AN INTEGRATED DECISION SUPPORT SYSTEM FOR CLOUD COMPUTING TECHNOLOGY SERVICE PROVIDER SELECTION

(BULUT BİLİŞİM TEKNOLOJİ SERVİS SAĞLAYICISI SEÇİMİNDE ENTEGRE KARAR DESTEK SİSTEMİ)

by

AYÇA MADEN, B.S.

Thesis

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

MASTER OF SCIENCE

in

LOGISTICS AND FINANCIAL MANAGEMENT

in the

INSTITUTE OF SCIENCE AND ENGINEERING

of

GALATASARAY UNIVERSITY

January 2015

AN INTEGRATED DECISION SUPPORT SYSTEM FOR CLOUD COMPUTING TECHNOLOGY SERVICE PROVIDER SELECTION

(BULUT BİLİŞİM TEKNOLOJİ SERVİS SAĞLAYICISI SEÇİMİNDE ENTEGRE KARAR DESTEK SİSTEMİ)

by

AYÇA MADEN, B.S.

Thesis

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

MASTER OF SCIENCE

Date of Submission : Jan 2 , 2015

Date of Defense Examination : Jan 26, 2015

Supervisor : Prof. Dr. Gülçin Büyüközkan FEYZİOĞLU

Committee Members: Yrd. Doç. Dr. Zeynep ŞENER

Yrd. Doç. Dr. İ. Burak PARLAK

ACKNOWLEDGEMENTS

I would like to thank Prof. Dr. Gülçin Büyüközkan Feyzioğlu, whom I am grateful not anly for her guidance in our study but also for her positive attitude and confidence in me. This work would not have been possible without her eternal patience and tolerance. Finally, I would like to thank my sister for her love, encouragement and trust in me.

Ayça MADEN
JAN, 2015

TABLE OF CONTENTS

LIST OF SYMBOLS

AHP	: Analytic Hierarchy Process
ANP	: Analytic Network Process
MCDM	: Multicriteria Decision Making
DEMATEL	: Decision Making and Evaluation Laboratory
CSMIC	: Cloud Service Measurement Index Consortium
TCO	: Total Cost of Ownership
ITO	: Information technology outsourcing
BPO	: Business process outsourcing
SDO	:Software development outsourcing
GRA	: Grey Relational Analysis
SMI	: Service Measurement Index
OS34CP	: Outsourced Service Selection Strategy for Cloud Platform
C.A.RE	:Complete-Auditable-Reportable
MADM	: Multi-attribute decision-making
SelCSP	: Select Cloud Service Provider
TAM	: Technology Acceptance Model
GSD	: Global Software Development
SLA	: Service Level Agreement
TOPSIS	: Technique for Order Performance by Similarity to Ideal Solution
TPA	: Third Party Auditor
CSS	: Cloud Storage Service

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Increasing competitive environment in businesses is shaping the way of Information Technology (IT) outsourcing. As a branch of IT, cloud computing technology is revolutionizing the IT industry in a promising way for delivering flexible and cheap computing resources via cloud platform. As a risky process of cloud computing technology service provider selection affects the existing capabilities of businesses and it must be well-organized. In literature, the evaluation of cloud computing technology especially systematically evaluated practices of cloud computing technology service provider selection remain limited. Service provider selection process requires a multi-criteria approach including the evaluation of both quantitative and qualitative factors. User experience, which presents an important part of this process, also needed to be included with decision makers' judgments. Therefore, this thesis study develops an integrated fuzzy MCDM (Multi Criteria Decision Making) approach based on fuzzy DEMATEL (Decision Making Trial and Evaluation Laboratory), fuzzy ANP (Analytic Network Process) and fuzzy TOPSIS (Technique for Order Performance by Similarity to Ideal Solution). After reviewing the literature in detail, cloud computing technology service provider evaluation criteria are determined and analysed with the guidance of expert evaluations using fuzzy DEMATEL to identify key criteria that will be used in a case study. Secondly, in lights of expert evaluations, fuzzy DEMATEL and fuzzy ANP methods are applied to calculate weights of the evaluation criteria and the most suitable company of cloud computing technology service provider is chosen with fuzzy TOPSIS method.

Keywords: Cloud Computing Technology, Cloud Service Provider, Fuzzy DEMATEL, Fuzzy ANP, Fuzzy TOPSIS

ÖZET

İşletmelerde giderek artan rekabet, bilgi teknolojilerinde dış kaynak kullanımı konusuna yeni bir boyut kazandırmıştır. Bilgi teknolojilerinin bir uzantısı olan bulut teknolojisi, bilgiye ucuz ve esnek erişim sağlayan ve bilgi teknolojisi endüstrisinde çığır açan bir teknolojidir. Bulut bilişim teknolojisi servis sağlayıcısı seçimi ise, düzgün planlanması gereken bir süreç olup şirketlerin mevcut kaynak kapasitelerini etkilemesi bakımından riskli bir yapıya sahiptir. Literatürde bulut bilişim teknolojisinin değerlendirildiği, özellikle de servis sağlayıcısı seçimi sürecinin sistematik olarak incelendiği çok az sayıda çalışma bulunmaktadır. Servis sağlayıcısı seçimi problemi nitel ve nicel faktörlerin birarada değerlendirilmesi gerektiği çok kriterli bir özelliktedir. Kullanıcı deneyimleri, bu değerlendirmenin önemli bir parçası olup, sözel ifadelerin seçim sürecine dahil edilmesi gerekmektedir. Bu sebeplerle bu çalışmada, bulut bilişim teknolojisinde en uygun servis sağlayıcısını seçebilmek için bulanık DEMATEL, bulanık ANP ve bulanık TOPSIS metotlarının dahil edildiği entegre bir çok kriterli karar verme metodolojisi geliştirilmiştir. Önerilen metodoloji, bir vaka analizi kapsamında uygulanarak geçerliliği test edilmiştir. İlk aşamada, detaylı yazın taramasıyla belirlenen bulut bilişim teknolojisi servis sağlayıcısı seçiminde kullanılacak değerlendirme kriterleri uzman görüşleri alınarak bulanık DEMATEL yöntemi ile analiz edilmiş ve vaka analizinde temel alınacak anahtar değerlendirme kriterleri belirlenmiştir. İkinci aşamada ise, uzman görüşleri ile bulanık DEMATEL ve bulanık ANP metodları uygulanarak değerlendirme kriterlerinin önem dereceleri hesaplanmış ve bulanık TOPSIS metodu kullanılarak en uygun servis sağlayıcı firma seçilmiştir.

Anahtar Kelimeler: Bulut Teknolojisi, Bulut Teknolojisi Servis Sağlayıcısı, Bulanık DEMATEL, Bulanık ANP, Bulanık TOPSIS

1. INTRODUCTION

The roots of clouds computing can be tracked by observing the advancement of several technologies, especially in hardware (virtualization, multi-core chips), Internet technologies (Web services, service-oriented architectures, Web 2.0), distributed computing (clusters, grids), and systems management (autonomic computing, data center automation) (Buyya et al., 2011). Cloud Computing has the potential to transform a large part of the IT industry and makes software even more attractive as a service and shapes the way of designed and purchased IT hardware (Armabrust et al., 2009). Therefore, the traditional concept of IT outsourcing is replaced by the idea of outsourcing only value added functions as offered by cloud service providers. Cloud computing technology aims to deliver a network of virtual services so that users can access them from anywhere in the world on subscription at competitive costs. It also offers significant benefits to the businesses and communities by freeing them from the low-level task of setting up Information Technology infrastructure and thus creating business value for their services (Garg et al. 2012). SMEs had to make high capital investment upfront for procuring IT infrastructure, skilled developers and system administrators, which results in a high cost of ownership. IT organisations need to look at the consumer trends. The possibility for innovation that cloud computing technology offers is critical for businesses. Therefore, service perspective allows to think about what they need without thinking about whether their IT function have the necessary skills, hardware or resources. In view of this, enriching the available computing resources of cloud platform is needed.

Cloud service providers should clarify their position to offer appropriate services which can affect customers' confidence for increasing their understanding of the cloud service adoption process. Each cloud provider offers similar services at different performance levels, therefore given this diversity of cloud service offerings, an important challenge is to discover who are the ‘‘right’’ cloud providers to meet their requirements. The candidate cloud computing technology services on the Internet are usually of diverse sources which cause a big challenge for businesses. In view of this challenge, we provided a framework as an outsourcing strategy in cloud platforms to help customers.

To enhance objective provider selection and determine users' preferences, we need to quantify subjective opinions automatically and precisely.

Although many researchers analyse this cloud computing technology service provider selection strategy, current practice remains limited about which cloud provider should be chosen and how to compare the candidates of several cloud computing service provider. The main issue in a cloud service selection process concerns the comparison of several service candidates by evaluating and aggregating multiple criteria, and the measurement of qualitative service attributes (Sun et al. 2014). The existing cloud service selection approaches are generally Multi Criteria Decision Making (MCDM) based, optimization based and logic based approaches for cloud service selection such as MCDM-Analytic Hierarchy Process (Godse & Mulik, 2009), Optimization (Martens & Teuteberg, 2012), Optimization-greedy (Jung et al. 2013), Logic-description logic (Kanagasabai, 2012). Based on the recent literature survey of Sun et al. (2014), three main points identified as open issues on contemporary cloud service selection approach; the lack of consideration of the interdependency of criteria, the lack of an advanced multi-criteria-based measurement of user preferences, and the lack of an efficient means to deal with qualitative parameters and fuzzy expression. Open issues on cloud service selection process can be identified for cloud service provider selection approach on which also has limited study. To determine these research gaps, an integrated fuzzy MCDM approach was proposed for a decision support system including fuzzy DEMATEL method for the interdependency of criteria, and fuzzy ANP method for qualitative parameters applying also fuzzy TOPSIS method.

In cloud service outsourcing, MCDM and handling fuzzy information are crucial for determining most suitable service provider. In view of this, a wide range of fuzzy information must be accomplished to achieve the best tradeoff between computational complexity and decision accuracy. The traditional approaches disregard some new trends in MCDM area and actual problems can be solved with this new concept using integrated MCDM methods. A new criteria could be added or deleted from our proposed framework, on the basis of practical requirement. Therefore, analyzing the structural model of fuzzy DEMATEL method, we firstly figured out which criteria are of more fundamental importance for the system, and which are not. In this thesis study we propose an integrated fuzzy MCDM framework for cloud technology service selection in three components; fuzzy DEMATEL to determine effect and cause criteria, and to reveal the relationships among criteria and dimensions and prioritize the criteria based on the type of relationships and severity of their effects on each criteria; fuzzy DEMATEL and fuzzy ANP for identifying criteria weights based on vague expressions and selecting the most effective alternative applying fuzzy TOPSIS method. It is also quite clear that few studies focused the integrated MCDM model using fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS on the selection of cloud computing technology service provider. For proving the applicability and creditability of the proposed methodology, our framework is validated by the case study based on real data obtained from case company Hipo to provide accurate, reliable prediction. Our proposed integrated MCDM approach not only ranked and selected an alternative, but also improved strategies to determine order of priorities to represent an important insight for decision-makers for selection process which is driven by numerous factors from cost to the vendor related.

The rest of this study is structured as follows: cloud computing technology service outsourcing is briefly reviewed in Section II. Section III presents a proposition of an integrated DEMATEL-ANP and TOPSIS methods in fuzzy environment for the cloud computing technology service provider selection framework and determines the cloud service provider evaluation criteria. Section IV includes the illustration of the proposed presents evaluation framework through a case study. Section V gives the concluding remarks with future directions.

2. CLOUD COMPUTING TECHNOLOGY SERVICE OUTSOURCING

2.1 CLOUD COMPUTING TECHNOLOGY

National Institute of Standards and Technology, Information Technology Laboratory defines cloud computing technology as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction (Mell & Grance, 2011).

The synergistic aim of cloud computing technology model is to provide on-demand resources in order to achieve higher throughput and be able to tackle large-scale computational problems (Rimal & Choi, 2012). While doing our jobs, we expect to access the information from everywhere we need. In view of this, cloud system delivers Internet-based technology in real time as an issue of both technology and economy. The cloud computing technology platform provides a flexible way in pay as you go manner for management and delivery of resources on Internet and it changes the financial model of the company and it enables us to focus on transforming our businesses. Cloud computing technology allows the forward thinking although moving to the cloud seems disruptive to the existing IT function. It provides more detailed provisioning and planning systems, and helps the enterprise to manage its own service level requirements by building redundancy into its cloud provisioning. Cloud also allows novel disaster recovery solutions that determine many of the pressing concerns of IT professionals.

Alshamaila & Papagiannidis (2013) focused on the empirically examined studies that need to be extant when considering the decision making processes on the adoption of cloud computing technology. In relevant study, cloud computing technology is described as a style of computing where massively scalable IT-related capabilities are provided as a service using Internet technologies to multiple external customers.

As a radical innovation in technology, cloud computing technology offers organisations a chance to improve their processes with free IT staff time to have a business and strategy focus and allow a much easier relationship with suppliers of services. Cloud computing is changing the future of businessas as a novel field in a broad sense, a part of distributed computing. It is a service, providing computing and software applications as well as data storage that can be easily accessed (Su et. al. 2012). The distinctive features of cloud computing technology would also offer third parties to be directly integrated with accountants, suppliers, regulators and allow them having opportunities with the flexibility that new technology provide. Today, companies prefer using the clouds for faster and reliable Internet. The internal roles have to be faster acting than before when we deploy cloud computing technology. With cloud computing technology, fast tracking gives you a robust system that makes assessments and changes really quickly.

The vulnerabilities of cloud computing technology platform must be critically examined which affects businesses trading on the internet before choosing an appropriate cloud service provider (Aleem & Sprott, 2013). There are many attributes that cloud computing technology has which should support its rapid diffusion and adoption on the technological basis. For example, the implementation of cloud computing technology is very important for large organisation with a large legacy of IT investments, infrastructure and outsourcing contracts. To determine the speed of implementation, exploitation and reinvention; cultural, structural and political legacies are also exist.

In the kind of commercial sector, people have started to think about how can they leverage these models within their business or how they can actually terminate existing models to be able to deliver these kind of levels of services internally and how they can drive costs out of their business and use these services. Additionally, particular studies prove that if a firm’s business processes satisfy its needs, it is likely less favorable to adopt cloud computing technology. Conversely, the firms that need higher levels of application functionality may be eager to adopt cloud computing technology.

2.1.1 CLOUD COMPUTING TECHNOLOGY SERVICES

The definition of cloud computing technology describes it as clusters of distributed computers (largely vast data centers and server farms) which provide on-demand resources and services over a networked medium (usually the Internet) seems to be commonly accepted (Sultan, 2011). Cloud offers enormous benefits to businesses such as reduced costs, since they no longer need to spend large amounts of capital on buying expensive application software or sophisticated hardware that they might never need (Park & Jeong, 2012).

The services that can be offered by cloud computing technology can be listed in the following three main areas (Sultan, 2011),

- *Infrastructure as a Service (IaaS):* Products offered via this mode include the remote delivery (through the Internet) of a full computer infrastructure (e.g., virtual computers, servers, storage devices, etc.). The most notable vendors under this category are Amazon's EC2, GoGrid's Cloud Servers, and Joyent
- *Platform as a Service (PaaS):* Services provided by the traditional computing model which involved teams of network, database, and system management experts to keep everything up and running (e.g., operating systems, databases, middleware, Web servers and other software) are now provided remotely by cloud computing technology providers under this layer. Among the early market leaders in this area are Google's App Engine, Microsoft's Azure, Amazon Web services, and Force.com.
- *Software as a Service (SaaS):* Under this layer applications are delivered through the medium of the Internet as a service. Instead of installing and maintaining software, one can simply Access it via the Internet; thus freeing oneself from complex software and hardware management. This type of cloud computing technology service offers a complete application functionality that ranges from productivity applications (e.g. word processing, spreadsheets, etc.) to programs such as those for Customer Relationship Management (CRM) or Enterprise-Resource Management (ERM). For example, products under this category include Yahoo mail, Google Apps, Saleforec.com, WebEx and Microsoft Office Live.

National Institute of Standards and Technology explains four deployment models of cloud computing technology (Mell & Grance, 2011). In view of this, private cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers (e.g., business units). It may be owned, managed, and operated by the organization, a third party, or some combination of them, and it may exist on or off premises, while community cloud infrastructure is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them, and it may exist on or off premises. Public cloud infrastructure is provisioned for open use by the general public. It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the cloud provider whereas hybrid cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds). Cloud computing benefits is shown in Figure 2.1,

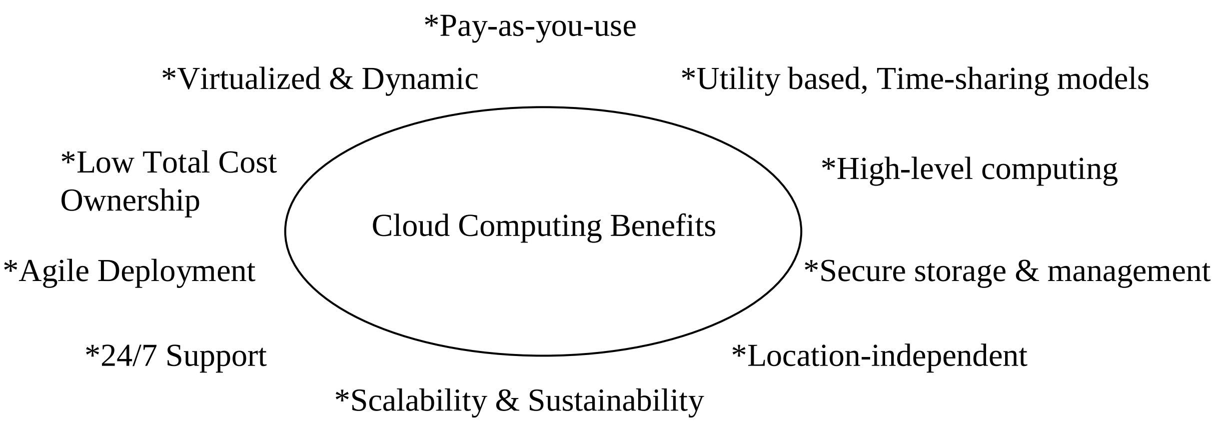

Figure 2.1. Cloud computing benefits

The main characteristics of cloud computing technology which help the development and adoption of this technology are service oriented, loose coupling, strong fault tolerant, business model and ease use (Gong et al. 2010). These characteristics of this area are proposed to understand the essentials of cloud computing technology. As service oriented conceptional characteristic, the details of inner implementations are determined. National Institute of Standards and Technology, Information Technology Laboratory defines the essential characteristics of cloud computing technology as on-demand self-service, broad network access, resource pooling, rapid elasticity and measured service. On-demand self service related with provisioning computing capabilities, such as server time and network storage without requiring human interaction with each service provider. Broad network access is the availability of capabilities over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops, and workstations). To serve multiple consumers, the provider’s computing resources are pooled and examples of resources include storage, processing, memory, and network bandwidth. Rapid elasticity stands for the Capabilities that can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward commensurate with demand.

2.1.2 WHY CLOUD COMPUTING TECHNOLOGY SERVICE OUTSOURCING?

The initiation point for cloud computing technology ideas started with outsourcing issues. The main problem of cloud service outsourcing process is to find an appropriate service provider. From the outsourcing domain, checking the different models, deciding the right criteria and choosing the right service provider are crucial for the design of cloud service contracts to create a healthy environment for cloud adoption.

The general areas of outsourcing used within IT management literature can be identified as Business process outsourcing (BPO), Information Technology Outsourcing (ITO) and Software development outsourcing (SDO) (Sebesta, 2013). BPO is more familier within large organisations, while ITO could be determined as the most enticing area for contemporary SMEs by cloud computing technologies.

