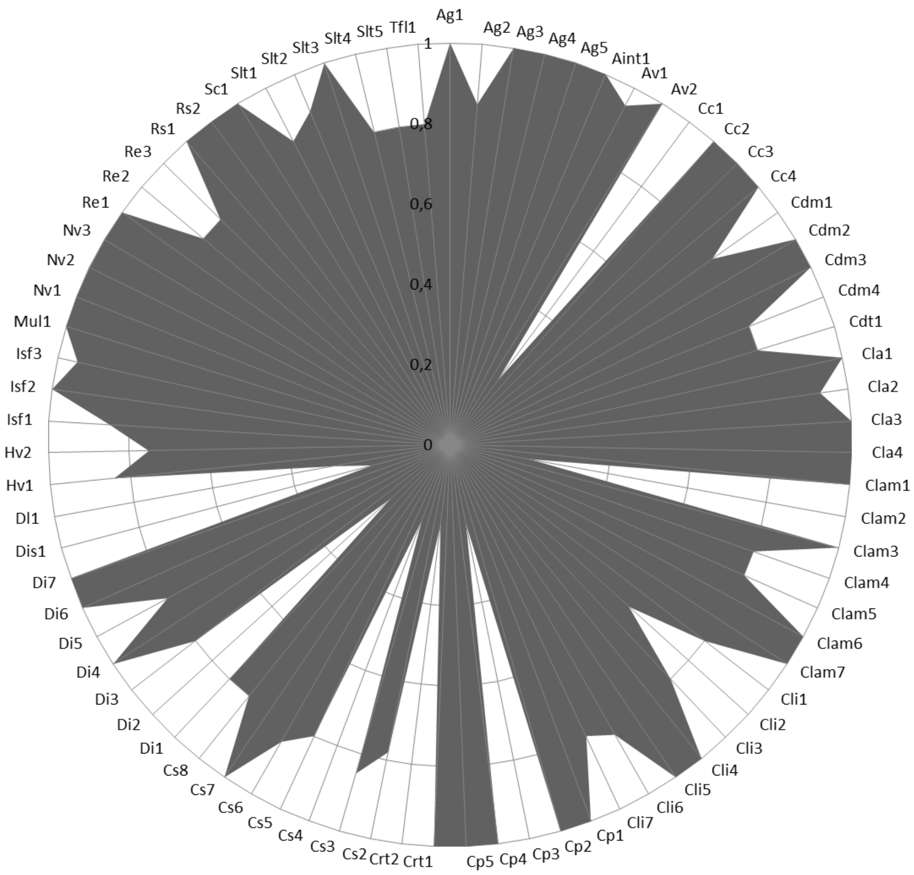

Figure 11. Technical dimension footprint of Company K

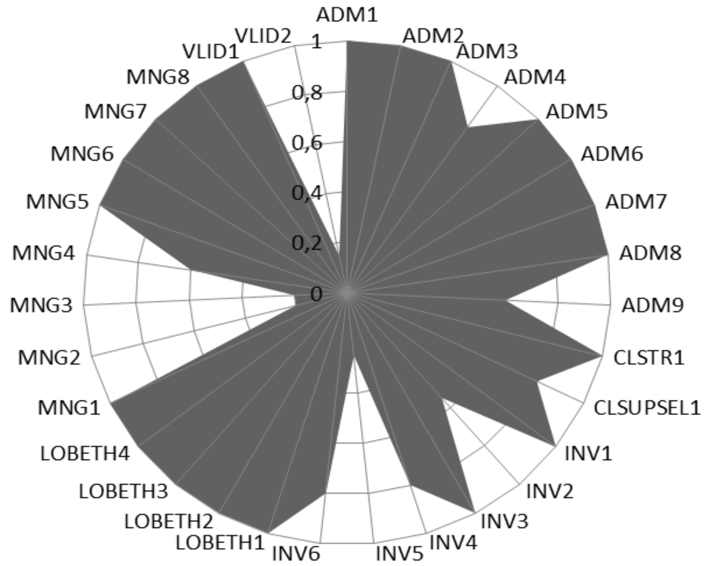

Figure 12. Organizational dimension footprint of Company K

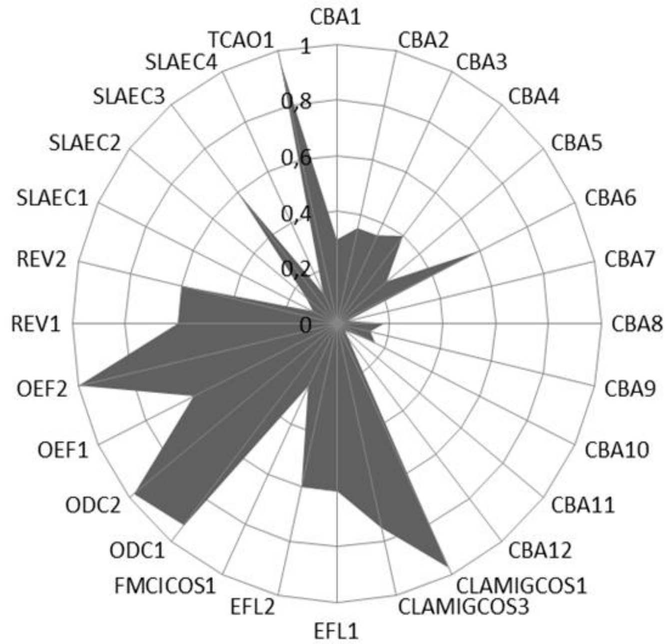

Figure 13. Economic dimension footprint of Company K

Technical, organizational and economic footprints of Company L are given in Figures 14, 15 and 16. The following inferences are made according to the technical, economic and organizational footprints of Company L:

- Level of data integrity is low for Company L because out of the 7 measures of data integrity, 3 of them are medium, 2 of them are low and 1 of them is very low.

- Level of infrastructure utilization is medium for Company L. They stated that they will try to increase infrastucture utilization through virtualization for rapid provisioning.
- Virtualization percentage for hardware and percentage of virtual machines for Company L are 0.3 and 0.45, respectively. These values denote that hardware virtualization level is low for Company L.
- They only publish guidance documents on cloud computing. But, they adjust neither academic training program nor conferences for cloud computing. For these reasons, it can be stated that the satisfaction level about the behavior of Company L in terms of community responsibility is low.
- They do not have a definite cloud strategy. The content of cloud computing for their organization is stated inside their IT strategy. Besides, they declared that they will develop a specific cloud strategy based on the features of their data center in the long term.
- It is observed that they obtain most savings in provisioning cost savings among all of the savings through cloud computing.