ITO is quite popular area of outsourcing which is closely connected with the SaaS and cloud computing technology trends. ITO means to short, medium and long-term outsourcing and is a method of purchasing IT services for the management of IT infrastructure and business applications and it addresses total and partial outsourcing and insourcing in combination with geographical location layers like domestic near-shore and offshore, within the frame of a service vendor constellation (Bensch et. al. 2014). ICT (Information and Communication Technologies) services can be rapidly delivered to its customers by cloud computing technology as a recent emergence of new technologies. Characteristics of cloud computing and IT outsourcing is shown in Table 2.1,

Table 2.1 Characteristics of Cloud Computing and IT Outsourcing (based on Martens & Teuteberg, 2012)

Characteristic	IT outsourcing	Cloud Computing
Negotiation	User company can negotiate pricing models, payment structures and SLAs completely.	Standardized SLAs with little possibilities for negotiation and customization solely offered by large providers.
Location of the Servers (Hardware)	Servers are located in-house or in the data center of the provider	Hardware resources are solely located in third-party data centers
Architecture and Resource Management	One physical server is identified for one particular client	To realize economies of scale Multi-tenant architecture is determined
Pricing Model	Licensing fee or pricing scheme like consulting services (low pricing transparency); resources are not divisible	Price discrimination is detailed on an usage-depend basis (e. g. per gigabyte or to-the-minute billing)
Degree of Automation	Provides Low Degree of Automation: manual scaling of required resources	Provides High Degree of Automation: automatic scaling of required resources
Standardization of IT Services	Assures individual development, implementation and/or management of IT services	Assures highly substitutable and standardized Cloud Computing services
Legal Responsibility	Data protection and the legal effects are in the responsibilities of the user company	

As an activity in cloud computing technology, outsourcing provides more value than organizations' own IT department,. Therefore, the outsourcing organizations benefits from economies of scale and is able to develop core competencies in areas of IT that would be difficult for a company that is in a different industry and has other core competencies (Bayrak, 2013).

To improve the performance of IT outsourcing engagement, working together of the contractual provisions and commitment must be well understood in order to enhance the design and management of contracts (Goo et. al. 2008). The authors found three sets of theoretically distinct SLA (Service Level Agreement) characteristics as foundation, change, and governance characteristics, reflecting common underlying themes of management control often used by firms to manage outsourcing relationships. Gantman (2011) focused on a multidimensional set of characteristics, as diverse as an organization's business model and size, industry specifics, organizational culture and external environment, were found to play a role in IT outsourcing decisions.

When managing an outsourcing project, selection of an effective provider is a critical issue and it must be determined as a long and complicated process. In this thesis study, we focused on this important provider selection topic with a proposed framework to choose an optimum cloud computing technology service provider.

2.1.3 LITERATURE SURVEY FOR CLOUD COMPUTING TECHNOLOGY

When evaluating cloud computing technology services, a set of suitable measurement criteria or metrics must be chosen, according to the rich research in the evaluation of traditional computer systems, the selection of metrics plays an essential role in evaluation implementations (O'Brien et al. 2012).

A comprehensive service evaluation method is brought forth for the cloud service selection by two key functions dependence functions between different QoS criteria, and satisfaction functions associated with various criteria (Dou et al. 2013). Sebesta & Vorisek (2010) proposed a view on management and outsourcing of ICT services. Economic viability and flexibility were important for using cloud computing technology by a UK-based SME (Sultan, 2011). Response time can be used as a good parameter in a service level agreement. But for small, large, and extra large instances it is important to improve the stability of response time before signing any agreement between cloud provider and user (Alhamad et al. 2010).

Park & Jeong (2012) aim to find the most suitable SaaS ERPs according to their correlation with the criteria and to recommend a SaaS ERP package which best suits users' needs. For QoS (Quality of Service) attributes in the SMI, Garg & Versteeg (2012) offered comparative evaluation of cloud services in SMI by cloud service Measurement Index Consortium-CSMIC defining all key performance metrics applying AHP in cloud computing technology. While the outsourced resources are usually of diverse sources, various service quality levels, and different structures bring a big challenge for the selection of outsourced resources (Ni et al., 2012). In view of this challenge, a selection strategy, named *OS34CP* (Outsourced Service Selection Strategy for Cloud Platform, *OS34CP*), is provided to help the service outsourcing process, in cloud platform.

A set of measurement criteria must be chosen when evaluating cloud services. A comprehensive investigation into evaluation metrics in the cloud computing technology focused on the several research gaps for evaluating elasticity and security of commercial cloud services (Li et al., 2013). They also recommended employing a suite of mixed types of benchmarks to evaluate cloud services in the future. Grubisic (2013) investigated the market readiness to adopt the cloud as the future ERP platform, using AHP methodology. The results demonstrate a concern for data privacy and availability. An original research survey helps to choose an appropriate cloud service provider with 200 IT professionals working in public and private sectors (Aleem & Sprott, 2013).

The security concerns are well founded in a cloud environment due to increasing organized cyber crime activities. Walterbusch et al. (2013) present a TCO approach for cloud computing technology services. Cloud computing technology enables rapid delivery of ICT services to its customers to its customers (Sebesta, 2013), and covers the 'Metrics for Application Service Variants Comparison' for ICT service architecture separating a special category of metrics for future extent of outsourcing. M. Sebesta identified connection between the extent of outsourcing and outsourcing success when compared different success rates. This approach is reasonable thanks to technological progress and changes in business environment (Sebesta, 2013). Ergu & Peng (2014) propose a framework for SaaS software packages evaluation and selection by combining the virtual team concept with the BOCR model of ANP taking feedbacks into consideration for SMEs. From a systematic and practical perspective; Ren et al. (2013), presents a study for cloud manufacturing as well as a cloud-to-ground solution. Cloud manufacturing customers can have access to on-demand services, such as engineering design, simulation, production, assembling, testing and management.

When assessing cloud computing technology services, the authors portrayed a set of suitable measurement criteria or metrics. As such, every single evaluation study inevitably mentions particular metrics when reporting the evaluation process and/or result. Dou et al. (2013), believe that the category and capacity of a services engaged in cloud platform are limited compared to the nearly unlimited Web resources on Internet, so an outsourcing scenario is introduced for developing an elastic cloud platform through making a tradeoff between the unlimited Web resources and the limited services held by a business cloud platform. Sultan (2011) presented a case study of a cloud experience by a British SME in order to further highlight the perceived values of cloud computing technology in terms of cost and efficiency for real small enterprises. Sebesta (2010), introduces a comprehensive methodology, together with important criteria to be considered for a much suited ICT service provisioning practice.

Benlian & Hess (2011) analyzed as a first study the opportunities and risks associated with adopting SaaS as perceived by IT executives at adopter and non-adopter firms and analyzed the data collected through a survey of 349 IT executives at German companies. Their findings suggest that in respect to both SaaS adopters and non-adopters, security threats are the dominant factor influencing IT executives' overall risk perceptions.

Garg et al. (2012) propose a framework and a mechanism that measure the quality and prioritize cloud services. Such a framework can make a significant impact and will create healthy competition among cloud providers to satisfy their SLA and improve their QoS, they have also shown the applicability of the ranking framework using a case study. Considering that the selection of metrics plays an essential role in evaluation implementations, Li et al. (2013) performed a comprehensive investigation into evaluation metrics in the cloud computing technology domain based on this SLR. To the best of their knowledge, this is the only metrics-intensive study of cloud services evaluation (Li et al. 2013). Walterbusch et al. (2013) present a TCO approach for cloud computing technology services, it was found that decision processes in cloud computing technology are conducted ad hoc and lack systematic methods and the presented method raises the awareness of indirect and hidden costs in cloud computing technology. Ouedraogo & Mouratidis (2013) proposes a well-defined approach, known as the Complete-Auditable-Reportable or C.A.RE, as a way to minimize one’s exposure to the insecurity we live within the cloud, they also summaries some security threats to cloud services with the description specific for cloud computing technology.

Both a partial- and full IT outsourcing approach discussed in a systematic classification to give an overview concerning ITO efforts in information systems research (Bensch et al. 2014). According to the authors, there is a lack of procedural approaches in the IT outsourcing. A framework SelCSP (Select Cloud Service Provider) facilitates selection of trustworthy and competent service provider. Trustworthiness is computed from personal experiences gained through direct interactions or from feedbacks related to reputations of vendors while competence is assessed based on transparency in provider’s SLA (Ghosh et al. 2014). Cloud computing technology literature survey is shown in Table 2.2.

Table 2.2.a. Cloud Computing Technology Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**
Aleem & Sprott (2013)	The paper aims to examine the appropriateness of the cloud computing and to identify security concerns for businesses to deploy one of the cloud platforms.	Original Research Survey	Illustrative Example
Alshamaila et. al. (2012)	The paper aims to contribute a research on cloud computing, by studying the (SME) adoption process.	Interviewing	Illustrative Example
Akioka & Muraoka (2010)	The paper aims to verify usability of Amazon Elastic Computing Cloud (Amazon EC2) from the view of both value as a research tool, and cost performance.	Benchmarking	Case Study
Benlian & Hess (2011)	The paper aims to analyze the opportunities and risks associated with adopting SaaS as perceived by IT executives at adopter and non-adopter firms.	Interviewing	Case Study
Bensch et. al.(2014)	The paper aims to give an overview concerning ITO efforts in information systems research.	Literature Review	Illustrative Example
Cao (2012)	The paper aims to propose a two-stage vendor selection framework for IT outsourcing in microfinance banks.	MCDM-ANP, Social choice function, Gray relational analysis	Case Study
Casas & Schatz (2014)	The paper aims to provide a ground truth basis for developing future Cloud services with QoE requirements.	Lab Experiments, Field Trials	Case Study

Table 2.2.b Cloud Computing Technology Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**
DaSilva et. al. (2013)	The paper aims to examine how Amazon.com, Salesforce.com and Siebel responded to the disruptive power of the cloud computing technology.	Research Study	Illustrative Example
Dou et. al. (2013)	The paper aims to investigate the service requirements of the business cloud platform.	Feasibility Study of the Method	Case Study
Feng et. al. (2014)	The paper aims to question: When multiple IaaS providers face a common pool of potential users, how should each one of them choose the optimal price that maximizes its own profit?	Game Theoretic Technique	Illustrative Example
Godse & Mulik (2009)	The paper aims to present an approach to select an appropriate SaaS product for enterprises.	MCDM-AHP	Case Study
Gong et. al. (2010)	The paper aims to summarize general characteristics of cloud computing.	Research Study	Illustrative Example
Grubisic (2013)	The paper aims to investigate the market readiness to adopt the Cloud.	Interviewing, Questionnaire	Case Study
Helvacioglu (2010)	The paper aims to provide an analysis of cloud computing in Turkey by exploring the players and the domestic patterns of cloud system.	Research Study	Illustrative Example

Table 2.2.c Cloud Computing Technology Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**
Hsua et. al. (2013)	The paper aims to improve the overall performance of suppliers in terms of carbon management.	MCDM-DEMATEL	Case Study
Jula et. al. (2014)	The paper aims to investigate all of the credible and effective studies that have examined Cloud Computing Service Composition (CCSC).	Systematic Literature Review	Illustrative Example
Lenk et. al. (2011)	The paper aims to measure the performance of virtual machines in IaaS offerings.	Benchmarking	Case Study
Li et. al. (2012)	The paper aims to standardize the details of performance evaluation of commercial Cloud services.	Taxonomy	Illustrative Example
Losup et. al. (2011)	The paper aims to analyse the performance of clouds for Many Tasks Computing-based scientific computing.	Traditional System Benchmarking,Trace Based Simulation	Case Study
Mell & Grance (2011)	The paper aims to serve broad comparisons of cloud services and deployment strategies.	Research Study	Illustrative Example

Table 2.2.d Cloud Computing Technology Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**
Mohammad & Mcheick (2011)	The paper aims to shed light on software testing in Cloud system development and testing.	Research Work	Illustrative Example
Park & Jeong (2012)	The paper aims to find the most suitable SaaS ERPs recommending a SaaS ERP package which best suits users' needs.	Quality Network Model	Case Study
Ren et. al. (2013)	The paper aims to present a new perspective for cloud manufacturing, as well as a cloud-to-ground solution.	Systematic and Practical Perspective, Cloud Platform Prototype	Illustrative Example
Sangjae et. al. (2013)	The paper aims to evaluate Saas via four measures: learning and growth, internal business processes, customer performance, and financial performance.	Balanced Scorecard, Interview	Case Study
Sebesta (2010)	The paper aims to assist end user organisations in deciding the most suited ICT sourcing solution.	Research Work	Illustrative Example
Sebesta (2013)	The paper aims to analyse available outsourcing models in the literature and presents an integrated view on IT outsourcing strategies.	Researh Analysis, Strategy Development	Illustrative Example

Table 2.2.e Cloud Computing Technology Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**
Sebesta & Vorisek (2010)	The paper aims to provide a view on management and outsourcing of ICT services.	Research Study	Illustrative Example
Sultan (2011)	The paper aims to demonstrate the economic viability (and flexibility) of using cloud computing by a UK-based SME.	Interview	Case Study
Ukor & Carpenter (2011)	The paper aims to presents a new problem model for service selection based on the notion of request tokens.	Integer programming, Tree-search heuristic, Genetic Algorithm	Case Study
Wang & He (2014)	The paper aims to explore the successful service strategies of small cloud service providers in the cloud service market.	Interviews, Cloud Service Strategy Matrix	Case Study
Willcocks et. al. (2013)	The paper aims to understand the factors that drive and inhibit the adoption of cloud computing in relation to its use for innovative practices.	Surveys and Interviews	Case Study
Wu et. al. (2013)	The paper aims to investigate the circumstances that affect a firm's intention to adopt cloud computing technologies in support of its supply chain operations.	Regression Analysis	Case Study
Yiming & Yiwei (2011)	The paper aims to provide a method for the enterprises to select the best SaaS vendor.	MCDM-Fuzzy AHP	Illustrative Example

2.1.4 LITERATURE SURVEY FOR CLOUD COMPUTING TECHNOLOGY EVALUATION

Considering the evaluation of cloud computing technology services, (MCDM) techniques are accepted as effective tools (Whaiduzzaman et al. 2014), and hybrid fuzzy MCDM approaches have been used to improve service levels and meet user needs to assess the quality of cloud computing technology services. Many small and medium size businesses concern about the trustworthiness of cloud-based services which is also a Multi-Attribute Decision Making problem under the fuzziness of human judgment (Fan et al. 2014).

While AHP has been applied widely in different domains, the use of ANP in IT outsourcing studies is still relatively uncommon. Cao et al. (2012) proposed a hybrid model using ANP and Grey Relational Analysis (GRA) for bank's IT outsourcing vendor selection. Li and Brien (2012) focused on employing suitable metrics for evaluating cloud computing technology services. Alshamaila et al. (2012) identified the main factors in SME adoption of cloud services as relative advantage, innovativeness, supplier efforts and external computing support. To identify a wide spectrum of taxonomy, Rimal & Choi (2011) aimed at a better understanding of functional as well as architectural components that could benefit from cloudification. A multi-criteria-based decision framework offered by Menzel et al. (2011) can be applied to cloud computing technology which allows organizations to create evaluation methods for their needs. (AHP) was also used to select the best SaaS analyzing the related attributes (Yiming & Yiwei, 2011).

The other researches in cloud computing technology evaluation in the literature are, survey of cloud platforms and their future (Rad et al., 2009), cloud services measures for global use (Siegel & Perdue, 2012), Multi-criteria cloud service search engine for cloud computing systems (Kang & Sim, 2010), towards application performance prediction in cloud (Li et al., 2011), comparison of several cloud computing platforms (Peng et al., 2009), ontology and search engine for cloud computing system (Kang & Sim, 2011).

Table 2.3.a Cloud Computing Technology Evaluation Literature Survey

Authors	**Objective of the Study**	**Method**	**Illustrative Example/Case Study**
Alabool & Mahmood (2013)	The paper aims to select the Cloud Infrastructure Service (CIS) according to trust criteria.	MCDM-Fuzzy Set, VIKOR	Illustrative Example
Alhamad et. al. (2010)	The paper aims to develop performance metrics to measure and compare the scalability of the resources of virtualization on the cloud data centres.	Benchmarking	Case Study
Chen et al. (2010)	The paper aims to select a suitable outsourcing manufacturing partner in pharmaceutical R&D.	MCDM-Fuzzy TOPSIS	Case Study
Chang et al. (2012)	The paper aims to select cloud service providers in order to maximize the benefits with a given budget.	Dynamic Programming	Case Study
Chen et al. (2012)	The paper aims to help enterprises in tackling problems when adopting cloud computing.	Constraint Programming	Case Study
Chiu & Agrawal (2010)	The paper aims to evaluate caching and storage options on the Amazon Web Services Cloud.	Experimental Comparing	Case Study

Table 2.3.b Cloud Computing Technology Evaluation Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**
Cunha et. al. (2011)	The paper aims to investigate the Impact of deployment configuration and user demand on a social network application in the Amazon EC2 Cloud.	Popular Cloud Benchmarking	Case Study
Dou et. al. (2013)	The paper aims to put forward a service evaluation method is to select an outsourcing service.	Feasibility Study of the Method	Case Study
Ergu et al. (2013)	The paper aims to propose a model for task-oriented resource allocation in a cloud computing environment.	MCDM-AHP	Illustrative Example
Ergu & Peng (2013)	The paper aims to propose a framework for SaaS software packages evaluation and selection.	MCDM-ANP	Case Study
Fan et. al. (2014)	The paper aims to assess cloud service trustworthiness.	Fuzzy Gap Evaluation	Case Study

Table 2.3.c Cloud Computing Technology Evaluation Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**
Karim et al. (2013)	The paper aims to map the users' QoS requirements of cloud services to the right QoS specifications of SaaS.	MCDM-AHP	Illustrative Example, Case Study
Kossmann et. al. (2010)	The paper aims to list alternative architectures affecting cloud computing for database applications.	Benchmarking	Case Study
Le et al. (2014)	The paper aims to address the issue of uncertainty in cloud service requests, service descriptions, user and expert preferences, as well as evaluation criteria.	Fuzzy MCDM-Fuzzy TOPSIS, Fuzzy AHP, Fuzzy Ontology	Illustrative Example
Lee et. al. (2013)	The paper aims to evaluate SaaS.	Balanced Scorecards	Case Study
Li et al. (2011)	The paper aims to compare public-cloud providers.	Performance Comparison	Illustrative Example
Li et. al. (2012)	The paper aims to employ suitable metrics for evaluating commercial cloud services.	Systematic Literature Review	Illustrative Example
Li et. al. (2013)	The paper aims to synthesize the existing evaluation implementations and to outline the state of-the-practice.	Systematic Literature Review	Illustrative Example

Table 2.3.d Cloud Computing Technology Evaluation Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**
Garg et al. (2011)	This paper aims to define all key performance metrics for QoS attributes in the SMI framework.	MCDM-AHP	Case Study
Ghosh et. al. (2014)	The paper aims to compute risk involved in interacting with a given cloud service provider.	Risk Estimation	Case Study
Iosup et al. (2011)	Performance analysis of cloud computing services for many-tasks scientific computing.	Benchmarking	Case Study
Jung et al. (2013)	The paper aims to introduce a cloud recommendation platform, referred to as CloudAdvisor.	Benchmarking-based Approximation Technique	Case Study
Low & Chen (2012)	The paper aims to examine the critical criteria for outsourcing the cloud-based hospital information systems.	MCDM-Fuzzy Delphi Method and Fuzzy AHP	Case Study

Table 2.3.e Cloud Computing Technology Evaluation Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**
Martens & Teuteberg (2012)	The paper aims to determine the selection of Cloud Computing services.	Simulation, Sensitivity Analysis of the Model	Illustrative Example
Menzel et al. (2013)	TThe paper aims to offer a multi-criteria-based decision framework that can be applied to Cloud computing.	Multi-Criteria Comparison Method	Illustrative Example
Ni et. al. (2012)	The paper aims to help the service outsourcing process in cloud platform.	Research Work	Illustrative Example
Ooi et al. (2011)	The paper aims to compare the existing resource selection methods.	Resource Evaluation Technique, Fuzzy Logic	Illustrative Example
Ouedraogo & Mouratidis (2013)	The paper aims to select a cloud service provider in the age of cybercrime.	C.A.RE	Case Study
Petcu (2014)	The paper aims to propose a specific taxonomy on multiple Cloud topics.	Taxonomy	Case Study
Prodan & Ostermann (2009)	The paper aims to establish a taxonomy that identifies a common terminology, architectural and functional similarities.	Taxonomy	Illustrative Example

Table 2.3.f Cloud Computing Technology Evaluation Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**
Qu & Buyya (2014)	The paper aims to support cloud service selection proposing a new personalized trust evaluation system.	Hierarchical Fuzzy Inference System	Case Study
Rehman et al. (2014)	The paper aims to present a quality of service history of cloud services over different time periods.	Parallel Multi-Criteria Decision Analysis	Case Study
Rimal & Choi (2011)	The paper aims to identify a wide spectrum of taxonomy	Service-Oriented Taxonomical Spectrum	Illustrative Example
Ristova & Gecevska (2011)	The paper aims to provide a tool for decision makers regarding their investment in such of technologies.	MCDM-AHP	Illustrative Example
Saripalli & Pingali (2011)	The paper aims to present a MADMAC framework for adoption of clouds.	Multi Attribute Decision Making-Delphi Method	Illustrative Example
Silas et al. (2012)	The paper aims to propose an efficient service selection middleware for Cloud environment.	MCDM-ELECTRE	Illustrative Example
Sun et al. (2013)	The paper aims to select customer-centered cloud services.	MCDM-AHP	Case Study
Sun et al. (2014)	The paper aims to survey state-of-the-art cloud service selection approaches.	Literature Review	Illustrative Example
Sundareswaran et al. (2012)	The paper aims to propose a novel brokerage-based architecture for cloud service selection.	Indexing Technique	Illustrative Example

Table 2.3.g Cloud Computing Technology Evaluation Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**
Walterbusch et. al. (2013)	The paper aims to present a (TCO) approach for evaluating cloud computing services.	Multi-Method approach	Illustrative Example
Wang et al. (2014)	The paper aims to evaluate the quality of cloud service in service-oriented cloud computing.	Fuzzy synthetic decision, Fuzzy logic control	Illustrative Example
Whaiduzzaman et. al. (2014)	The paper aims to present MCDM methods in Cloud Service Selection.	Literature Review	Illustrative Example
Yazır et al. (2010)	The paper aims to propose a new approach for dynamic autonomous resource management in computing clouds.	MCDM-PROMETHEE	Illustrative Example
Zeng et al. (2009)	The paper aims to describe the cloud service architecture and key algorithms about service selection.	Two-step Algorithm.	Illustrative Example
Zhao et al. (2012)	The paper aims to find the appropriate services with satisfying the users'multiple QoS requirements.	Service Scheduling Algorithm	Case Study
Zheng et al. (2013)	The paper aims to identify the critical problem of personalized QoS ranking for cloud services.	Similarity Computation	Case Study

3. PROPOSED EVALUATION FRAMEWORK

A general view of the proposed cloud computing technology service provider evaluation framework is shown in Figure 3.1. Based on this framework, we identify firstly the cloud computing technology service provider evaluation criteria and we present the proposed integrated evaluation methodology in the following sub-sections.

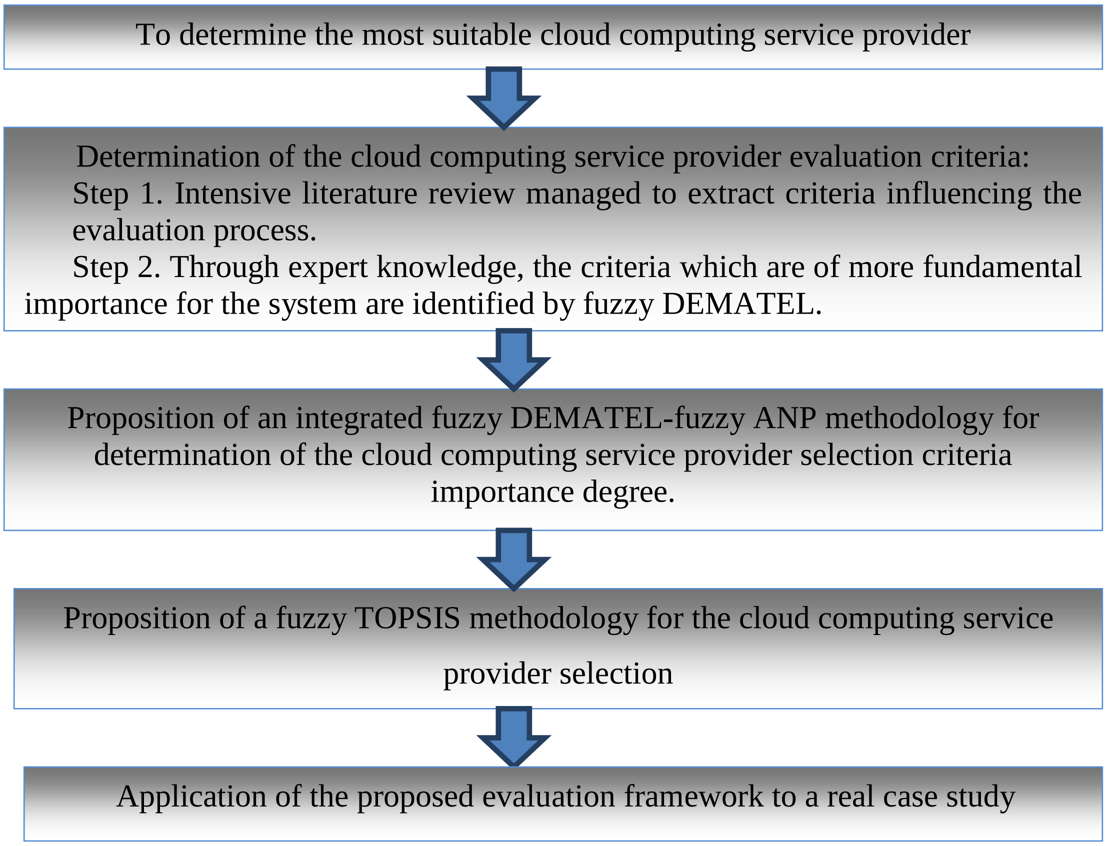

Figure. 3.1 A general view of the proposed evaluation framework

A set of complex criteria under different dimensions divided into a cause group and an effect group considering the interdependence among criteria. According to the results of fuzzy DEMATEL method, essential criteria for dimensions are figured out with combinings and extracts from the proposed framework, based upon the consensus of experts and academics

The service attributes are not independent of one another, and there are interdependencies between dimensions and attributes when evaluating different services. We need to consider more integrated techniques to model the relationships between multiple attributes and it must enable service selection based on mutually inter-dependent criteria. In view of this, firstly we determined the cloud computing service provider evaluation criteria, and then we proposed an integrated fuzzy DEMATEL-fuzzy ANP methodology for the cloud computing service provider selection, and after that we applied an application of this evaluation framework using fuzzy TOPSIS method.

3.1 CLOUD COMPUTING TECHNOLOGY SERVICE PROVIDER EVALUATION CRITERIA

After reviewing the related studies, cloud computing technology service provider selection is an important problem for users to compare different providers for the selection of an appropriate one to meet their needs. This problem must be determined as a MCDM problem involving multi-criteria and interdependent relationship between them. And there are also attributes like security which is really difficult to quantify. Seeing that, the introduction of an extensive set of criteria facilitates more precise evaluation results. Based on a detailed literature survey and interviews with industrial experts, seven evaluation dimensions were arranged according to different cloud computing technology service features covering the following aspects: Cloud security, cost, physical property, capacity, management services, service quality, vendor related.

To stay functional, legal and competitive; confidentiality, integrity, availability and auditability of business data are important criteria for businesses. The auditability feature has potential to give information about security and also drive the revision in addressing potential vulnerabilities that may emerge with time. (Ouedraogo & Mouratidis, 2013) The availability is the percentage of time a customer can use the cloud service which is an important characteristic according to user perspective.

Hosting data under another organization’s control is a critical issue in confidentiality concept especially for Banking, Security administration, Law Enforcement businesses verticals. Either maliciously or accidentally, a company’s data can be tampered or leaked by cloud provider’s employees, which can damage the reputation or finances of a company (Saripalli & Pingali, 2011). Involving data integrity and privacy, financial organizations generally need compliance with regulations.

A wide range of characteristics must be considered before moving to cloud computing technology. To measure the value of cost dimension for an alternative, all related costs in the decision making process need to be involved. In this way, the correctness of the decision making process becomes strengthened by adding more cost categories (Menzel et al. 2013). As one of the vital attributes, businesses analyze the cost evaluation metric when applying cloud computing technology to find answers the questions whether it is cost effective or not. The ability of expressing cost in the specific characteristics is highly adventageous for these business organizations. When faced with an outsourcing decision in cost incentive, it is recommended considering investment, maintenance, integration, flexibility and support costs for efficient decision making.

IT infrastructure must fulfill SLAs. Users want having stable and reliable cloud service but today high availability assurance isn’t provided by most cloud vendors although they made huge investments to make their system reliable. Service-level agreement management gives customer level of guarantee within contract legal bound.

The detailed explanation of Service Quality is described in three criteria as SLA Management, Service Stabiliy and Enrich Content. Service Stability defines the variability of a cloud service performance as promised to customers. To ensure good service quality, IT departments must pursue improved service levels for their efficient management of operations when it comes to consider the characteristics of enrich content . To meet the users’ needs, the capabilities of suppliers must enable specializing in particular specifications which gives higher quality of outsourced services.

The sub-taxonomy of vendor related criteria consists of vendor’s reputation, experience in related products, quality of support service attributes. Vendor reputation factor can be explained in two attributes, Number of clients/users defines the level of usage, which roughly indicates whether the product is fairly new entry or is well-established one. Sometimes a new product from well-known vendor may be preferred over a product having vast customer base which defines the brand value of vendor (Godse & Mulik, 2009). The experience in related products is an hardly measurable characteristic. Vendors’ success in the completed projects and satisfied customers may indicate the experience in related products but not as a qualitative view. To fulfill customer expectations and lead creation of quality services, appropriate quality specifications of support services must be determined.

Management services consists of deployment, configuration, billing, reporting and monitoring. The trust level of user towards cloud services will be increased by transparent metering (QoS and SLA aware). Pay-as-you go subscription or pay as you consume model of billing are introduced to charge the customer for resource usages (server-RAM-hours, gigabyte-storage-hours, CPU-hours, network bandwidth, server-configuration hours) (Rimal & Choi, 2012).

We need a monitoring and reporting mechanism to face problems such as increased management costs, and complex performance related factors. Monitoring systems record the resource utilization (such as CPU, RAM, disk, bandwidth) on each node. (Rimal & Choi, 2012). Performance feature can be divided into two parts as Physical Property part and Capacity part. A combination of a physical property of cloud service and its capacity represent an evaluated performance feature. All these elements of performance features are Communication, Computation, Memory and Storage in Physical Property part; Transaction Speed, Availability, Latency (Time), Reliability in Capacity part. (Rimal & Choi, 2012)

It is hard to evaluate the performance of cloud services without having knowledge and control over those services for cloud provider selection. In practise, a combination of a physical property of cloud services and its capacity represents an evaluated performance feature. (Li, et al 2012) Seeing that, performance feature can be divided into two parts as Physical Property part and Capacity part. All these elements of performance features are Communication, Computation, Memory and Storage in Physical Property part; Transaction Speed, Availability, Latency (Time), Reliability in Capacity part.

Spesifically, when adopting cloud services through Internet/network, communication will inevitably appear and it is not an internal physical property of cloud services. To reflect the computation of a commercial service, we can directly evaluate the virtual CPU, if the service exists as virtual machine (VM) instances. Memory and Cache can be treated as a unified physical property of cloud services. For storage property, different cloud services for example Amazon S3, vs. EC2. can supply storage either as the main functionality or partial respectively (Li, et al 2012).

The vendor-specific factors include vendor's reputation, experience in related products and quality of support services. The success of cloud computing technology services is directly affected by the vendor related dimension. It is important that we examine all these relevant factors in selecting a cloud computing technology system and a vendor who designs and delivers the system. There is a need systematic process of identifying and prioritizing relevant criteria and evaluating the trade-offs between technical, economic and performance criteria. (Tam & Tummala, 2001) Vendors' success in the completed projects and satisfied customers may indicate the experience in related products but not as a qualitative view. To fulfill customer expectations and lead creation of quality services, appropriate quality specifications of support services must be determined.

Garg et al. (2011) propose a framework (Service Measurement Index-Cloud) that can compare different cloud providers based on user requirements helping users to select whatever is appropriate to their needs. Seeing this framework, we can not easily quantify the attributes like security and user experience. This is a problem of multi-criteria decision-making involving multi-criteria and an interdependent relationship between them. The authors defines the stability critera for storage as the variance in the average read and write time. For computational resources, stability is described as the deviation from the performance specified in SLA.

To check the integrity and availability of the stored data, offering an efficient audit service by cloud service provider is necessary (Zhu et. al. 2012). And it is important to realize public auditability for CSS, so that data owners may resort to a TPA for periodically auditing the outsourced data.

R&D capability is a quantitative and positive attribute whose initial value can be the R&D investment of cloud vendors every year (Yimig & Yiwei, 2011). For Community support, the bigger the community that a cloud service has, the more support the firms can have. Community is a crucial part in the growth of an cloud technology (Lee et al, 2014). They can contribute to the development of the services and make it larger and more powerful. Support from the community is often in the form of documentation, plugins or add-on packages, bug detection, module development, and so on. “The amount of activity within the community is important to an open source project, as a thriving community will drive updates for the software, and increase the number of bugs reported and removed” (Bruce et al. 2006).
Cloud computing technology outsourcing dimensions and criteria is shown in Table 3.1.

Table 3.1 Cloud Computing Technology Outsourcing Dimensions and Criteria

Dimenison	Criteria	Definition
A: Cloud Security (Garg et al., 2013; Saripalli & Pingali, 2011; Su et al., 2012; Sun et al., 2014)	Confidentiality	*In the cloud, special attention should be paid on the confidentiality of the transactional information, in addition to the storage and processing of consumer's information. (Martens & Teuteberg, 2012; Ouedraogo & Mouratidis, 2013)
	Integrity	*Describes avoiding security risks of missing or corrupted data to ensure the integrity of outsourced data. (Godse & Mulik, 2009; Martens & Teuteberg, 2012; Zhu et al. 2012)
	Availability	*Characterises the extent to which computational resources are accessible and usable during a given time frame. (Jung et al. 2013; Martens & Teuteberg, 2012; Ouedraogo & Mouratidis, 2013)
	Auditability	*Descibes the potential to allow one to get information on the status of the security but also drive the revision of the security in view of addressing potential vulnerabilities that may emerge with time. (Garg et al., 2013; Ouedraogo & Mouratidis, 2013)
	Multi-tenant Trust	*Describes the interaction of the system as expected. (Ghosh et al., 2013; Qu & Buyya, 2014)
B: Cost (Ergu & Peng, 2014; Qu & Buyya, 2014; Low & Chen, 2012; Menzel et al. 2013; Silas et al., 2012; Su et al, 2012; Zeng et. al, 2009)	Investment Cost	*Describes direct initial costs to obtain and locate the IT Infrastructure. (Menzel et al. 2013)
	Maintenance Cost	*Describes frequently arising costs to maintain the IT infrastructure. (Ergu & Peng, 2014; Low & Chen, 2012; Martens & Teuteberg, 2012; Menzel et al. 2013)
	Integration Cost	*Describes the cost of integration of the IT infrastructure into the processes of the organization. (Menzel et al. 2013)
	Flexibility Cost	*Further IT infrastructure changes can raise the costs. (Tsai et al., 2010; Menzel et al. 2013)
	Support Cost	*Describes the expenses for support requests or consultants that should be considered in the overall costs. (Ergu & Peng, 2014; Menzel et al. 2013)
C: Physical Property Part (Li, et al. 2012)	Communication	*The data/message transfer between internal service instances, or between external client and the Cloud. (Li et al. 2012)
	Computation	*Refers to the computing-intensive data/job processing in the cloud. (Li et al. 2012)
	Memory	*Memory (Cache) is intended for fast access to temporarily saved data. (Garg et al., 2013; Li et al. 2012)
	Storage	*Storage is used to permanently store users' data, until the data are removed or the services are suspended intentionally. (Chang et al., 2012; Garg et al., 2013; Li et al. 2012; Ni & Yan, 2012)

D: Capacity Part (Garg et al., 2013; Li, et al 2012; Low & Chen, 2012; Yang et al. 2013)	Transaction Speed	*Describes how fast transactions can be processed. (Li et al. 2012)
	Availability	*Describes the probability a system works in functioning condition. (Chang et al., 2012; Garg et al., 2013; Li, et al. 2012; Yang et al. 2013; Zeng et. al, 2009)
	Latency (Time)	*Latency is related to the measure of time delay for a particular job. (Alhamad et al., 2010; Li, et al. 2012)
	Reliability	*The probability a system can properly perform its intended function. (Li et al. 2012; Low & Chen, 2012; Garg et al., 2013; Godse & Mulik, 2009; Silas et al., 2012; Yang et al. 2013)
E:Management Services (Rimal & Choi 2012)	Deployment	*Three stages of cloud application deployment lifecycle such as design, manage and deploy that need to be automated processes to reduce the burden across cloud deployment.
	Configuration	*Automated configuration of computers from the policy specification is very important for complex cloud environment.
	Billing	*Pay-as-you go subscription or pay as you consume model of billing for resource usages . (server-RAM-hours, gigabyte-storage-hours, CPU-hours etc..) (Rimal & Choi, 2012)
	Reporting	*Describes the system that provides reporting stuffs and produce the health report. (Rimal & Choi, 2012)
	Monitoring	*Describes monitoring cloud systems directly and easily with monitoring systems that record the resource utilization (such as CPU, RAM, disk, bandwidth) on each node. (Rimal & Choi, 2012)
F: Service Quality (Rimal & Choi, 2012; Tsai & Leu, 2010; Yiming & Yiwei, 2011)	SLA Management	*SLA is a component to negotiate and establish resource agreements between resource consumers and resource provider. (Ghosh et al., 2013; Rimal & Choi, 2012)
	Service Stability	*Describes providing services to customers as expected or promised. (Alhamad et al., 2010; Garg et al. 2012; Yiming & Yiwei, 2011; Karim et al. 2013),
	Enrich Content	*The quality aspects of the cloud service content. (Tsai & Leu, 2010)
G: Vendor Related (Low & Chen, 2012; Cardoso et al. 2004; Tam & Tummala, 2001)	Vendor's Reputation	*Includes two attributes; *Nımber of clients/users*, and *the brand value of vendor.* (Ghosh et al., 2013; Sun et al., 2014; Tam & Tummala, 2001; Yiming & Yiwei,2011),
	Experience in related products	*Experience of vendor about development of the software products (Alshamaila, 2012; Ghosh et al. 2013; Jadhav & Sonar, 2009; Low & Chen, 2012)
	Quality of support service	*Quality of support service requires the modification and extension of several workflow system components, and the development of additional modules. (Alhamad et al., 2010; Cardoso et al. 2004; Ni & Yan, 2012)

	Community support	*The bigger the community that a cloud service has, the more support the firms can have. (Lee et al, 2014)
	R&D capability	*A quantitative and positive attribute whose initial value can be the R&D investment of cloud vendors every year. (Su et al., 2012; Yiming & Yiwei, 2011)

3. 2 INTEGRATED FUZZY MCDM METHODOLOGY

3.2.1. FUZZY THEORY

Fuzzy Set Theory was introduced by Zadeh (1965) in order to deal with the vagueness of human thought and different linguistics variables in decision making. A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership function which assigns to each object a grade of membership ranging between zero and one (Zadeh, 1965).