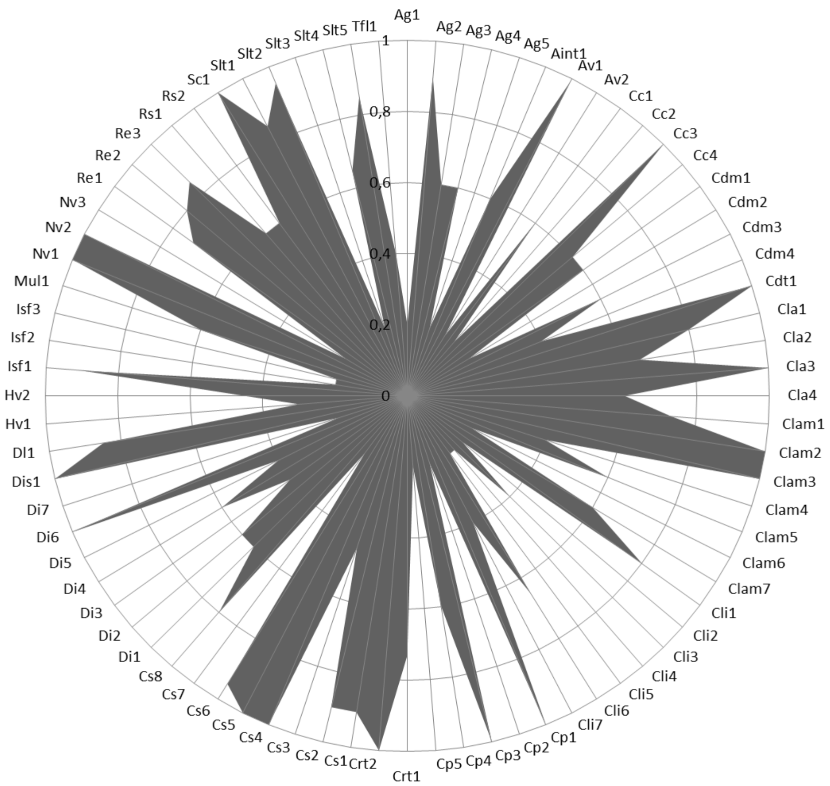

Figure 14. Technical dimension footprint of Company L

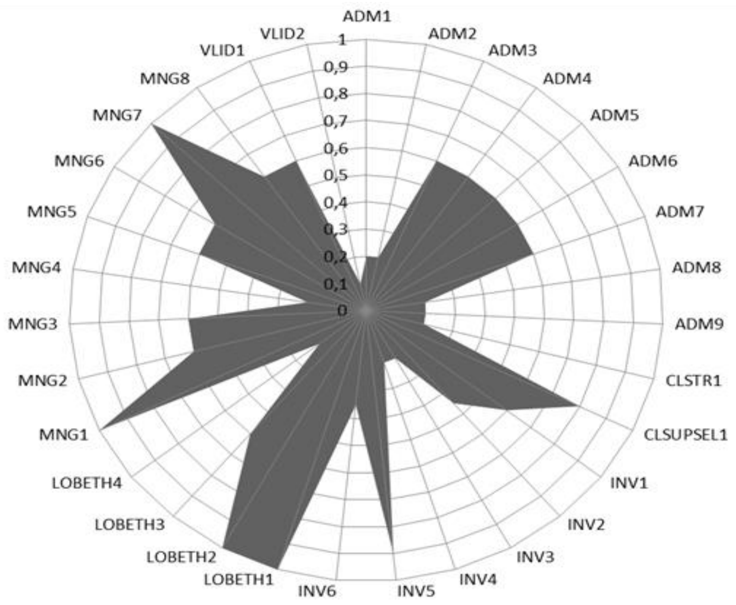

Figure 15. Organizational dimension footprint of Company L

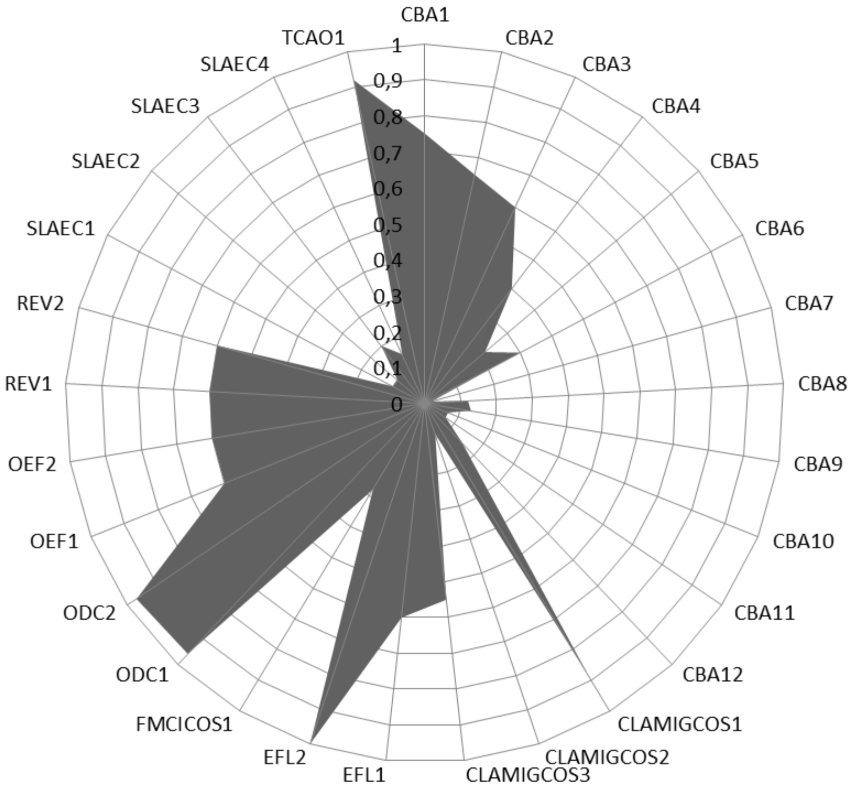

Figure 16. Economic dimension footprint of Company L

5.8. External Dimension Results for all Companies

As the external dimension consists of only two characteristics, rather than footprint diagrams, we compare the five companies in two bar charts, presented in Figures 17 and 18, one corresponding to each characteristic. Normalized values of them stated in Table 5.4 are used in order to draw these bar charts.