Most operation managers also cannot provide exact numerical values to express opinions based on human perception and more realistic measurement uses linguistic assessments. Metrics can be measured as linguistic labels such as very high, high, middle, low, and very low (Wang & Chuu, 2004). It is better to convert the linguistic estimation into fuzzy numbers to integrate opinions, ideas, and motivations of an individual decision-maker. Thus, the group decision-making problems have created a need to employ fuzzy logic (Lin & Wu, 2008). In practice, the triangular fuzzy number is commonly used. In the following, some essential definitions of fuzzy set theory were reviewed (Chen, 1996; Tseng & Lin, 2008),

Let X be the universe of discourse, $X = \{x_1, x_2, x_3, \ldots x_n\}$.

A fuzzy set $\tilde{A}$ of X is a set of order pairs $\{(x_1 , f_{\tilde{A}}(x_1)), (x_2 , f_{\tilde{A}}(x_2), (x_3 , f_{\tilde{A}}(x_3))\}$, where $f_{\tilde{A}} : X \rightarrow [0, 1]$ is the membership function of $\tilde{A}$ and $f_{\tilde{A}}(x_i)$ stands for the membership degree of x_i in $\tilde{A}$.

Definition 1 When X is a continuous rather than a countable or finite set, the fuzzy set $\tilde{A}$ is denoted as: $\tilde{A} = \int X f_{\tilde{A}}(x_i)/(x)$, where $x \in X$.

Definition 2 When X is a countable or finite set, the fuzzy set $\tilde{A}$ is represented as $\tilde{A} = \sum_i f_{\tilde{A}}(x_i)/(x_i)$, where $x_i \in X$.

Definition 3 A fuzzy set $\tilde{A}$ of the universe of discourse X is normal when its membership function $f_{\tilde{A}}(x)$ satisfies max $f_{\tilde{A}}(x)$ =1.

Definition 4 A fuzzy number is a fuzzy subset in the universe of discourse X that is not convex but also normal.

Definition 5 The fuzzy α-cut $\tilde{A}_\alpha$ and strong α-cut $\tilde{A}_{\alpha+}$ of the fuzzy set $\tilde{A}$ in the universe of discourse X is defined by

$$\tilde{A}_\alpha = \{ x_i \mid f_{\tilde{A}}(x_i) \geq \alpha , x_i \in X \} \text{, where } \alpha \in [0,1] \quad (1)$$

$$\tilde{A}_{\alpha+} = \{ x_i \mid f_{\tilde{A}}(x_i) \geq \alpha , x_i \in X \} \text{, where } \alpha \in [0,1]$$

Definition 6 A fuzzy set $\tilde{A}$ of the universe of discourse X is convex if and only if every $\tilde{A}_\alpha$ is convex, that is $\tilde{A}_\alpha$ is a close interval of R. It can be written as

$$\tilde{A}_\alpha = [P_1^{(\alpha)}, P_2^{(\alpha)}] \text{, where } \alpha \in [0,1] \quad (2)$$

Definition 7 A triangular fuzzy number (TFN) can be defined as a triplet (α_1, α_2, α_3); the membership function of the fuzzy number $\tilde{A}$ is defined.

$$f_{\tilde{A}}(x) = \begin{Bmatrix} 0, \ x < \alpha_1 \\ (x - \alpha_1)/(\alpha_2 - \alpha_1), \alpha_1 \leq x \leq \alpha_2 , \\ (\alpha_3 - x)/(\alpha_3 - \alpha_2), \alpha_2 \leq x \leq \alpha_3 , \\ 0, \ x > \alpha_3 \end{Bmatrix} \quad (3)$$

Let $\tilde{A}$ and $\tilde{B}$ be two TFN parameterized by the triplet (α_1, α_2, α_3) and (b_1, b_2, b_3) respectively, then the operational laws of these two TFN as follows:

$$\begin{aligned} \tilde{A} \ (+) \ \tilde{B} &= (\alpha_1, \alpha_2, \alpha_3) \ (+) \ (b_1, b_2, b_3) \\ &= (\alpha_1 + b_1, \alpha_2 + b_2, \alpha_3 + b_3) \\ \tilde{A} \ (-) \ \tilde{B} &= (\alpha_1, \alpha_2, \alpha_3) \ (-) \ (b_1, b_2, b_3) \\ &= (\alpha_1 - b_1, \alpha_2 - b_2, \alpha_3 - b_3) \\ \tilde{A} \ (\times) \ \tilde{B} &= (\alpha_1, \alpha_2, \alpha_3) \ (\times) \ (b_1, b_2, b_3) \\ &= (\alpha_1 b_1, \alpha_2 b_2, \alpha_3 b_3) \\ \tilde{A} \ (\div) \ \tilde{B} &= (\alpha_1, \alpha_2, \alpha_3) \ (\div) \ (b_1, b_2, b_3) \end{aligned} \quad (4)$$

$= (a_1/b_3,\ a_2/b_2\ , a_3/b_1)$
Where α_1, α_2 and α_3 are real numbers and $\alpha_1 \leq \alpha_2 \leq \alpha_3$.

There are different kinds of defuzzification methods which can be divided into two classes by considering either the vertical or the horizontal representation of possibility distribution (Oussalah, 2002). The most widely used defuzzification method is the Centroid (Center-of-gravity) Method (Yager & Filev, 1994). However, this method cannot distinguish two different-shaped fuzzy numbers which can be converted into the same crisp number (Wu & Lee, 2007). Therefore, this study applies the CFCS (Converting Fuzzy data into Crisp Scores) defuzzification method developed by Opricovic & Tzeng (2003) which can give a better crisp value than the Centroid method. The CFCS method is based on the procedure of determining the left and right scores by fuzzy minimum and maximum; the total score is determined as a weighted average according to the membership functions.

Let $\widetilde{w}_{ij}^{k} = (\ a_{1ij}^{k}, a_{2ij}^{k}, a_{3ij}^{k})$; suppose that a decision group has k members, take $\widetilde{w}_{ij}^{k}$ to present the fuzzy weight of ith criteria which affects the jth criteria assessed by kth evaluators.

Normalization:

$$xa_{1ij}^{k} = \left(a_{1ij}^{k} - \min a_{1ij}^{k}\right) / \ \Delta_{\min}^{\max}$$
$$xa_{2ij}^{k} = \left(a_{2ij}^{k} - \min a_{1ij}^{k}\right) / \ \Delta_{\min}^{\max}$$
$$xa_{3ij}^{k} = \left(a_{3ij}^{k} - \min a_{1ij}^{k}\right) / \ \Delta_{\min}^{\max} \qquad (5)$$

Where $\Delta_{\min}^{\max} = \max a_{3ij}^{k} - \min a_{1ij}^{k}$

Compute left (ls) and right (rs) normalized value:

$$xls_{ij}^{k} = xa_{2ij}^{k} / \left(1 + xa_{2ij}^{k} - xa_{1ij}^{k}\right)$$
$$xrs_{ij}^{k} = xa_{3ij}^{k} / \left(1 + xa_{3ij}^{k} - xa_{2ij}^{k}\right) \qquad (6)$$

Compute total normalized crisp value

$$x_{ij}^{k} = \left[xls_{ij}^{k}\left(1 - xls_{ij}^{k}\right) + xrs_{ij}^{k} xrs_{ij}^{k}\right] / \left[1 - xls_{ij}^{k} + xrs_{ij}^{k}\right] \qquad (7)$$

Compute crisp values:

$$w_{ij}^{k} = \min a_{1ij}^{k} + x_{ij}^{k} \Delta_{\min}^{\max} \qquad (8)$$

Integrate crisp values:

$$\widetilde{w}_j = \frac{1}{k}\left(\widetilde{w}_{ij}^1 + \widetilde{w}_{ij}^2 + \widetilde{w}_{ij}^3 + \cdots + \widetilde{w}_{ij}^k\right) \quad (9)$$

3.2.2 FUZZY DEMATEL METHOD AND ITS LITERATURE SURVEY

There are some studies involving Fuzzy Theory and DEMATEL methods.Wu & Lee (2007) proposed an effective method combining fuzzy logic and DEMATEL to segment required competencies for better promoting the competency development of global managers. In order to verify management strategies and satisfy customer's needs, Hsu, Chen and Tzeng (2007) used the fuzzy DEMATEL for finding the key factors and attributes in building the structure relations of an ideal Customer's Choice Behavior Model. Traditional Technology Acceptance Model (TAM) studies establish and verify the model of causal relationship between variables by factor analysis or structural equation modeling (Lee et al. 2011). However, some technology is highly complicated, not all respondents have thorough comprehension and certain variables are not compatible with assumption of independence.

A wide range of criteria is used to analyze the quality of cloud computing technology services. But it can be difficult to effectively analyze and increase usage intentions of cloud computing technology services when the criteria have interdependent or interactive characteristics. Therefore, Su et al. 2012 modeled strategies that can be pursued to improve the adoption of cloud services for green innovation entertainment purposes in Taiwan using a novel hybrid fuzzy MCDM method that combines the fuzzy concept with the DEMATEL (used to construct the FSINRM), fuzzy DANP (used to determine the relative weights of the criteria) and fuzzy VIKOR (used to determine the improvement priority) methods. To identify main Green Supply Chain Management criteria described in practices, performances and external drivers, Lin (2013) proposed fuzzy DEMATEL method trying to discover the interactive relationships.

Many enterprises consider outsourcing to be an operational initiative to increase competitiveness, reduce costs and risks and enhance operating flexibility (Su et al. 2012). Datta & Mahapatra (2014) proposed a hierarchical IT Outsourcing risk structure representation to develop a formal model for qualitative risk assessment using the concept of 'Incentre of centroids method' in generalized trapezoidal fuzzy numbers.

Fuzzy DEMATEL method literature survey is shown in Table 3.2.

Table 3.2.a Fuzzy DEMATEL Method Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**	**Country**	**Firm**
Chang et. al. (2011)	This study aims to find influential factors in selecting Supply Chain Management suppliers.	Fuzzy DEMATEL	Case Study	Taiwan	Electronic Industries
Chen et. al. (2008)	This study aims to develop a causal and dffect model of hot spring service quality expectation.	Fuzzy DEMATEL	Case Study	Taiwan	Hot Spring Hotel
Chou et. al. (2012)	This study aims to evaluate the performance of Human Resource for Science and Technology (HRST).	Fuzzy AHP, Fuzzy DEMATEL	Illustrative Example		
Fekri et. al. (2009)	This study aims to help the NPD (New Product Development) managers for improving their decision making quality.	Fuzzy DEMATEL	Case Study	Iran	Iranian Companies
Hiete et. al. (2012)	This study aims to analyze and correct for relations between variables in a composite indicator for disaster resilience.	Fuzzy DEMATEL	Illustrative Example		
Hsu et. al. (2007)	This study aims to find a more useful way to solve customers purchasing-decision problems and construct a Customer's Choice Behavior Model (CCBM) for Customer's Choice.	Fuzzy DEMATEL	Case Study	Taiwan	Automobile market

Table 3.2.b Fuzzy DEMATEL Method Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**	**Country**	**Firm**
Hung et. al. (2007)	This study aims to help managers in assessings complex and confusing situations, initiating Knowledge Management, identifying the causal relationships between problems.	Fuzzy DEMATEL	Illustrative Example		
Jassbi et. al. (2011)	This study aims to build the structural relationships among the strategic objectives for a strategy map.	Fuzzy DEMATEL, Strategy mapping	Case Study	Iran	Saipa Yadak Trading Company
Jeng & Tzeng (2012)	The study aims to examine whether social influence affects medical professionals' behavioral intention to use while introducing a new Clinical Decision Support System (CDSS).	Technology Acceptance Model (TAM), Fuzzy DEMATEL	Case Study	Taiwan	Medical Center
Lin (2013)	This study aims to examine the influential factors among eight criteria of three main Green Supply Chain Management practices, namely practices, performances, and external pressures.	Fuzzy DEMATEL	Illustrative Example		
Lin & Wu (2008)	This study aims to gather group ideas and analyze the cause–effect relationship of complex problems in fuzzy environments.	Fuzzy DEMATEL	Illustrative Example		

Table 3.2.c Fuzzy DEMATEL Method Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**	**Country**	**Firm**
Lin et. al. (2011)	This study aims to aid in GSCM performance evaluation in the industry under uncertainty.	Fuzzy DEMATEL	Case Study	Taiwan	Automobile Manufacturing Industry
Liou et. al. (2008)	This study aims to build an effective safety management system for airlines.	Fuzzy DEMATEL	Case Study	Taiwan	Taiwanese civil aviation industry
Lee et. al. (2011)	This study aims to calculate the causal relationship and level of mutual effect, building on the technology acceptance model by applying the Product Life Cycle Management (PLM) system.	Fuzzy DEMATEL, Technology Accetance Model	Case Study	Taiwan	AUO Optronics Corporation
Su et. al. (2012)	This study aims to improve the adoption of cloud services for green innovation entertainment purposes in Taiwan.	Fuzzy DEMATEL, Fuzzy DANP, Fuzzy VIKOR	Case Study	Taiwan	Mobile communications industry
Samantra et. al. (2014)	This study aims to develop a unified hierarchical risk model that can effectively be used to estimate the degree of risk extent in IT outsourcing.	Fuzzy Set Theory	Case Study	India	One of the leading IT Industry

Table 3.2.d Fuzzy DEMATEL Method Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**	**Country**	**Firm**
Tseng (2009)	This study aims to present a perception approach to deal with real estate agent service quality expectation ranking with uncertainty.	Grey theory Fuzzy set theory DEMATEL	Case Study	Taiwan	Real Estate Agent
Tseng & Lin (2009)	This study aims to build up a cause and effect model for the government of Metro Manila.	Fuzzy DEMATEL	Case Study	Metro Manila	Government
Tseng et. al. (2011)	This study aims to prove the impact of IT in supply chain management.	Fuzzy DEMATEL	Case Study	Vietnam	Vietnam textile industry
Wu (2012)	This study aims to segment the critical factors for successful KM implementations.	Fuzzy DEMATEL	Case Study	Taiwan	Company G
Wu et. al. (2007)	This study aims to segment required competencies for better promoting the competency development of global managers.	Fuzzy DEMATEL	Case Study	Taiwan	Company P
Zhou et. al. (2011)	This study aims to identify the CSFs of emergency management, and classify and analyze these CSFs according to the structural relationship in order to improve emergency management systemically.	Fuzzy DEMATEL	Illustrative Example		

3.2.3 FUZZY ANP METHOD AND ITS LITERATURE SURVEY

ANP is a general form of AHP first introduced by Saaty (1996). it has been used in solving many complicated problems. The AHP only employs a unidirectional hierarchical relationships among decision levels, but the ANP method is capable of handling interdependences through the stucture of a supermatrix. And these interdependencies must be evaluated within levels of clusters and mutually dependent elements in a cluster.

Unclear human judgment causes difficulties in determining exact numerical values, so fuzzy logic is logical in cloud service evaluation combining both fuzzy set theory and ANP. The use of the ANP in provider selection has increased substantially in recent years because this method can consider the interrelationships among elements in a problem setting.

In the literature many researches in different fields such as supplier selection as applied to IC packaging (Kang et al. 2012), and for measurement of the sectoral competititon level (SCL) (Dagdeviren & Yuksel, 2010), selecting the location of distribution center (Wei & Wang, 2009), and proposing an experts knowledge-based systems measurement model (Chang et. al. 2011),

(Dargi et. al. 2014) focused on developing a framework to support the supplier selection process, (Ozgen & Tanyas, 2011) applied Fuzzy ANP to consider a joint selection of customs broker agency and international road transportation firm, (Changa et. al. 2015) evaluates the risk level for both intra-organizational cultures and for different industries in implementing an (ERP) system. Fuzzy ANP method literature survey is shown in Table 3.3.

Table 3.3.a Fuzzy ANP method Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**	**Country**	**Firm**
Ayub et. al. (2009)	This study aims to provide an approach to minimizing subjective judgments in the crucial procedures of personnel selection.	Fuzzy ANP	Illustrative Example		
Boran et. al. (2010)	This study aims to develop a fuzzy decision support system for commodity acquisition.	Fuzzy ANP	Illustrative Example		
Chang et. al.(2011)	This study aims to propose an experts knowledge-based systems measurement model.	Fuzzy ANP	Case Study	Taiwan	Firm A, B, C, D
Chang et. al. (2015)	This study aims to evaluate the risk level for both intra-organizational cultures and for different industries in implementing an enterprise resource planning (ERP) system.	Fuzzy ANP	Illustrative Example		
Dagdeviren & Yuksel (2010)	This study aims to measure the sectoral competition level of an organization within the framework of Porter's five forces analysis.	Fuzzy ANP	Case Study	Turkey	Manufacturing Company
Dargi et. al. (2014)	This study aims to develop a framework to support the supplier selection process.	Fuzzy ANP	Case Study	Iran	Automative Company
Guneri et. al. (2009)	This study aims to present an approach for shipyard location selection.	Fuzzy ANP	Illustrative Example		
He et. al. (2014)	This study aims to measure the complexity of mega construction projects in China.	Fuzzy ANP	Case Study	China	World construction project

Table 3.3.b Fuzzy ANP Method Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**	**Country**	**Firm**
Isalou et. al. (2013)	This study aims to locate a suitable location for landfilling municipal solid wastes generated in Iran.	Fuzzy ANP	Case Study	Kahak Town, Iran	Sanitary Landfill site
Jaafari et. al. (2015)	This study aims to select the best wood extraction method.	Fuzzy ANP, BOCR	Case Study	Iran	Caspian (Hyrcanian) Forest
Ju (2011)	This study aims to implement risk assessment of runway excursion accident.	Fuzzy ANP	Illustrative Example		
Kang et. al. (2012)	This study to evaluate various aspects of suppliers as applied to IC packaging.	Fuzzy ANP	Case Study	Taiwan	IC Packaging factory
Kumar & Maiti (2012)	This study aims to model the problem of maintenance policy selection for an industrial unit.	Fuzzy ANP	Case Study	India	A chemical safety consultancy firm
Lin & Hsu (2011)	This study aims to create a hierarchical framework for brand image management.	Fuzzy ANP	Case Study	Taiwan	Four outstanding Department stores
Nuhodzic et. al. (2010)	This study aims to choose the optimal organizational structure of a rail company.	Fuzzy ANP	Case Study	Serbia	Montenegro Railway

Table 3.3.c Fuzzy ANP Method Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**	**Country**	**Firm**
Ozdagoglu (2012)	This study aims to present a systematic approach to facility location and evaluation.	Fuzzy ANP, Fuzzy AHP	Case Study	Turkey	Company from food Industry
Ozgen & Tanyas (2011)	This study aims to consider a joint selection of customs broker agency and international road transportation firm.	Fuzzy ANP	Illustrative Example		
Qu et. al. (2009)	This study aims to evaluate materiel support plan in development phase.	Fuzzy ANP	Illustrative Example		
Razmi et. al. (2009)	This study aims to evaluate and select suppliers designing a decision support system.	Fuzzy ANP, Non-linear programming	Illustrative Example		
Razmi et. al. (2009)	This study aims to develop a practical framework for ERP readiness assessment.	Fuzzy ANP	Case Study	Iran	Power (electricity) holding company
Sevkli et. al. (2012)	This study aims to provide a quantitative basis to analytically determine the ranking of the factors in SWOT analysis.	Fuzzy ANP, Fuzzy AHP	Case Study	Turkey	Turkish airline industry
Shafiee (2015)	This study aims to select the ‘‘most appropriate risk mitigation strategy’’ for offshore wind farms.	Fuzzy ANP	Case Study		Offshore Wind Farm

Table 3.3.d Fuzzy ANP Method Literature Survey

Authors	**Objective of the Study**	**Method**	**Case Study/Illustrative Example**	**Country**	**Firm**
Vinodh et. al. (2010)	This study aims to select the best agile concept in a manufacturing organisation	Fuzzy ANP	Case Study	India	Salzer, Electronics Limited
Vinodh et. al. (2011)	This study aims to determine best supplier in a manufacturing organisation.	Fuzzy ANP	Case Study	India	Salzer Electronics Limited
Wei & Wang (2009)	This study aims to select the location of distribution center.	Fuzzy ANP	Illustrative Example		
Wei et. al. (2010)	This study aims to select a supplier effectively in supply chain management.	Fuzzy ANP	Illustrative Example		
Yang et. al.(2010)	This study aims to translate the ambiguous and abstract concept of the trust into quantifiable, specific indicators to be evaluated.	Fuzzy ANP	Illustrative Example		
Yang et. al. (2010)	This study aims to design a group decision support system under uncertainty.	Fuzzy ANP	Case Study	China	Oil company
Yazgan (2011)	This study aims to select a best dispatching rule.	Fuzzy ANP	Illustrative Example		

3.2.4 FUZZY TOPSIS METHOD AND ITS LITERATURE SURVEY

TOPSIS method was proposed by Hwang & Yoon (1981) based on the concept that the chosen alternative should have the shortest distance from the positive-ideal solution and the longest distance from the negative-ideal solution. Under many conditions, incomplete and non-obtainable data make accurate judgment impossible to model decision problems. Extension of the TOPSIS method to the fuzzy environment is necessary because in many conditions, the ratings of the alternatives are not known precisely and can not be treated as crisp numerical data. Triangular fuzzy number for fuzzy TOPSIS is used by the decision makers because of the easy usage to formulate decision problems (Rouhani et. al. 2012).

In literature, fuzzy TOPSIS method was applied in different field. Jiang et. al. adopted fuzzy TOPSIS to solve Group Belief MCDM problems. Chen (2011) used this method aiming at estimating the importance of criteria and reducing the leniency bias in multiple-criteria decision analysis based on interval-valued fuzzy sets.

Taylan et. al. (2014) applied fuzzy TOPSIS to use novel analytic tools to evaluate the construction projects and their overall risks under incomplete and uncertain situations. Chamodrakas & Martakos (2012) focused on the selection the optimal network which achieves the best balance between performance and energy consumption. Sun & Lin (2009) used this method to evaluate the competitive advantages of shopping websites. Kim et. al. (2013) aimed to prioritize the best sites for treated wastewater instream use in an urban watershed using fuzzy TOPSIS. Fuzzy TOPSIS method literature survey is shown in Table 3.4.

Table 3.4.a Fuzzy TOPSIS Method Literature Survey

Authors	Objective of the Study	Method	Case Study/Illustrative Example	Country	Firm
Awasthi et. al. (2011)	This work aims to evaluate sustainable transportation systems.	Fuzzy TOPSIS	Illustrative Example		
Cavallaro (2010)	This work to investigate the feasibility of utilizing a molten salt.	Fuzzy TOPSIS	Illustrative Example		
Chamodrakas & Martakos (2012)	This work aims to select the optimal network which achieves the best balance between performance and energy consumption.	Fuzzy TOPSIS	Illustrative Example		
Chen & Hung (2010)	This study aims to select a suitable OMP in pharmaceutical R&D.	Fuzzy TOPSIS, Fuzzy AHP	Illustrative Example		
Chen (2011)	This work aims to estimate the importance of criteria and reducing the leniency bias in multiple-criteria decision analysis.	Fuzzy TOPSIS	Illustrative Example		
Chu & Lin (2009)	This work aims to provide an interval arithmetic based fuzzy TOPSIS model.	Fuzzy TOPSIS	Illustrative Example		
Ghorbani et. al. (2011)	This work aims to determine strategy priorities by SWOT analysis.	Fuzzy TOPSIS	Illustrative Example		
Jiang et. al.(2011)	This work aims to solve Group Belief MCDM problems.	Fuzzy TOPSIS	Illustrative Example		

Table 3.4.b Fuzzy TOPSIS Method Literature Survey

Authors	Objective of the Study	Method	Case Study/Illustrative Example	Country	Firm
Junior et. al. (2014)	This work aims to choose more effective approaches for supplier selection.	Fuzzy TOPSIS, Fuzzy AHP	Illustrative Example		
Kannana et. al. (2009)	This work aims to guide the selection process of best third Party Reverse Logistics Provider.	Fuzzy TOPSIS, Interpretive Structural Modeling (ISM)	Case Study	India	Battery Recycling Industry
Kannan & Jabbour (2014)	This work aims to select green suppliers for a Brazilian electronics company.	Fuzzy TOPSIS	Case Study	Brazil	Electronics Assembling Company
Kelemenis et. al. (2011)	This work aims to support managers' selection.	Fuzzy TOPSIS	Illustrative Example		
Kim et. al. (2013)	This work aims to prioritize the best sites for treated wastewater instream use in an urban watershed.	Fuzzy TOPSIS	Case Study	South Korea	Ten sites in an urban watershed
Krohling & Campanharo (2011)	This work aims to find out the best combat responses in case of accidents with oil spill in the sea.	Fuzzy TOPSIS	Case Study	Brazil	Brazilian Oil Reservoirs
Mahdevari et. al. (2014)	This work aims to assess the risks associated with human health in order to manage control measures and support decision making.	Fuzzy TOPSIS	Case Study	Iran	Three Underground Coal Mines

Table 3.4.c Fuzzy TOPSIS Method Literature Survey

Authors	Objective of the Study	Method	Case Study/Illustrative Example	Country	Firm
Matin (2011)	This work aims to solve personnel selection problem.	Fuzzy TOPSIS	Illustrative Example	Iran	Padir Company
Roszkowsk & Wachowicz (2015)	This work aims to support the process of building the scoring system for negotiation offers in ill-structured negotiations.	Fuzzy TOPSIS	Illustrative Example		
Rouhani et. al. (2012)	This work aims to propose a new model to provide a simple approach to assess enterprise systems in business intelligence aspects.	Fuzzy TOPSIS	Illustrative Example		
Singh & Benyoucef (2011)	This study aims to solve the sealed bid,multi-attribute reverse auction problem of e-sourcing in which the sales item is defined by several attributes.	Fuzzy TOPSIS	Illustrative Example		
Sun & Lin (2009)	This work aims to evaluate the competitive advantages of shopping websites.	Fuzzy TOPSIS	Illustrative Example		
Tansel & Yurdakul (2010)	This work aims to develop a quick credibility scoring decision support system.	Fuzzy TOPSIS	Case Study	Turkey	Manufacturing Firms
Taylan et. al. (2014)	This work aims to use novel analytic tools to evaluate the construction projects and their overall risks under incomplete and uncertain situations.	Fuzzy TOPSIS, Fuzzy AHP	Case Study	Saudi Arabia	King Abdulaziz University
Torlak et. al. (2011)	This work aims to analyze business competition in the Turkish domestic airline industry.	Fuzzy TOPSIS	Case Study	Turkey	Turkish Airline Industry

Table 3.4.d Fuzzy TOPSIS Method Literature Survey

Authors	Objective of the Study	Method	Case Study/Illustrative Example	Country	Firm
Wang & Lee (2009)	This work aims to develop a fuzzy TOPSIS approach based on subjective weights and objective weights.	Fuzzy TOPSIS	Illustrative Example		
Wang et. al. (2009)	This work aims to simplify the complicated metric distance method, and proposes an algorithm to modify Chen's Fuzzy TOPSIS.	Fuzzy TOPSIS, Fuzzy AHP	Illustrative Example		
Wang (2014)	This work aims to evaluate of financial performance for Taiwan container shipping companies.	Fuzzy TOPSIS	Case Study	Taiwan	Container Shipping Company
Zouggari & Benyoucef (2011)	This work aims to present a new decision making approach for group multi-criteria supplier selection problem.	Fuzzy TOPSIS, Fuzzy AHP	Illustrative Example		

3.2.5 LITERATURE SURVEY FOR INTEGRATED METHODOLOGY

In order to develop a decision support system, integrated fuzzy DEMATEL, fuzzy ANP and Fuzzy TOPSIS methodology approaches evaluated from relevant studies summarized in Table 3.6.

3.3 THE PROPOSED INTEGRATED MCDM MODEL

The following explains the computational steps of the hybrid MCDM model that has been developed in this thesis for the purpose of cloud computing technology service provider ranking as follows,

Step 1: Determination of the evaluation model. After defining the alternatives, i.e., cloud computing technology service providers in this paper, the set of dimensions for their evaluation is formed, and then the set of criteria based on which the weights are defined. (Table 3.5)

Step 2: Design fuzzy linguistic scale for evaluations. Relationships among the structure's elements are defined using experts' opinions through paired comparison. To measure the relationships between elements, we need to design the linguistic scale with corresponding triangular fuzzy numbers to convert fuzzy numbers into a crisp score.

Table 3.5 Corresponding linguistic terms for evaluation

Linguistic term	**Abbrev.**	**Fuzzy scales**
None	N	(0,1; 0,1; 1,0)
Very low	VL	(0,0; 0,1; 0,2)
Low	L	(0,1; 0,2; 0,3)
Fairly low	FL	(0,2; 0,3; 0,4)
More or less low	ML	(0,3; 0,4; 0,5)
Medium	M	(0,4; 0,5; 0,6)
More or less Good	MG	(0,5; 0,6; 0,7)
Fairly Good	FG	(0,6; 0,7; 0,8)
Good	G	(0,7; 0,8; 0,9)
Very Good	VG	(0,8; 0,9; 1,0)
Excelent	E	(0,9; 1,0; 1,0)

Table 3.6.a Fuzzy DEMATEL and/or Fuzzy ANP and/or Fuzzy TOPSIS Integrated Methodology Literature Survey

Author	**Focus Area**	**Utilised Integrated Methodology**
Baykasoğlu et. al. (2013)	Modeling and solving truck selection problem of a land transportation company	Fuzzy DEMATEL, Fuzzy Hierarchical TOPSIS
Baykasoglu & Durmusoglu (2014)	Private primary school assessment	DEMATEL, ANP, Fuzzy Cognitive Map
Büyüközkan & Çifçi (2012)	Evaluation of green suppliers	Fuzzy DEMATEL, Fuzzy ANP, Fuzzy TOPSIS
Chamzini et. al. (2014)	Prioritising the investment strategies in the private sector	DEMATEL, Fuzzy TOPSIS
Chen & Chen (2010)	Innovation support system for Taiwanese higher education	DEMATEL, Fuzzy ANP, TOPSIS
Chiu et. al. (2013)	Assessing and improving strategies to reduce the gaps in customer satisfaction	DEMATEL, ANP, VIKOR
Chyu & Fang (2014)	New product development selection problem	Fuzzy DEMATEL, Fuzzy ANP, Fuzzy Kano
Dorri et. al. (2014)	Selection of Repair & Maintenance strategy for IT systems	DEMATEL, Fuzzy ANP
Govindana et. al. (2014)	Evaluation of green manufacturing practices	DEMATEL, ANP with PROMETHEE
Hsu et. al. (2013)	Selection of an outsourcing provider	DEMATEL, ANP,Grey Relation
Hsu (2012)	Best selection to conduct the recycled materials	DEMATEL, ANP, VIKOR
Hu et. al. (2014)	Exploring smart phone improvements based on a hybrid MCDM model	DEMATEL, ANP, VIKOR
Huang et. al. (2011)	Expatriate manager selection for an overseas manufacturing site	DEMATEL, ANP, VIKOR
Huang et. al. (2012)	Evaluating the impact derivations for integrated marketing communications on the high-technology brands	Fuzzy DEMATEL, ANP

Table 3.6.b Fuzzy DEMATEL Fuzzy ANP Fuzzy TOPSIS Integrated Methodology Literature Survey

Author	**Focus Area**	**Utilised Integrated Methodology**
Huang & Kao (2012)	Analyzing the factors influencing the acceptance of padfones	Fuzzy DEMATEL, ANP, Technology Acceptance Model
Huang & Ting (2012)	Derivations of factors influencing the word-of-mouth marketing strategies for smart phone applications	Fuzzy DEMATEL, ANP
Kuo & Liang (2011)	Selecting locations in a fuzzy environment	DEMATEL, Fuzzy ANP, TOPSIS
Le et. al. (2014)	Cloud service selection	Fuzzy TOPSIS, Fuzzy AHP
Lee et. al. (2011)	This study aims to provide more efficient and effective investment decision making process.	DEMATEL, ANP
Liou et. al. (2011)	Offering a quantitative decision model that can help practitioners to select outsourcing provider and reap the most benefits from outsourcing.	DEMATEL, ANP, Fuzzy Preference Programming
Lin et. al. (2010)	Evaluating vehicle telematics system	DEMATEL, ANP, TOPSIS
Liou & Chuang (2010)	Selection of outsourcing providers	DEMATEL, ANP, VIKOR
Liu et al. (2012)	Improving tourism policy implementation	DEMATEL, ANP, VIKOR
Liu et. al. (2013)	Improving metro–airport connection service for tourism development	DEMATEL, ANP, VIKOR
Liu et. al. (2014)	Material selection with target based criteria	DEMATEL, ANP, VIKOR
Lu et. al. (2013)	Improving RFID adoption	DEMATEL, ANP
Peng & Tzeng (2012)	Improvement of tourism competitiveness	Fuzzy DEMATEL, ANP, VIKOR
Sangaiah et. al. (2014)	Evaluating global software development (GSD) project outcome factors	Fuzzy DEMATEL, Fuzzy TOPSIS
Shen et. al.(2014)	Glamor stock selection and stock performance improvement	DEMATEL, ANP, VIKOR

Table 3.6.c Fuzzy DEMATEL Fuzzy ANP Fuzzy TOPSIS Integrated Methodology Literature Survey

Author	**Focus Area**	**Utilised Integrated Methodology**
Sinrat & Atthirawong (2013)	Supplier selection based on supply chain risk management	Fuzzy ANP, TOPSIS
Shen et. al. (2012)	Glamour stock selection	DEMATEL, ANP, TOPSIS
Su et. al. (2012)	Improving cloud computing service with a new hybrid FMCDM model	Fuzzy DEMATEL, Fuzzy ANP, Fuzzy VIKOR
Tsai et. al. (2010)	Offering the priority of sourcing mode to execute Information Systems task in IT projects.	DEMATEL, ANP, ZOGP
Tsai et. al. (2011)	An effectiveness evaluation model for the web-based marketing of the airline industry	DEMATEL, ANP, VIKOR
Tsai & Kuo (2011)	Entrepreneurship policy evaluation and decision analysis for SMEs	DEMATEL, ANP, ZOGP
Tabriz et. al. (2014)	Solving of supplier selection problems	Fuzzy DEMATEL-ANP-TOPSIS
Tadic´ et. al. (2014)	City logistics concept selection	Fuzzy DEMATEL, Fuzzy ANP, Fuzzy VIKOR
Tseng (2011)	Evaluating firm environmental knowledge management in uncertainty	DEMATEL, ANP
Uygun et. al. (2013)	Supplier selection for automotive industry	DEMATEL, ANP, TOPSIS
Uygun et al. (2014)	Evaluation and selection of outsourcing provider for a telecommunication company	DEMATEL, Fuzzy ANP
Wang & Tzeng (2012)	Brand marketing for creating brand value	DEMATEL, ANP, VIKOR
Wu (2008)	Proposing companies that need to evaluate and select knowledge management strategies.	DEMATEL, ANP
Yang et. al. (2013)	Proposing an information security risk-control assessment model	DEMATEL, ANP, VIKOR
Zhou & Lu (2012)	Risk evaluation of dynamic alliance to choose a coalition partner	Fuzzy ANP, Fuzzy TOPSIS

Step 3: Establish causal relations within dimensions applying fuzzy DEMATEL (Wu & Lee, 2007).

Step 3.1: Obtain fuzzy direct-relation matrix. Experts are making sets of the pair wise comparisons of elements (dimensions and criteria), i.e., forming an *nxn* matrix $\tilde{A}$ whose elements, triangular fuzzy numbers.

$\tilde{a}_{ij}$= (l_{ij}, m_{ij}, u_{ij}), represent the degree to which the element *i* affects the element *j*.

Step 3.2: Obtain normalized fuzzy direct-relation matrix $\tilde{X}$ obtained from the matrix $\tilde{A}$ by using the equation:

$$\tilde{X} = s \times \tilde{A} \qquad (10)$$

where $s = 1/\max_{1 \leq i \leq n} \sum_{j=1}^{n} u_{ij}$ and $\tilde{a}_{ij}$= (l_{ij}, m_{ij}, u_{ij}).

Step 3.3: Obtain fuzzy total-relation matrix $\tilde{T}$. Let $\tilde{x}_{ij}$= (l_{ij}, m_{ij}, u_{ij}) be the element of matrix $\tilde{X}$. It is necessary to define three crisp matrices whose elements are extracted from $\tilde{X}$ as folows:

$$X_l = \begin{bmatrix} 0 & l_{12} & \cdots & l_{1n} \\ l_{21} & 0 & \cdots & l_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ l_{n1} & l_{n2} & \cdots & 0 \end{bmatrix} \qquad X_m = \begin{bmatrix} 0 & m_{12} & \cdots & m_{1n} \\ m_{21} & 0 & \cdots & m_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ m_{n1} & m_{n2} & \cdots & 0 \end{bmatrix}$$

$$Xu = \begin{bmatrix} 0 & u_{12} & \cdots & u_{1n} \\ u_{21} & 0 & \cdots & u_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ u_{n1} & u_{n2} & \cdots & 0 \end{bmatrix}$$

Fuzzy total-relation matrix $\tilde{T}$ is obtaining using the following equation:

$$\tilde{T} = \tilde{X}\,(I - \tilde{X})^{-1}. \qquad (11)$$

Let $\tilde{T} = \begin{bmatrix} \tilde{t}_{11} & \tilde{t}_{12} & \cdots & \tilde{t}_{1n} \\ \tilde{t}_{21} & \tilde{t}_{22} & \cdots & \tilde{t}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{t}_{n1} & \tilde{t}_{n2} & \cdots & \tilde{t}_{nn} \end{bmatrix}$

Where $\tilde{t}_{ij}$ = (l_{ij}', m_{ij}', u_{ij}') then

Matrix $[l_{ij}^{'}] = X_l (I - X_l)^{-1}$, (12)

Matrix $[m_{ij}^{'}] = X_m (I – X_m)^{-1}$, (13)

Matrix $[u_{ij}^{'}] = X_u (I – X_u)^{-1}$. (14)

where I is the identity matrix ($n \times n$ square matrix with ones on the main diagonal).

Step 3.4: Obtain inner dependence matrix. In order to obtain the values of inner dependence between the elements within the same cluster, elements of matrix $\tilde{T}$ are being defuzzyfied using the following equation.

$$F(\tilde{t}_{ij}) = 1/2 \int_0^1 \left(\inf_{x \in \Re} \tilde{t}_{ij}^{\alpha} + \sup_{x \in \Re} \tilde{t}_{ij}^{\alpha} \right) d\alpha \quad (15)$$

Step 4: Establish remaining relations using the fuzzy ANP. Those are the relations between the elements from different clusters. In ANP, pair wise comparisons of the elements in each cluster are conducted with respect to their relative importance towards their control criterion. By using triangular fuzzy numbers again, the relative strength, i.e., the preference of each element in relation to other elements is evaluated. Via pair wise comparison, the fuzzy judgment matrix $\tilde{A}^{'}$ is constructed as:

$$\tilde{A}' = \begin{bmatrix} \tilde{a}'_{11} & \tilde{a}'_{12} & \cdots & \tilde{a}'_{1n} \\ \tilde{a}'_{21} & \tilde{a}'_{22} & \cdots & \tilde{a}'_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{a}'_{n1} & \tilde{a}'_{n2} & \cdots & \tilde{a}'_{nn} \end{bmatrix} \quad (16)$$

where $\tilde{a}'_{ij} = (l_{ij}, m_{ij}, u_{ij})$ indicates the importance of element i over element j, and $i = j = 1,2, ...,n$.