Investigation of these bar charts lead to the following observations:

- The characteristic of computer literacy rate is more effective than the characteristic of cloud-specific legislation for these five companies. This means that computer literacy can not be considered as significant an issue as cloud-specific legislation for them.
- Company M is more effective than the other companies in terms of cloud-specific legislation because they give consultancy support to their customers about cloud computing laws and regulations.

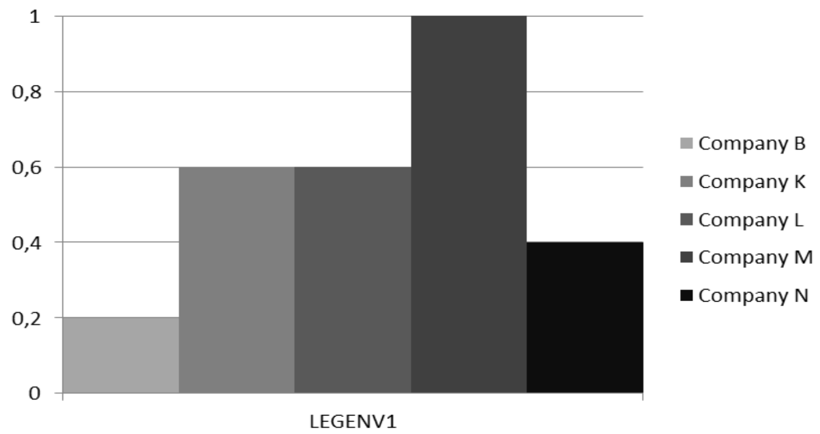

Figure 17. Cloud-specific legislation

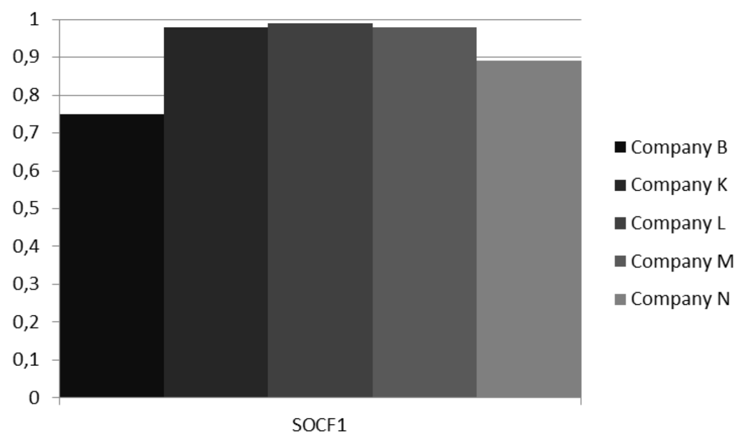

Figure 18. Computer literacy rate

5.9. Validation through Case Studies

The model was validated through four confirmatory case studies. In the scope of validation, the first aim is to confirm the applicability of the model by validating the applicabilities of all 142 measures in the model. In Case1, companies from the cloud service provider category, out of 91 relevant measures, 87 of them are available in Company M. Company M also declared that the operational definitions of remaining 4 measures are also meaningful and suitable. For Case 2, from cloud user category, out of 63 relevant measures, all of them are available in Company B. From Case 3, companies from solution provider category, out of 26 relevant measures, 25 of them are available in Company N. Company N also stated that the operational definition of remaining 1 measure is also suitable and meaningful. From Case 4, for the companies which receive as well as provide cloud services, out of 142 relevant measures, all of them are available in Company L and 140 of them are available in Company K. Company K also found the operational definitions of remaining two measures suitable and meaningful. These results verified the applicabilities of all of the 142 measures in the model. Besides, the operational definitions of all of them are also found suitable and meaningful by the companies participated in the confirmatory case studies.

The second aim of validation through case studies is to confirm that the strengths and weaknesses of companies can be determined through the assessment results via application of the model. Since, normalized values of measures are used for assessment results, the strong and weak measures are determined easily. The normalization process applied for the values of measures provided to compare the measures in a common framework. For instance, from the assessment results displayed in the footpring diagram, it can easily be observed that 33 technical measures of Company M, from cloud service provider category, are very strong since their normalized values are 1.