Step 5: Estimate triangular fuzzy priorities $\tilde{w}_k$ where i = 1,2, …, n from the judgment matrix. The logarithmic least-squares method in (16) can be used for calculating these weights:

$\tilde{w}_k = (w^l{}_k, w^m{}_k, w^u{}_m)$ k = 1, 2, …, n where

$$w_k^s = \frac{\left(\prod_{i=1}^{n} a_{kj}^{s}\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{i=1}^{n} a_{ij}^{m}\right)^{1/n}} \quad , s \in \{l,m,u\} \tag{17}$$

for $0 < \alpha \leq 1$ and all i, j, where $i = 1, 2 \ldots n$, $j = 1, 2 \ldots n$.

In order to control the result of the method, we calculate the Consistency Ratio *(CR)* for each matrix as follows (Saaty, 1996):

$$CR = CI/RI \tag{18}$$

where *CI* is the Consistency Index and is calculated as follows:

$$CI = \frac{\lambda_{\max - n}}{n-1} \tag{19}$$

λ_{max} is the Perron root or principal eigenvalue of the matrix $\tilde{A}$ (Forman, 1990). *RI* is the Random Index whose values for matrices of various sizes are contained in Saaty (1996). We use *CR* to directly estimate the consistency of the pair wise comparisons and should be less than 0.10. Then we can say the comparisons are acceptable.

Step 6: Form a supermatrix (W). ANP uses the formation of a supermatrix to allow for the resolution of the effects of the interdependence between the elements of the network structure. The supermatrix is a partitioned matrix where each submatrix is composed of a set of quantified relations between the elements from the same or different clusters. General representation of the supermatrix hierarchy (W) with three levels is as follows:

$$W = \begin{matrix} \text{Goal (G)} \\ \text{Criteria (C)} \\ \text{Alternatives (A)} \end{matrix} \begin{pmatrix} 0 & 0 & 0 \\ W_{21} & W_{22} & 0 \\ 0 & W_{32} & I \end{pmatrix} \tag{20}$$

where the influence of the goal on the attribute is represented by vector W_{21}, the mutual influence among criteria is represented by vector W_{22}, the influence of the attribute on each of the alternatives is represented by vector W_{32}, and I is the identity matrix (Saaty & Takizawa, 1986).

Step 6.1: Obtain the limit supermatrix. Raising the supermatrix to the power 2p + 1, where *p* is a sufficiently large number, the matrix is converging, i.e., the row values of the matrix are converging to the same values for every column of the matrix (Lee et. al. 2009). We call the obtained matrix as the limit supermatrix.

Step 7: Evaluate the alternatives by using fuzzy TOPSIS. The procedure is adapted from Chen (2000), and computational steps are described below.

Step 7.1: Establish fuzzy decision matrix for alternatives.

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ \vdots \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \dots & C_n \end{array} \\ \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \dots & \tilde{x}_{mn} \end{bmatrix} \end{array}$$

$\tilde{D}$ represents the fuzzy decision matrix with alternatives A and criteria C.

Step 7.2: Normalize the decision matrix. Normalized fuzzy decision matrix $\tilde{R}$ is calculated as:

$\tilde{R} = [r_{ij}]_{mxn}$, $i=1,\dots,m$ $j=1,\dots,n$

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^+}, \frac{a_{ij}}{c_j^+}, \frac{a_{ij}}{c_j^+} \right), \tag{21}$$

where $C_j^+ = \max_i C_{ij}$. To avoid the complicated normalization Formula used in the classical TOPSIS, the linear scale transformation is used to transform the various criteria scales into a comparable scale (Chen, 2000). Linear scale transformation for normalization is also employed by Kuo et al. (2007) and Celik et al. (2009). Here normalized decision matrix remains the same because maxCij=1.

Step 7.3: Compute weighted decision matrix. Weighted normalized fuzzy decision matrix is computed where w_j is the weight for the criterion j obtained from supermatrix.

$$\tilde{v}_{ij} = \tilde{r}_{ij} \ x \ \tilde{w}_j , \tag{22}$$

where $\tilde{v} = [v_{ij}]_{mxn}$, $i=1,\dots,m$ $j=1,\dots,n$

Step 7.4: Calculate the distances from positive and negative ideal points. Since the triangular fuzzy numbers are included in [0,1] range, positive and negative ideal reference points (FPIRP, FNIRP) are as follows:

$$A^{+} = \{ V_1^{+}, V_2^{+}, \ldots\ldots, V_n^{+} \} \quad (23)$$

where V_j^{+} = (1,1,1) V_j^{-} = (0,0,0)

The next step is to calculate the distance of alternatives from FPIRP and FNIRP.

$$d_i^{+} = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^{+}) \quad , \; i=1,\ldots.,m \;\; j=1,\ldots,n \quad (24)$$

$$d_i^{-} = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^{-}) \quad , \; i=1,\ldots.,m \;\; j=1,\ldots,n \quad (25)$$

$$d(\tilde{A}, \tilde{B}) = \sqrt{\frac{1}{3} \; (a_1-b_1)^2 + (a_2-b_2)^2 + (a_3-b_3)^2} \quad (26)$$

Step 7.5: Rank the alternatives. The performance indices are computed to rank the alternatives. Performance indices are sorted in a decreasing order.

The steps of proposed hybrid MCDM model is also shown in Figure 3.2,

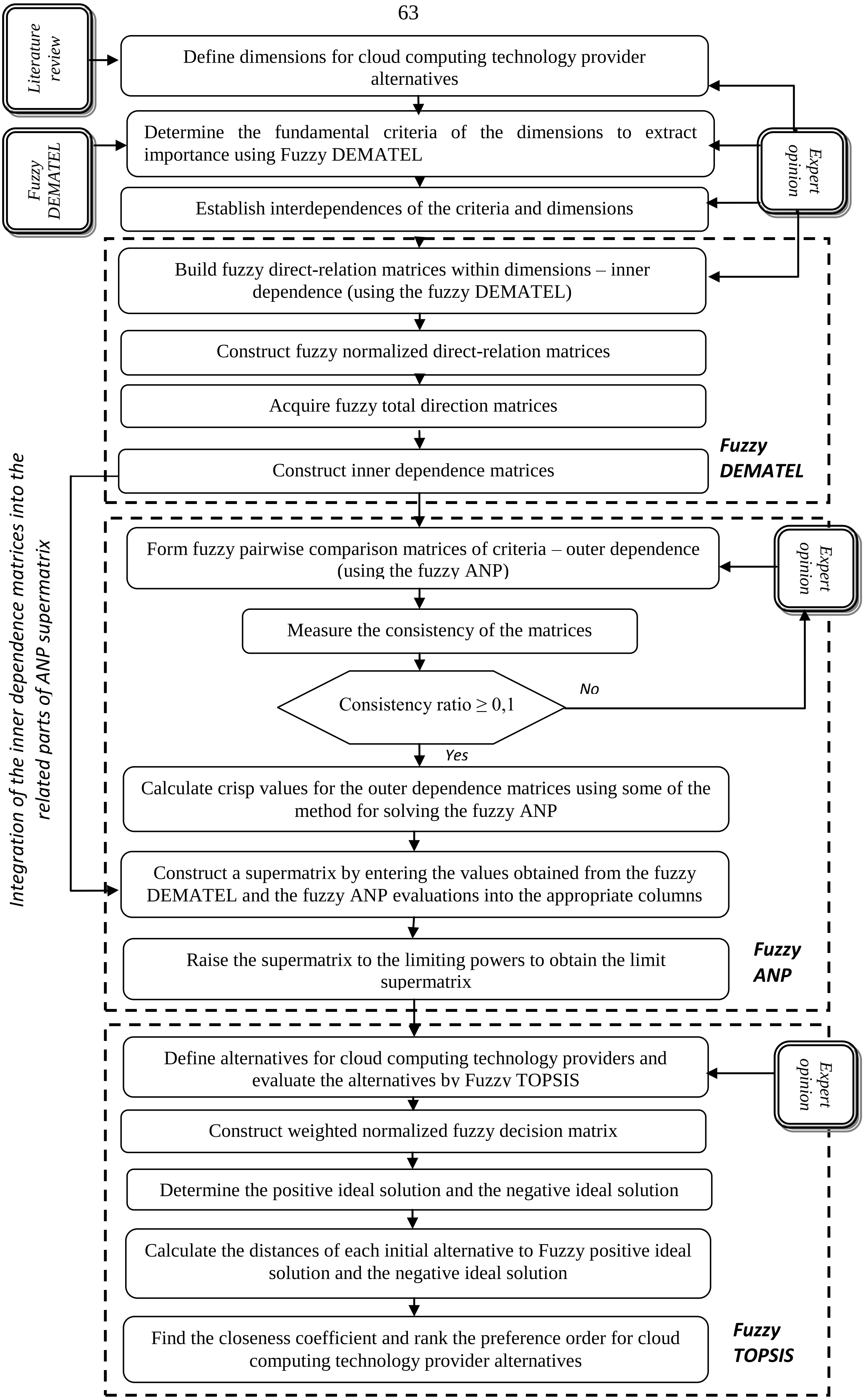

Figure 3.2 The proposed hybrid MCDM Model

4. APPLICATION OF THE PROPOSED METHODOLOGY

The methodology mentioned in the previous sections is applied in a real case study (Buyukozkan & Maden, 2015).

4.1 PURIFICATION OF THE EVALUATION CRITERIA

Through an intensive literature review, this thesis has managed to extract criteria influencing the cloud computing technology provider evaluation process. The complexity of the criteria was easier to discover using a visible casual diagram. Through analyzing and discussing the structural model, we figured out which factors are of more fundamental importance for the system, and which are not. Therefore, a set of complex criteria under different dimensions can be divided into a cause group and an effect group considering the interdependence among criteria. Then according to the results of fuzzy DEMATEL method, essential criteria for functionality dimension are figured out based upon the consensus of experts and academics. Finally, 6 criteria are identified under Functionality dimension out of 16 criteria under management services, capacity part, physical property part and service quality dimensions as shown in Figure 4.1-4.4.

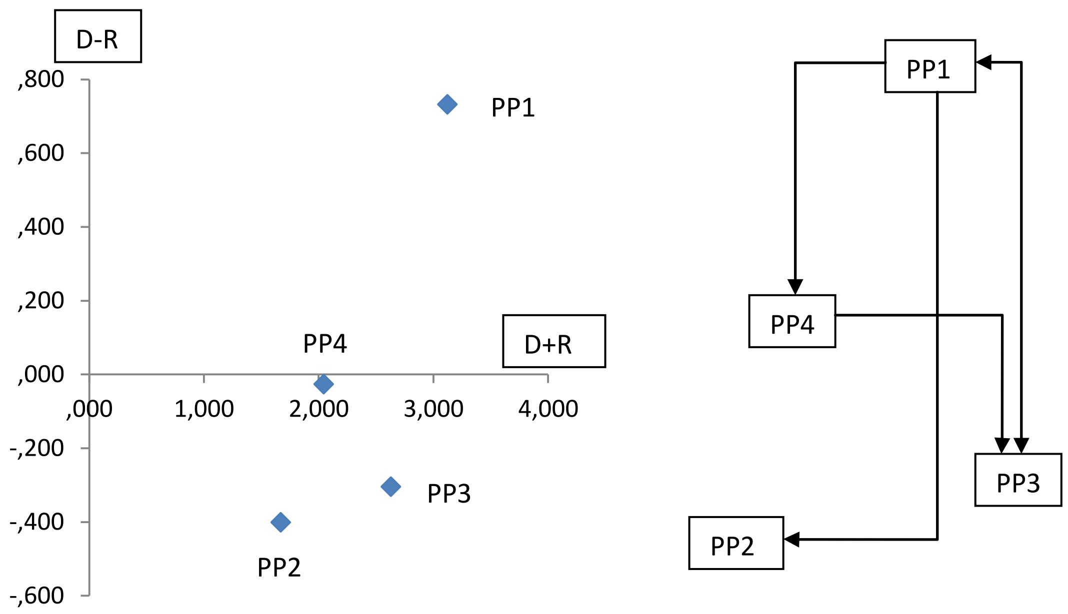

Figure 4.1 Cause and effect diagram for physical property part dimension

In view of the physical property dimension, communication is the most important criterion in terms of positive (D+R) and (D-R) values. Computation criterion is directly affected by communication criterion but it doesn't influence other criteria. The communication criterion is assumed to have higher priority and is called cause criterion. And those computation, storage and memory criteria are receiving more influence from another so they are assumed to have lower priority and are called effect criteria.

Fig. 4.2 depicts that availability affects transaction speed, latency, reliability and influenced by reliability criterion. The criterion with larger (D+R) value represents higher importance under the same dimension. Transaction speed has no impact on the others and it is relatively unimportant in terms of smaller (D+R) values, and improving this criteria doesn't receive positive impacts on availability, transaction speed and latency from cause-effect viewpoints. Availability and reliability are the most important criteria since they dispatche the influence to other evaluation criteria more than they receive, and they receive the influence from other evaluation criteria more than they dispatch.

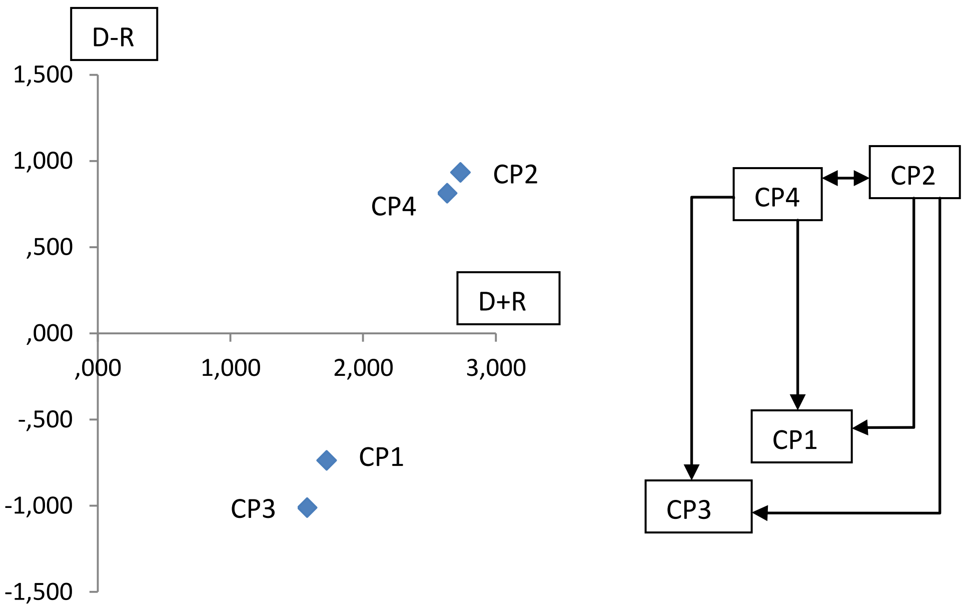

Figure 4.2 Cause and effect diagram for capacity part dimension

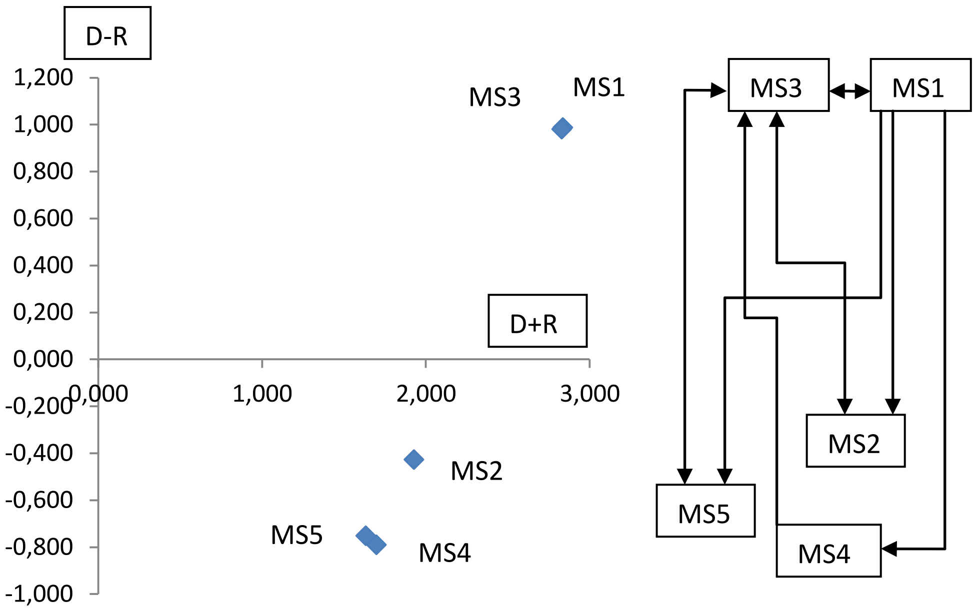

Figure 4.3 Cause and effect diagram for management services dimension

Fig. 4.3 depicts that deployment and billing are the two essential criteria though these two criteria are influenced by each other or other criteria. In addition, deployment is slightly more important than billing in terms of positive (D+R) values.

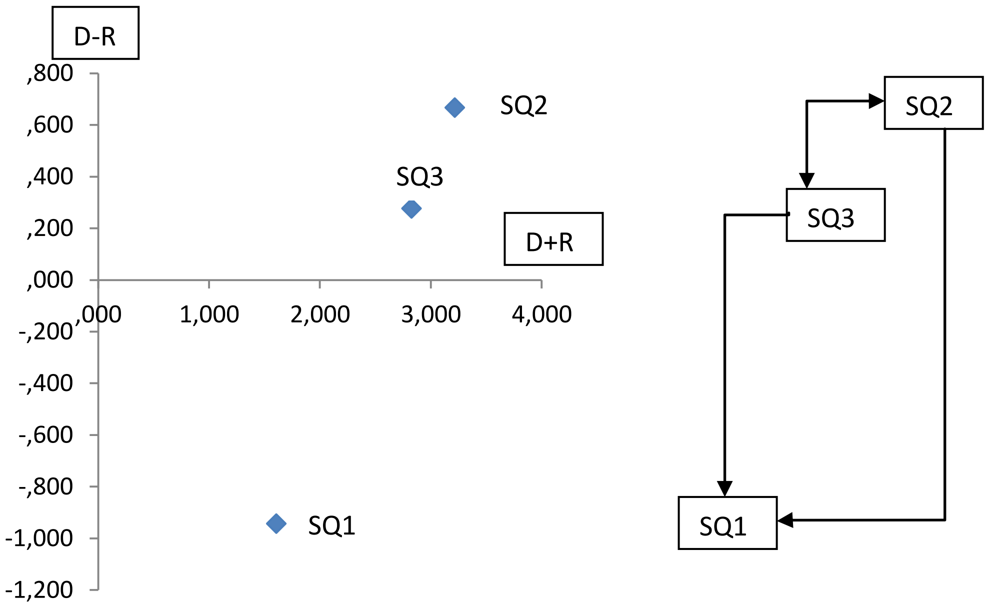

Figure 4.4 Cause and effect diagram for service quality

Enrich content and service stability are critical criteria so they should be evaluated first by the suppliers. Service stability is more important than enrich content in terms of positive (D+R) values. Service stability is the most essential criterion based on Figure

4.4, since this criterion affects the other two criteria. In view of the service quality dimension, service stability is the most important dimension followed by enrich content and SLA Management.

4.2 CASE STUDY

After demonstrating the proposed framework, a case study was applied of a company in Turkey. The case company ABC faced the difficulties of choosing an efficient cloud computing technology provider and spent a lot of time on this issue. To meet the needs of customer BlogTO.com, a popular site in Toronto, the company aggregated the assessments of our proposed framework with their current status of the factors that affecting the selection process of the appropriate cloud computing technology provider. The company indicates that confidentiality, integrity, multi-tenant trust and availability are the most important criteria of achieving cloud security in the case cloud computing services. Especially integrity criterion represents higher importance among them. Multi-tenant trust is critically important in terms of authorization related issues. When evaluating cloud security dimension, the impact of auditability would be disregarded.

For the development of cost-efficient processes and accomplishment of faster responses to the changes, flexibility cost that covers the further IT infrastructure changes is the most critical criteria among cost related factors. For a sufficient pyhsical property part, it is recommended to involve communication criteria as for free in the same domain. It is also suggested to disregard storage criterion on account of provider's infinite storage capacity. In addition to availability criterion, the reliability of a system for the proper high quality capacity part is also an essential factor; so it is suggested to focus on these criteria to increase the efficiency of customer's performance when deploying cloud computing technology. It is recommended not to pay much attention to the latency (time) criterion which they often choose the closest measure of time delay for intended performance in capacity part of cloud computing technology provider. The importance of deployment is due to automated processes to reduce the burden across cloud deployment. For that, the other suggested criteria are deployment and billing when considering the management services dimension. With regard to obtained reviews about their own processes, configuration and monitoring can be disregarded because their system have already had these characteristics in their company.

A new criteria could be added or deleted from our proposed framework, on the basis of experiences of the experts and deep knowledge of academics. In addition to distractions and combinations of criteria from our proposed framework, two new criteria were being added in vendor related dimension as documentation and trustworthiness of the provider. We can judge a provider or the organization with its trustworthiness and reputation. Indicators like number of customers might be partly measurable, but we should consider a qalitative evaluation framework. Documentation refers to the quality of documents or reference materials related to the cloud computing technology that the vendor provides to guide the users as to how to set up, operate, and customize the software. "The availability of documentation is important, including technical documentation".

In the service quality dimension, the experts consider service stability to be the most important criterion. When selecting the best cloud provider for the given application, experts believe that vendor's reputation is the most important criteria in the vendor related dimension. The customers are also suggested to be careful about the brand value of the vendor, the experience of current cloud service users and the threats resulted from misguidance of cloud services. As another recommendation, proper documentation is essential for short time cloud deployment procosses. After adapting the DEMATEL procedures to determine the degrees of influence of the criteria, the ANP method is used to calculate the weight of each criterion and apply these to normalize the unweighted supermatrix in the ANP to demonstrate proposed framework in a series of pairwise comparisons.

Step 1: Determination of the evaluation model. The set of dimensions for their evaluation was reviewed, and then the set of criteria were defined. Our proposed criteria framework for cloud computing technology service provider selection was developed based on the broad literature review including seven dimensions as cloud security, cost, physical property part, capacity part, vendor related, cloud security, management services, service quality. These surveys helped us to classify the various decision-making criteria into different dimensions avoiding the shortcomings of classic outsourcing decisions where cost alone is used as the deciding factor. With regard to obtained assessments of the experts for the processes of case company ABC and in light of our proposed criteria framework, the final dimensions were determined as cloud security, cost, functionality and vendor related. In view of these assessments, we classified the criteria of communication, availability, reliability, service stability, deployment and billing under the functionality dimension disregarding the separateness of particular service quality, management services, physical propert part and capacity part dimensions. And the experts specifically focused on the vendor related dimension which must be evaluated with documentation, R&D capability, trustworthiness of the provider and community support criteria in addition to experience in related products and vendor's experience criteria. Using the assessments of the experts in light of our reviewed criteria framework, graphical representation of the relationships among the dimensions are shown in Figure.4.5,

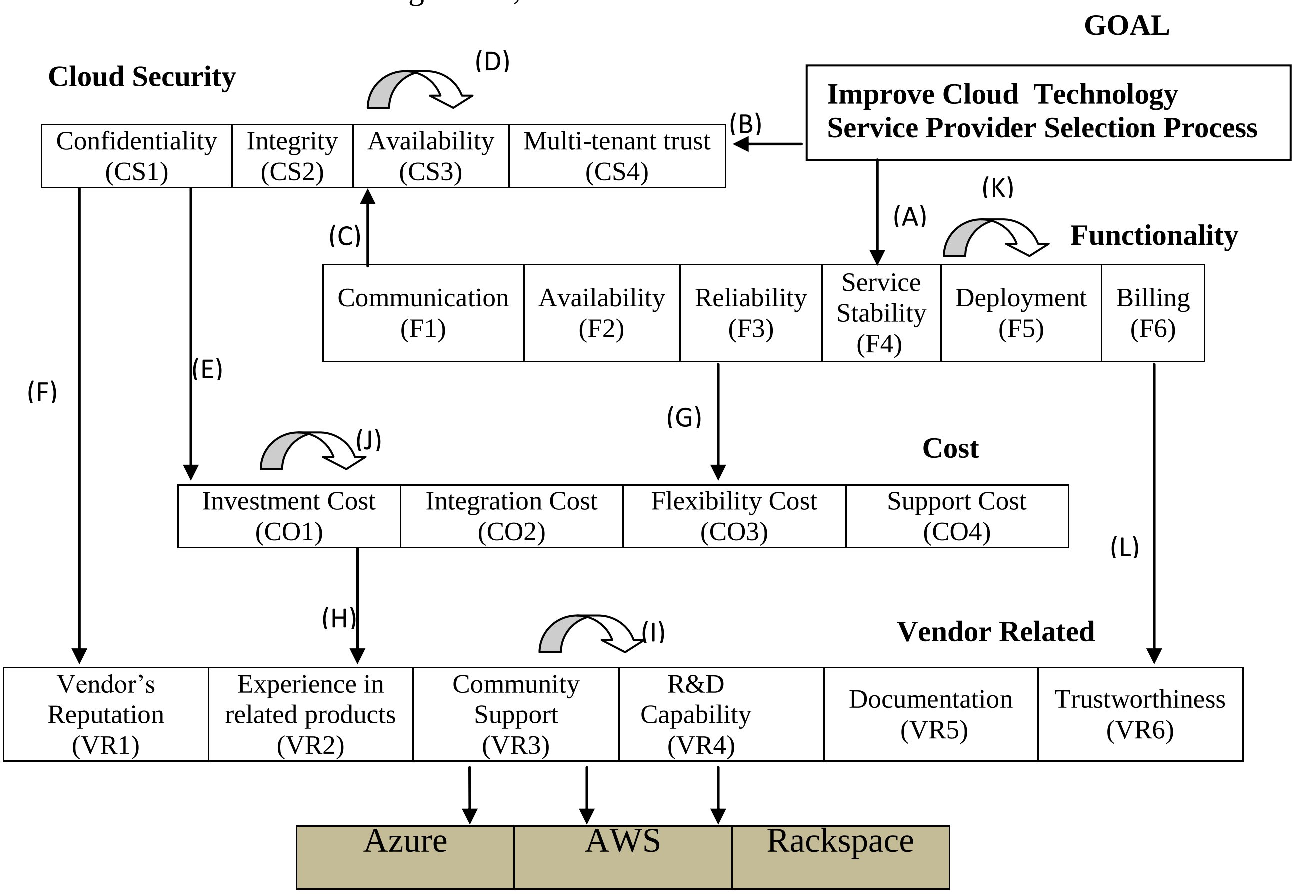

Figure 4.5 Graphical framework of the proposed dimensions

The arrows in the model indicate a one or two-way relationship and the interdependency relationship of dimensions is shown by a looped arc and calculated using fuzzy DEMATEL. The capital letters from A to J in parentheses represent the weight matrices used in the supermatrix. General sub-matrix for supermatrix is shown in Figure 4.2.,

	Goal	CO	CS	F	VR
Goal	0	0	0	0	0
Cost (CO)	0	**J**	E	G	0
Cloud Security (CS)	B	0	**D**	0	0
Functionality (F)	A	0	0	**K**	0
Vendor Related (VR)	0	H	F	L	**I**

Figure 4.6 General sub-matrix notation for supermatrix.

Step 2: Relationships among the structure's elements were defined using experts' opinions and academics' knowledge through paired comparison. Four dimensions and twenty criteria are used in this study. Since there are four dimensions, the seven 4x4 fuzzy direct-relation matrix A,

Table 4.1 Initial linguistic direct relation matrix

	CS	CO	F	VR
CS	0	G	M	VG
CO	FG	0	MG	VL
F	VL	VL	0	MG
VR	VG	VG	FG	0

Table 4.2 Initial fuzzy direct relation matrix

	CS	CO	F	VR
CS	0	(0,7; 0,8; 0,9)	(0,4; 0,5; 0,6)	(0,8; 0,9; 1)
CO	(0,6; 0,7; 0,8)	0	(0,5; 0,6; 0,7)	(0; 0,1; 0,2)
F	(0; 0,1; 0,2)	(0; 0,1; 0,2)	0	(0,5; 0,6; 0,7)
VR	(0,8; 0,9; 1)	(0,8; 0,9; 1)	(0,6; 0,7; 0,8)	0

Step 3: Causal relations were established within dimensions applying fuzzy DEMATEL.

Table 4.3 The normalized direct-relation matrix X

	CS	CO	F	VR
CS	0,00	0,32	0,17	0,36
CO	0,28	0,00	0,22	0,04
F	0,04	0,04	0,00	0,22
VR	0,36	0,36	0,28	0,00

In Step 3, Matrix T can be computed by the following formula $T=X.(I-X)^{-1}$,

Table 4.4 Total relation matrix of the dimensions

	CS	CO	F	VR
CS	0,50	0,76	0,63	0,71
CO	0,52	0,31	0,48	0,35
F	0,26	0,27	0,21	0,38
VR	0,80	0,82	0,74	0,49

The importance of dimensions can be determined by the (D+R) values. Table 4.5 shows that Vendor related is the most important dimension with the largest (D+R) value of -4,76 whereas Functionality is the least important dimension with the smallest value.

Table 4.5 Row and column values among dimensions.

	D+R	D-R
CS	4,67	0,52
CO	3,82	-0,51
F	3,19	-0,94
VR	4,76	0,92

Table 4.6 Row and column values for the criteria in the various dimensions

Dimension	Criteria	D	R	D+R	D-R
Cloud Security	(CS1) Confidentiality	6,46	6,14	12,60	0,32
	(CS2) Integrity	6,54	6,30	12,84	0,24
	(CS3) Availability	4,64	5,26	9,91	-0,62
	(CS4) Multi-tenant trust	5,26	5,21	10,47	0,06
Cost	(CO1) Investment Cost	1,03	1,97	3,00	-0,94
	(CO2) Integration Cost	1,24	1,98	3,22	-0,74
	(CO3) Flexibility Cost	2,66	1,76	4,42	0,90
	(CO4) Support Cost	2,67	1,89	4,56	0,77
Functionality	(F1) Communication	7,36	7,24	14,60	0,12
	(F2) Availability	6,34	6,20	12,54	0,14
	(F3) Reliability	6,41	5,20	11,60	1,21
	(F4) Service Stability	6,08	5,54	11,62	0,54
	(F5) Deployment	7,03	6,80	13,83	0,23
	(F6) Billing	4,22	6,45	10,67	-2,23
Vendor Related	(VR1) Vendor’s Reputation	5,81	5,60	11,41	0,21
	(VR2) Experience in related products	4,99	5,86	10,85	-0,87
	(VR3) Community Support	4,36	4,52	8,88	-0,17
	(VR4) R&D Capability	4,38	4,19	8,57	0,18
	(VR5) Documentation	5,59	4,29	9,88	1,29
	(VR6) Trustworthiness of the provider	4,60	5,26	9,87	-0,65

To further investigate the cause-effect relationship of dimensions, cloud security and vendor related are net causes based on positive (D-R) values. Cost and functionality are net receivers due to negative (D-R) values.

In this study, the threshold value is set up by computing the average of the elements in Matrix T (Total Relation Matrix) to obtain the digraph. In doing so, only the effects greater than the threshold value would be chosen and shown in digraph.

Figures 4.7-4.10 describe the causal relations among the criteria under the dimensions of cost, cloud security, vendor related and functionality.

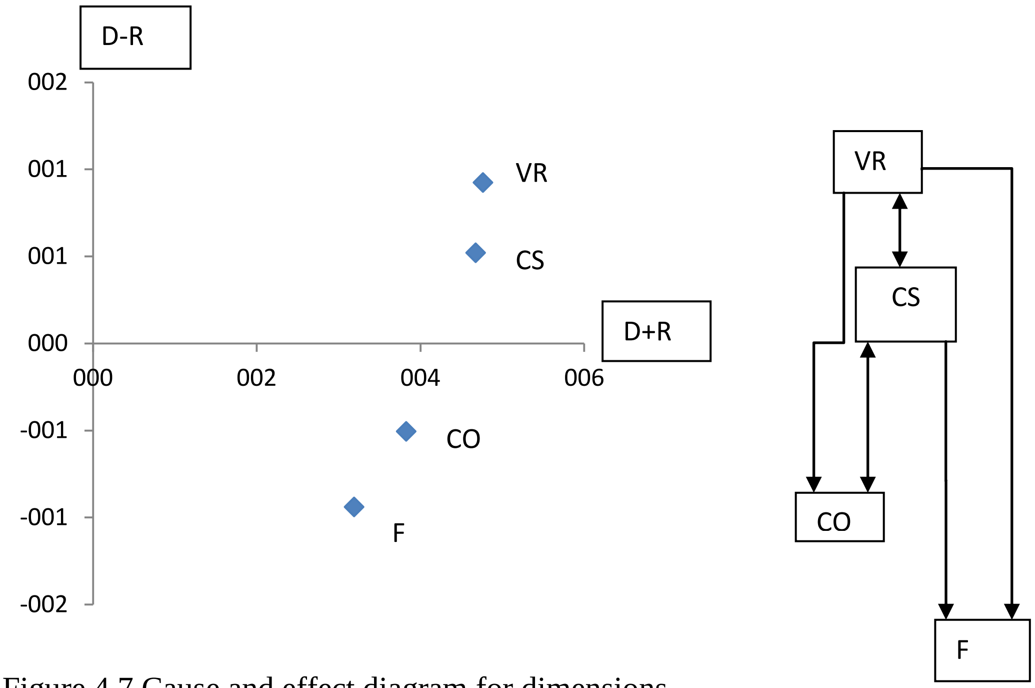

Figure 4.7 Cause and effect diagram for dimensions

Vendor related and cloud security are critical dimensions so they should be evaluated first by the suppliers when considering the application study. Vendor related is more important than cloud security in terms of positive (D+R) values. These are essential dimensions based on Figure. 4.3 since they affect the other three dimensions. In view of the general dimensions, vendor related is the most important dimension followed by cloud security, cost and functionality.

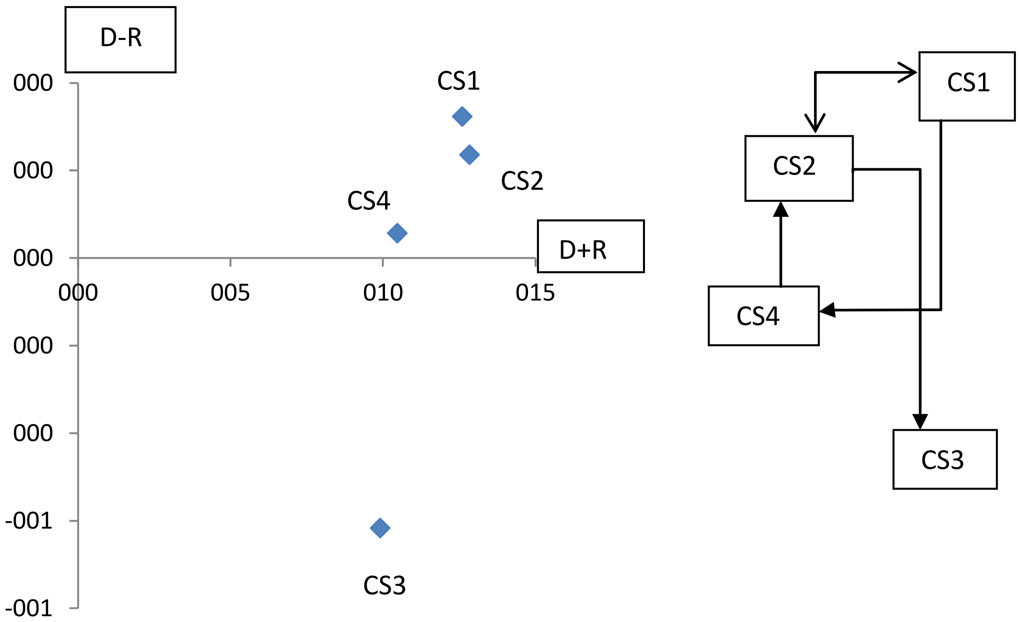

Figure 4.8 Cause and effect diagram for cloud security dimension

To choose a right cloud computing technology provider alternative, cloud security dimension is the mostly evaluated critical dimension used by both practitioners and academics in their related studies. For that, our application study focused especially two criteria as integrity and confidentiality. Integrity criterion is slightly more important than confidentiality criterion in view of positive D+R values.

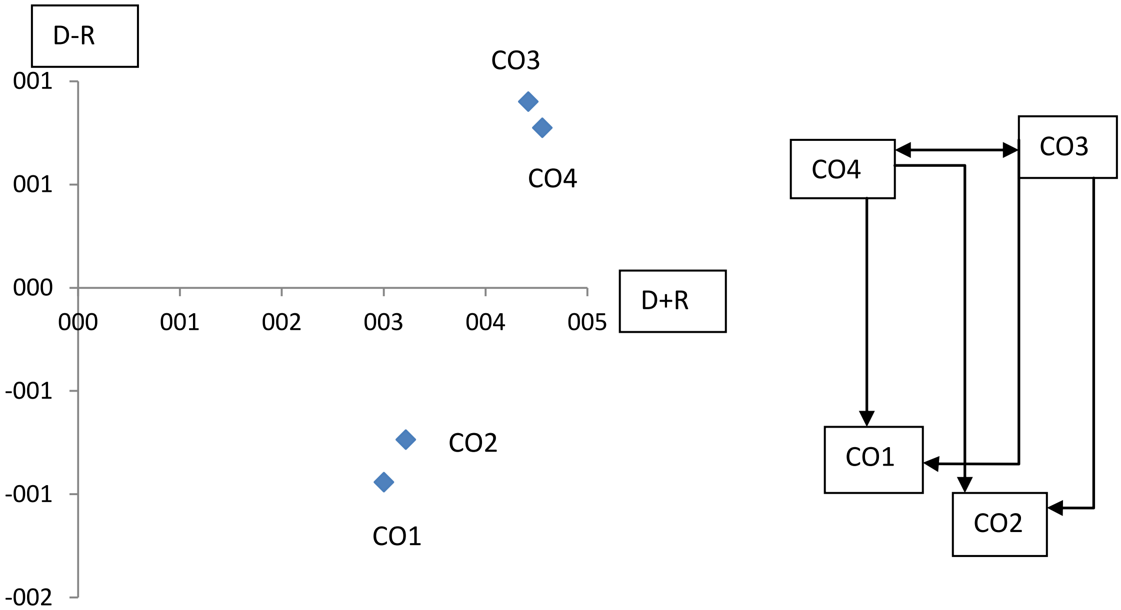

Figure 4.9 Cause and effect diagram for cost dimension

When considering cost dimension, two critical criteria as support cost and flexibility must be first evaluated both by customers and providers for healty and cost-effective processes. Support cost is more important than flexibility cost considering higher D+R.