The third aim of validation is to confirm that comparison of different organizations in the same company category can be realized through the application of model for assessment. As stated before, Company K and L are from the same category. According to the assessment results of the economic dimension, Company K is stronger than L for 12 measures, on the other hand, Company L is stronger than K for 9 measures. Besides, for 7 of the economic measures, they are at the same effectiveness level. According to the assessment results of the organizational dimension, Company K is stronger than L for 23 measures, on the other hand, Company L is stronger than K for 3 measures. Besides, for 5 of the organizational measures, they are at the same effectiveness level. For external dimension, Company L is stronger for 1 measure and they are at the same effectiveness level for the remaining measure. Finally, for the technical dimension, Company K and L are superior at 49 and 18 measures, respectively. Besides, for 12 of the technical measures, it can be stated that they are at the same effectiveness level.

Consequently, these case studies have validated that the model is applicable and it provides a meaningful and useful assessment for cloud computing effectiveness.

CHAPTER 6

CONCLUSION

6.1. Discussion and Summary

As stated with the research problems of this study, our aims were to identify the characteristics that effect cloud computing effectiveness assessment and to propose an appropriate method for assessing effectiveness in terms of the characteristics identified, for any service provider or cloud customer.

At the end of the study, we have come up with the answers for these research questions. We obtained the characteristics that determine cloud computing effectiveness, categorized as technical, organizational, external and economic, together with their operationally and objectively defined measures. The characteristics and their measures that consitute the model are presented in Tables 4.2 to 4.11. The final model consists of 42 characteristics and 142 measures, in four different dimensions.

Effectiveness is to be assessed in terms of characteristics evaluated by means of measures.

Footprint diagrams were used for presenting effectiveness assessment results for each of the four dimensions, separately. Each of the characteristics of the model have been associated with at least one measure. Besides, the applicability of all 142 measures were validated through case studies. This means that they have all been found applicable in the context of the studied cases selected from the cloud computing and IT sector. Furthermore, they are linked with the related literature, emphasizing their theoretical justification.

Participants in the confirmatory case studies were requested to decide whether they considered measures of CCEAM to be sufficient to assess cloud computing effectiveness. In Case 1, companies from the cloud service provider category, the staff stated that the model is *mostly* suitable for the effectiveness assessment of cloud computing. In Case 2, from cloud user category, the company staff found the model, again, *mostly* suitable for effectiveness assessment. In Case 3, companies from solution provider category, the representatives were of the opinion that the model is *mostly* suitable for effectiveness assessment. And finally, for Case 4, for the companies which receive as well as provide cloud services, staff from both of the companies stated that the model is *somewhat* suitable for the effectiveness assessment of cloud computing.

6.2. Contributions

The main contribution of this study is that an effectiveness assessment model including four separate dimensions and 142 measures was constructed.
Corollaries of this contribution can be outlined as follows:

- The list of cloud computing effectiveness measures, together with their objective operational definitions, was compiled.
- The model was validated for four different categories of companies, viz. cloud computing service providers, service provider/receivers, solution providers, and users.
- Effectiveness assessment of cloud computing in the context of different organizations in terms of four separate dimensions (technical, organizational, economic, and external) was comparatively presented.

6.3. Shortcomings of the Study

There are two noteworthy limitations of this study:

The first limitation has originated from having to work through a large number of open-ended interview questions in the case studies. For that reason, possibly intimidated by the time and effort all those questions would require, some of the invited companies did not participate in our case studies, hence generalizability of the results, even though still sufficiently strong, has not been achieved at the level originally aimed for.

The second limitation is related to the deficiency of individual cloud experts having comprehensive knowledge on each of the technical, organizational, economic and external dimensions. While each one possessed expertise on some aspects of the evaluation, not all were equally qualified to respond to all interview questions. Hence, to ensure validity, multiple interviewees with different organizational roles were selected and approached in most cases.

6.4. Future Work

Future work may focus on the usage of CCEAM as a decision support for migration to cloud and the construction of an improvement strategy and method based on this assessment model, to assist companies in enhancing their cloud computing effectiveness in accordance with their own strategies and goals. In such a context, feasibility assessment for full or partial migration to cloud can be carried out. Potential cloud users can be studied as specific cases and the measures associated with migration may be evaluated. Besides, new measures associated with migration can be derived. Effectiveness assessment results of all of these measures may provide decision support for migration to cloud.

It is obviously also possible to use CCEAM for planning process or infrastructure improvements to enhance cloud computing effectiveness. A structured approach for such usage may possibly be formulated, provided that strategies, priorities and goals are also studied in a structured fashion.

The most important issue that needs to be addressed for using CCEAM as a basis for effectiveness enhancement is the mapping between CCEAM characteristics and cloud processes. A particular approach addressing this issue, not explicitly using CCEAM terms, has been adopted by the Oracle Cloud Computing Capability Maturity Model [229] developed based on best practices; and the "Cloud Computing Best Practices Book" by H. Beard [39], can be used for describing the cloud processes. But, further work needs to be undertaken to rigorously address this mapping. Comparison of CCEAM with Oracle Cloud Computing Capability Maturity Model is presented in Appendix B.

Other issues that need to be resolved for usability of CCEAM in process improvement may be listed as follows:

- Measures of CCEAM can not be used to determine the capability of cloud processes because their aims are different. For instance, financial management process is accepted as one of the cloud processes [39]. To evaluate the effectiveness of this process, whether the traceability of financial assets of an organization is provided through this process has to be investigated [39]. On the other hand, the economic measures of CCEAM address financial effectiveness in general terms, without explicit focus on financial traceability.
- Confidential nature of organizational priorities may hamper objective and open formulation of improvement plans.
- Even if all of the problems stated above are solved, internal validity will still remain as an issue. The same measures will be used for assessing the effectiveness of more than one cloud process. For instance, measures of cloud security will be used in determining the achievement of both information security management process and risk management process, which may lead to an internal validity problem.
- Determining the appropriate scale for achievement of process attributes is also a major issue.
- Most of the characteristics proposed in CCEAM can not be used in cloud process improvement practically because most of the cloud processes are not defined explicitly by many companies, even by highly IT experienced ones.

Because of these challenging issues; this work has been left out of the scope of the present study.

If the theoretical requirements of process mapping, information transparency issues regarding the organizational priorities of company, questions regarding internal validity and the need for determining the appropriate scale for achievement of process attributes are tackled in a proper way, a structured approach for CCEAM based process improvement may be formulated.

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APPENDICES

APPENDIX A. OPEN-ENDED INTERVIEW QUESTIONS

1. Bulut bilişim ile ilgili sağladığınız ve/veya kullandığınız hizmetler var mıdır? Varsa bunlar hakkında açıklamalarda bulunabilir misiniz?

2. Çalışmamız kapsamında yapılan yayın incelemeleri ve saha araştırması sonucunda, bulut etkinlik değerlendirmelerinde teknik, ekonomik ve organizasyonel olmak üzere ele alınan 3 farklı boyut olduğunu saptadık. Bulut bilişim ile ilgili yaşadığınız deneyimleri dikkate aldığınız takdirde; bu 3 boyut bulut etkinlik değerlendirmeleri için yeterli midir? Bunlara eklenmesi gereken başka boyut ya da boyutlar var mıdır?

3. Yazılım olarak hizmet (SaaS), platform olarak hizmet (PaaS), altyapı olarak hizmet (IaaS) şeklinde nitelendirilen bulut hizmet modellerinden hangilerini kullanıyorsunuz? Bu modellerden hangilerini çözüm olarak müşterilerinize sunuyorsunuz? Bu çözümlerin etkinliğini değerlendirmede kullandığınız yöntem ve değişkenler varsa, bunları bir örnek çerçevesinde ifade eder misiniz?

4. Bulut bilişim ile ilgili aşağıdaki değişkenlerin değerlendirmelerinde hangi ölçütleri kullanıyorsunuz?

a) Ölçeklenebilirlik
b) Güvenilirlik
c) Bulut uygulamaları
d) Veri tümleşimi
e) Bulut uygulama bütünleştirmesi
f) Bulut güvenliği
g) Bilgi işleme kapasitesi
h) Esneklik
    h1) Teknik açıdan
    h2) Ekonomik açıdan
i) Kullanılabilirlik
j) Yalıtım aksama
k) Bulut uygulamalarını taşıma
l) Bulut yanıt süresi
m) Hizmet düzeyi anlaşması
    m1) Teknik açıdan
    m2) Ekonomik açıdan
n) Bulut performansı
o) Ağ sanallaştırması
p) Bulut birlikte işlerliği
q) Bulut yönetimi
r) Bulut geliri

5. Sunduğunuz ya da kullandığınız bulut bilişim hizmetlerinde ölçeklenebilirlik ve güvenilirlik ile ilgili yaptığınız etkinlik değerlendirmelerinde belirli bir düzey değerlendirmesi yapıyor musunuz? Örneğin; bir bulut hizmetinin ölçeklenebilirlik ve güvenilirlik etkinlik değerlendirmesinde, yüksek, orta, düşük olmak üzere üç düzeyin kullanılması.

6. Müşterilerinize bulut uygulamalarının değerlendirmeleri için bir kontrol listesi sunuyorsanız; aşağıdaki unsurlardan hangilerinin etkinliğini bu kapsamda değerlendiriyorsunuz?

a) Bulut destekli masaüstü uygulamaları
b) Bulut bileşenlerinin kullanışlılığı
c) Bulut uygulamalarına destek

7. Bulut bilişim ortamında veri tümleşiminin değerlendirilmesinde aşağıdaki bileşenlerden hangilerini kullanıyorsunuz?

a) Veri kalitesi
b) Teknik altyapı
c) Veri yönetimi
d) Maliyetler
e) Çevrimiçi işbirliği ve paylaşım
f) Hız
g) Konuşlandırma (yerleştirme) kolaylığı

8. Bulut güvenliğinin değerlendirilmesinde, veri güvenliği boyutu dışında farklı boyutları da ele alıyor musunuz?

8.1 Değerlendirmelerinizde, "bulut bilişim çalışanı, barındırma hizmeti ortamı, güvenlik denetimleri, bulut ortak firması" gibi unsurlar da dikkate alınmakta mıdır?

8.2 Şirketiniz bulut güvenlik denetimlerini uygulamakta mıdır? Bulut hizmeti aldığınız şirketlerin bulut güvenlik denetimlerini yaptırmalarına önem veriyor musunuz?

8.3 Örnek bir olay ile bulut güvenlik denetimlerinin sizin için ne anlam ifade ettiğini açıklar mısınız?

9. Bulut uygulamalarını taşıma etkinliği değerlendirmelerinde, aşağıdaki değişkenlerden hangilerini kullanıyorsunuz?

a) Esneklik
b) Güvenilirlik
c) Geniş alan ağı gecikme süresi
d) Bant genişliği
e) Eş zamanlama
f) Yığınsal dönüştürme
g) Harcama (gider)

10. Bulut bilişiminde kullanılan karma teslim çerçevesi yöntemi, bulut müşterilerine sunulan çözümlerin en iyi birleşimle teslim edilmesini hedefler. Bu yöntem, sunulan çözümün ortama entegre edilmesini de sağlar. Karma teslim çercevesi yöntemi ayrıca, bulut teslim ve geleneksel teslim yöntemlerinin en uygun şekilde birleştirildiği bir yapıyı ifade etmektedir. Böylece, bulut müşterisi, kendisine sunulan çözümde çoklu kaynaklı hizmet ortamından yararlanmış olunur. Bu yapıyı, bulut ile ilgili çalışmalarınızda takip ediyor musunuz? Takip ediyorsanız, şirketiniz dahilinde karşılaştığınız bir örnek ile açıklar mısınız? Karma teslim çerçevesi yöntemi ile bulut yanıt süresi arasında sizce nasıl bir ilişki vardır?

11. Bulut performansını değerlendirmede kullanılan ölçütler, yaptığınız hizmet düzeyi anlaşmalarında kesin tanımlarla yer almakta mıdır? Örnek bir olay ile bulut performansı değerlendirmesinin hizmet düzey anlaşması üzerinde oluşturduğu etkileri açıklayabilir misiniz?

12. Aşağıdaki unsurlardan hangileri, bulut üzerinde birlikte işlerliğin etkinlik değerlendirmelerinde ele alınmalıdır?

a) Üretilen verinin çoktürelliği (heterojenliği)
b) Farklı kullanım senaryoları
c) Programlama uygulamaları
d) Veri kopyalama
e) Taşınan veri
f) İş akışları ve dağıtılmış veritabanlarının yönetimi

13. Yaptığınız bulut bilişim etkinlik değerlendirmeleri yenilenme (innovasyon) değişkenini içermekte midir?

14. Bulut bilişimin, bilişim sektörü açısından bir yenilenme olduğu kabul edilebilir mi?

15. Şirketinizin uyguladığı iş modelini de dikkate alarak, bulut bilişim ile diğer iş modelleri arasında bir karşılaştırma yapabilir misiniz?

16. "Bulut bilişimin diğer iş modelleri ile kıyaslandığında daha insan merkezli bir iş modeli olduğu " düşüncesine katılır mısınız?

17. Şirketinizin belirli bir bulut bilişim stratejisi varsa, bu stratejiyi kısaca açıklar mısınız? Bulut hizmeti alacağınız bulut tedarikçisini seçerken, daha önceden tanımlanmış belirli stratejiler uygulamakta mısınız? Bu stratejilerden en uygun olanını belirlemede, hangi ölçütleri kullanıyorsunuz?

18. Uygulamalarınızı buluta taşıma maliyetini hesaplarken, fayda-maliyet analizi yapıyor musunuz? Uygulamaların maliyeti, bulut bilişim kullanımından önce ve sonra şeklinde hesaplanmakta mıdır? Mümkünse, şirketinizde uygulanmış olan temel bir örnek dahilinde, fayda-maliyet analizinde kullandığınız değişkenleri açıklar mısınız?

19. Şirket olarak gelecekte bir bulut altyapı maliyeti ile karşılaşmanız olası mıdır? Bu maliyete ilişkin, çeşitli tahminlemeler yapıyor musunuz? Bu tahminlemede hangi parametreler yer almalıdır?

20. Şirketinizin bulut bilişim kapsamında görüşmemiz sırasında ele almadığımız başka düşünceleri var mıdır?

APPENDIX B. COMPARISON OF CCEAM with ORACLE CLOUD COMPUTING CAPABILITY MATURITY MODEL (OCCCMM)

The differences between these two models are outlined in the following table.

Table B.1: Comparison of CCEAM with OCCCMM

	CCEAM	**OCCCMM**
Key Components	Characteristics, Measures, Dimensions	Capabilities, Domains
Number of each of the key Components	42 characteristics, 142 Measures, 4 Dimensions	60 Capabilities, 8 Domains
Scope	Effectiveness Assessment of Measures of Cloud Computing	Assessment of maturity and adoption of capabilities
Subjective Assessment/Objective Assessment	Objective Assessment through concrete measures	Subjective Assessment of cloud experts for each of the capabilities through a 5-point Likert Scale structure
Relationship with Improvement	May be used as a basis for improvement, as strengths and weaknesses are identified.	Yes, it provides an actual plan for improving associated capabilities
Assessment Steps	**Step1:** Evaluation of each of the concrete measures through case study interviews **Step2:** Normalization of the values of each of the measures **Step3:** Constructing footprint graphs for economic, organizational and technical dimension; bar charts for the external dimension.	**Step1:** Interview with cloud experts **Step2:** These cloud experts assign values to each capability for maturity and adoption with a 5-point Likert Scale structure **Step3:** The average of assessment scores of cloud experts for each capability is taken. **Step4:** The capabilities that have to be improved are determined according to the assessment results.
Display of Assessment Results	Footprint graphs, bar charts	Spider graph, cloud capability heat map, and cloud capability scatter plot
Associated Company Categories in terms of Applicability	• CSP • CPR • SPCSP • CU	• CSP • CPR • CU

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TEZ FOTOKOPİ İZİN FORMU

ENSTİTÜ

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YAZARIN

Soyadı : YARLIKAŞ
Adı : SERDAR
Bölümü : BİLİŞİM SİSTEMLERİ

TEZİN ADI (İngilizce) : **CLOUD COMPUTING EFFECTIVENESS ASSESSMENT**

TEZİN TÜRÜ: Yüksek Lisans [ ] Doktora [X]

1. Tezimin tamamı dünya çapında erişime açılsın ve kaynak gösterilmek şartıyla tezimin bir kısmı veya tamamının fotokopisi alınsın. [X]
2. Tezimin tamamı yalnızca Orta Doğu Teknik Üniversitesi kullanıcılarının erişimine açılsın. (Bu seçenekle tezinizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) [ ]
3. Tezim bir (1) yıl süreyle erişime kapalı olsun. (Bu seçenekle tezinizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) [ ]

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