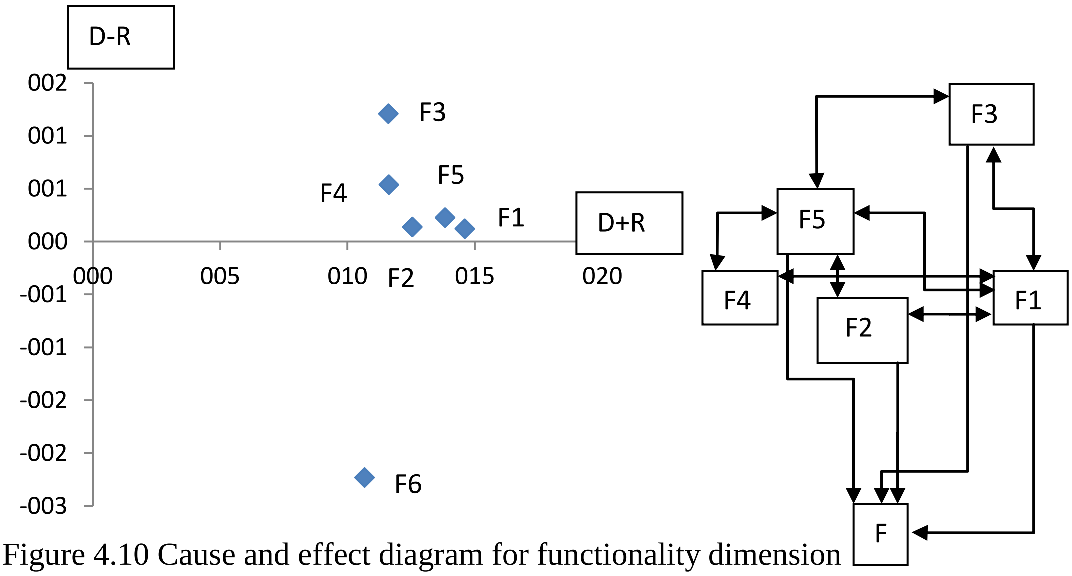

Figure 4.10 Cause and effect diagram for functionality dimension

When evaluating functionality dimension; communication, deployment, availability, reliability and service stability are the most critical criteria that focusing positive D-R values and positive D+R values. These are the criteria that must be first improved by providers and they help giving efficient way for customers to make healty decisions.

Fuzzy evaluation matrixes of cloud security, cost, functionality and vendor related dimensions are given in Table 4.7 and in Table 4.15,

Table 4.7 Linguistic evaluation matrix of cloud security

	CS1	CS2	CS3	CS4
CS1	0	G	VL	VG
CS2	VG	0	VG	VL
CS3	FG	VL	0	M
CS4	VL	VG	M	0

Table 4.8 Fuzzy evaluation matrix of cloud security

	CS1	CS2	CS3	CS4
CS1	0	(0,7; 0,8; 0,9)	(0; 0,1; 0,2)	(0,8; 0,9; 1)
CS2	(0,8; 0,9; 1)	0	(0,8; 0,9; 1)	(0; 0,1; 0,2)
CS3	(0,6; 0,7; 0,8)	(0; 0,1; 0,2)	0	(0,4; 0,5; 0,6)
CS4	(0; 0,1; 0,2)	(0,8; 0,9; 1)	(0,4; 0,5; 0,6)	0

Table 4.9 Linguistic evaluation matrix of functionality

	F1	F2	F3	F4	F5	F6
F1	0	VG	FG	VG	FG	VL
F2	FG	0	VL	MG	FG	VG
F3	VG	FL	0	VL	VG	FL
F4	ML	ML	ML	0	G	ML
F5	VL	VG	VG	FG	0	FL
F6	VG	MG	VL	VL	VL	0

Table 4.10 Fuzzy evaluation matrix of functionality

	F1	F2	F3	F4	F5	F6
F1	0	(0,8; 0,9; 1,0)	(0,6; 0,7; 0,8)	(0,8; 0,9; 1,0)	(0,6; 0,7; 0,8)	(0; 0,1; 0,2)
F2	(0,6; 0,7, 0,8)	0	(0; 0,1; 0,2)	(0,5; 0,6; 0,7)	(0,6; 0,7; 0,8)	(0,8; 0,9; 1,0)
F3	(0,8; 0,9; 1,0)	(0,2; 0,3; 0,4)	0	(0; 0,1; 0,2)	(0,8; 0,9; 1,0)	(0,2; 0,3; 0,4)
F4	(0,3; 0,4; 0,5)	(0,3; 0,4; 0,5)	(0,3; 0,4; 0,5)	0	(0,7; 0,8; 0,9)	(0,3; 0,4; 0,5)
F5	(0; 0,1; 0,2)	(0,8; 0,9; 1,0)	(0,8; 0,9; 1,0)	(0,6; 0,7; 0,8)	0	(0,2; 0,3; 0,4)
F6	(0,8; 0,9; 1,0)	(0,5; 0,6; 0,7)	(0; 0,1; 0,2)	(0; 0,1; 0,2)	(0; 0,1; 0,2)	0

Table 4.11 Fuzzy evaluation matrix of cost

	CO1	CO2	CO3	CO4
CO1	0	VL	MG	VL
CO2	VL	0	VL	FG
CO3	VG	G	0	VG
CO4	G	VG	VG	0

Table 4.12 Fuzzy evaluation matrix of cost

	CO1	CO2	CO3	CO4
CO1	0	(0; 0,1; 0,2)	(0,5; 0,6; 0,7)	(0; 0,1; 0,2)
CO2	(0; 0,1; 0,2)	0	(0; 0,1; 0,2)	(0,6; 0,7; 0,8)
CO3	(0,8; 0,9; 1)	(0,7; 0,8; 0,9)	0	(0,8; 0,9; 1)
CO4	(0,7; 0,8; 0,9)	(0,8; 0,9; 1)	(0,8; 0,9; 1)	0

Table 4.13 Linguistic evaluation matrix of vendor related

	VR1	VR2	VR3	VR4	VR5	VR6
VR1	0	VG	MG	VL	VG	VL
VR2	MG	0	ML	MG	ML	MG
VR3	M	VL	0	ML	ML	ML
VR4	MG	M	VL	0	VL	L
VR5	VL	M	VG	ML	0	VG
VR6	VG	M	ML	VG	M	0

Table 4.14 Fuzzy evaluation matrix of vendor related

	VR1	VR2	VR3	VR4	VR5	VR6
VR1	0	(0,8; 0,9; 1,0)	(0,5; 0,6; 0,7)	(0; 0,1; 0,2)	(0,8; 0,9; 1,0)	(0; 0,1; 0,2)
VR2	(0,5; 0,6; 0,7)	0	(0,3; 0,4; 0,5)	(0,5; 0,6; 0,7)	(0,3; 0,4; 0,5)	(0,5; 0,6; 0,7)
VR3	(0,4; 0,5; 0,6)	(0; 0,1; 0,2)	0	(0,3; 0,4; 0,5)	(0,3; 0,4; 0,5)	(0,3; 0,4; 0,5)
VR4	(0,5; 0,6; 0,7)	(0,4; 0,5; 0,6)	(0; 0,1; 0,2)	0	(0; 0,1; 0,2)	(0,1; 0,2; 0,3)
VR5	(0; 0,1; 0,2)	(0,4; 0,5; 0,6)	(0,8; 0,9; 1,0)	(0,3; 0,4; 0,5)	0	(0,8; 0,9; 1,0)
VR6	(0,8; 0,9; 1,0)	(0,4; 0,5; 0,6)	(0,3; 0,4; 0,5)	(0,8; 0,9; 1,0)	(0,4; 0,5; 0,6)	0

Step 4: Remaining relations were established using the fuzzy ANP and pair wise comparisons of the elements in each cluster were conducted with respect to their relative importance towards their control criterion.

Step 5: In order to control the result of the method, we calculated the Consistency Ratio *(CR)* for each matrix and the obtained consistency ratio (CR) values were all acceptable so the eigenvectors displayed were ready to enter into the supermatrix.

Step 6: We formed Supermatrix (W) and general representation of the supermatrix hierarchy (W). When entering the priorities found by fuzzy DEMATEL and fuzzy ANP into their related columns, initial supermatrix can be constructed as shown in Table 4.15

Normalization procedure is applied by transforming columns such that sum of each column is exactly 1. This new matrix is called weighted supermatrix. We took the power of the weighted supermatrix until the weights of the alternatives are stabilized.

After entering the normalized values, the limiting power of the weighted supermatrix is obtained indicating the weight of each alternative outsourcing provider. For our objective of improving cloud computing technology provider selection activites, weights of each criteria are identified to calculate in fuzzy TOPSIS later.

Table 4.15 Initial supermatrix (M) for selection of alternatives

	Goal	CO1	CO2	CO3	CO4	CS1	CS2	CS3	CS4	F1	F2	F3	F4	F5	F6	VR1	VR2	VR3	VR4	VR5	VR6
Goal	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
CO1	0,000	**0,103**	**0,122**	**0,199**	**0,125**	0,595	0,596	0,596	0,587	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
CO2	0,000	**0,143**	**0,125**	**0,151**	**0,235**	0,270	0,284	0,284	0,311	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
CO3	0,000	**0,383**	**0,370**	**0,253**	**0,386**	0,075	0,087	0,087	0,089	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
CO4	0,000	**0,371**	**0,383**	**0,397**	**0,253**	0,060	0,066	0,066	0,067	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
CS1	0,519	0,000	0,000	0,000	0,000	**0,248**	**0,303**	**0,268**	**0,311**	0,564	0,564	0,564	0,564	0,564	0,459	0,000	0,000	0,000	0,000	0,000	0,000
CS2	0,263	0,000	0,000	0,000	0,000	**0,311**	**0,249**	**0,312**	**0,273**	0,145	0,151	0,151	0,145	0,140	0,126	0,000	0,000	0,000	0,000	0,000	0,000
CS3	0,173	0,000	0,000	0,000	0,000	**0,221**	**0,194**	**0,174**	**0,220**	0,162	0,156	0,150	0,156	0,161	0,162	0,000	0,000	0,000	0,000	0,000	0,000
CS4	0,063	0,000	0,000	0,000	0,000	**0,220**	**0,254**	**0,245**	**0,196**	0,162	0,156	0,150	0,156	0,161	0,266	0,000	0,000	0,000	0,000	0,000	0,000
F1	0,100	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	**0,173**	**0,207**	**0,209**	**0,215**	**0,202**	**0,182**	0,000	0,000	0,000	0,000	0,000	0,000
F2	0,298	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	**0,173**	**0,151**	**0,157**	**0,177**	**0,173**	**0,182**	0,000	0,000	0,000	0,000	0,000	0,000
F3	0,317	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	**0,179**	**0,166**	**0,153**	**0,159**	**0,181**	**0,181**	0,000	0,000	0,000	0,000	0,000	0,000
F4	0,091	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	**0,172**	**0,152**	**0,170**	**0,146**	**0,173**	**0,159**	0,000	0,000	0,000	0,000	0,000	0,000
F5	0,035	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	**0,173**	**0,199**	**0,204**	**0,194**	**0,165**	**0,199**	0,000	0,000	0,000	0,000	0,000	0,000
F6	0,114	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	**0,130**	**0,125**	**0,106**	**0,110**	**0,105**	**0,097**	0,000	0,000	0,000	0,000	0,000	0,000
VR1	0,000	0,197	0,197	0,203	0,203	0,203	0,208	0,208	0,208	0,208	0,208	0,208	0,208	0,208	0,208	1,000	0,000	0,000	0,000	0,000	0,000
VR2	0,000	0,133	0,133	0,134	0,133	0,134	0,134	0,134	0,134	0,134	0,134	0,134	0,134	0,134	0,134	0,000	1,000	0,000	0,000	0,000	0,000
VR3	0,000	0,194	0,197	0,198	0,198	0,198	0,198	0,203	0,207	0,207	0,207	0,207	0,207	0,207	0,207	0,000	0,000	1,000	0,000	0,000	0,000
VR4	0,000	0,190	0,190	0,186	0,195	0,188	0,184	0,184	0,179	0,170	0,170	0,179	0,184	0,179	0,172	0,000	0,000	0,000	1,000	0,000	0,000
VR5	0,000	0,139	0,139	0,139	0,139	0,145	0,145	0,145	0,142	0,151	0,154	0,154	0,150	0,154	0,160	0,000	0,000	0,000	0,000	1,000	0,000
VR6	0,000	0,185	0,181	0,181	0,177	0,177	0,177	0,173	0,175	0,176	0,172	0,167	0,167	0,167	0,167	0,000	0,000	0,000	0,000	0,000	1,000

X=

	CS1	**CS2**	**CS3**	**CS4**
CS1	0,00	0,42	0,06	0,47
CS2	0,47	0,00	0,47	0,06
CS3	0,37	0,06	0,00	0,23
CS4	0,06	0,47	0,23	0,00

$T = X.(I-X)^{-1} =$

	CS1	**CS2**	**CS3**	**CS4**
CS1	1,52	1,91	1,41	1,62
CS2	1,91	1,57	1,64	1,42
CS3	1,36	1,22	0,92	1,15
CS4	1,35	1,60	1,29	1,02

	CS1	**CS2**	**CS3**	**CS4**
CS1	0,19	0,26	0,24	0,25
CS2	0,34	0,25	0,35	0,33
CS3	0,28	0,26	0,19	0,25
CS4	0,19	0,23	0,22	0,16

(1) Fuzzy Normalized Direct Relation Matrix

(2) Total Relation Matrix

(3) Normalized Total Relation Matrix

In our application study, we raised the supermatrix to the power 51.

Table 4.16 Weighted supermatrix for cloud technology provider alternatives

	Goal	CO1	CO2	CO3	CO4	CS1	CS2	CS3	CS4	F1	F2	F3	F4	F5	F6
VR1	0,20	0,19	0,19	0,19	0,19	0,19	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20	0,20
VR2	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13
VR3	0,19	0,19	0,19	0,19	0,19	0,19	0,19	0,19	0,19	0,19	0,19	0,19	0,19	0,19	0,19
VR4	0,18	0,18	0,18	0,18	0,18	0,18	0,18	0,18	0,18	0,17	0,17	0,17	0,18	0,17	0,17
VR5	0,14	0,13	0,13	0,13	0,13	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,14
VR6	0,17	0,18	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17	0,17

Step 7: Alternatives were evaluated by using fuzzy TOPSIS. Amazon Web Services provides a variety of cloud-based computing services including a wide selection of compute instances which can scale up and down automatically to meet the needs of your application, a managed load balancing service as well as fully managed desktops in the cloud. Amazon Web Services also provides low-cost data storage with high durability and availability. Pay-as-you-go pricing with no commitment means greater flexibility and agility. With AWS, high security is available at no extra cost. AWS offers storage choices for backup, archiving, and disaster recovery, as well as block, file, and object storage (aws.amazon.com).

With Azure Cloud Services, we can develop, package, and deploy powerful applications and services to the cloud. We can test our application before deploying to the cloud using the Azure Emulator, which brings the platform’s key functionality right to our dev machine. Azure helps us to keep tabs on the health and available of your applications. The health metrics dashboard shows key stats at-a-glance on the health metrics dashboard (azure.microsoft.com).

Rackspace helps run our day-to-day cloud operations to provide proactive infrastructure monitoring, operating system maintenance and patching, application maintenance, and more all supported by a dedicated account team whose focus is understanding our business and helping it grow. Rackspace offers much more than infrastructure alone, because it takes much more than high-performance, reliable infrastructure to succeed in the cloud (rackspace.com).

Table 4.17 Linguistic decision matrix for provider evaluation

	VR1	VR2	VR3	VR4	VR5	VR6
Azure	ML	FL	FL	FL	MG	M
AWS	VG	MG	G	MG	VG	M
Rackspace	MG	M	MG	ML	G	FL

Table 4.18 Fuzzy decision matrix for provider evaluation

	VR1	VR2	VR3	VR4	VR5	VR6
Azure	(0,3; 0,4; 0,5)	(0,2; 0,3; 0,4)	(0,2; 0,3; 0,4)	(0,4; 0,5; 0,6)	(0,2; 0,3; 0,4)	(0,5; 0,6; 0,7)
AWS	(0,8; 0,9; 1,0)	(0,5; 0,6; 0,7)	(0,5; 0,6; 0,7)	(0,4; 0,5; 0,6)	(0,7; 0,8; 0,9)	(0,8; 0,9; 1,0)
Rackspace	(0,5; 0,6; 0,7)	(0,4; 0,5; 0,6)	(0,3; 0,4; 0,5)	(0,2; 0,3; 0,4)	(0,5; 0,6; 0,7)	(0,7; 0,8; 0,9)

Table 4.19 Weighted decision matrix for supplier alternative evaluation

	VR1	VR2	VR3	VR4	VR5	VR6
Azure	(0,06; 0,08; 0,10)	(0,02; 0,30; 0,40)	(0,04; 0,06; 0,08)	(0,07; 0,09; 0,11)	(0,03; 0,04; 0,06)	(0,08; 0,10; 0,12)
AWS	(0,16; 0,18; 1,20)	(0,50; 0,60; 0,70)	(0,10; 0,11; 0,13)	(0,07; 0,09; 0,11)	(0,10; 0,11; 0,12)	(0,14; 0,15; 0,17)
Rackspace	(0,10; 0,12; 0,14)	(0,40; 0,50; 0,60)	(0,06; 0,08; 0,10)	(0,04; 0,05; 0,07)	(0,07; 0,08; 0,10)	(0,12; 0,14; 0,15)

Table 4.20 Positive distances of cloud computing technology service provider alternatives

	d1	d2	d3	d4	d5	d6	dtot
Azure	0,92	0,96	0,94	0,09	0,96	0,90	4,77
AWS	0,82	0,91	0,90	0,89	0,85	0,85	5,22
Rackspace	0,88	0,93	0,94	0,92	0,86	0,86	5,40

Table 4.21 Negative distances of cloud computing technology service provider alternatives

	d1	d2	d3	d4	d5	d6	dtot
Azure	0,08	0,04	0,06	0,09	0,04	0,10	0,41
AWS	0,18	0,08	0,12	0,09	0,11	0,15	0,72
Rackspace	0,12	0,06	0,08	0,05	0,08	0,14	0,54

Table 4.22 Final performance indices of cloud computing technology service provider alternatives

Final performance indices	
Performance Indices	
Azure	0,09
AWS	0,14
Rackspace	0,10

Table 4.22 shows the final ranking and the most efficient cloud computing technology provider is AWS.

5. CONCLUSION

Cloud computing is an important technology aiming to deliver a network of virtual services so that users can access them from anywhere in the world on subscription at competitive costs. The cloud service selection criteria are developed based on the literature review and a series of discussions with the case company's experts. The objective of this thesis was determining critical dimensions and critea in outsourcing of cloud service using integrated fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS methods and applying this framework to an application study for deciding the most effective alternative.

Based on the assesements of the experts and our case study, the importance of the criteria for each dimension can be prioritized based on (D+R) values. In view of this, we evaluated the importance of dimensions/criteria using their (D+R) value that represents their importance. Thus, the priority rank is Vendor Related, Cloud Security, Cost and Functionality respectively. Obviously, Vendor Related and Cloud Security are the two most critical dimensions by numerical figures, while functionality is the least dimension to be taken into account. Considering both Vendor Related and Cloud Security is not helpful to effectively outsource a provider since these two dimensions are affected by the other dimensions. For functionality dimension; communication, deployment, availability, reliability and service stability are the most critical criteria. For healty and cost-effective processes of customers, cost dimension requires two critical criteria as support cost and flexibility must be first evaluated both by customers and providers.

The interdependencies between criteria obtained by fuzzy DEMATEL are then normalized and carried in the supermatrix of fuzzy ANP in order to evaluate and select the most suitable outsourcing alternative using fuzzy TOPSIS.

In light of the expert opinions and deep academics knowledge, priorities of our reviewed vendor related criteria were identified as vendor's reputation, community support, R&D capability, trustworthiness of the provider, documentation and experience in related products rexpectively. Eventually, relative weights for each cloud service outsourcing alternative are found out and the AWS is preferred as the most eligible partner since it has the greatest relative weight. The rest of the alternatives are ranked as Rackspace, and the least preferred cloud computing technology service provider alternative is Azure to meet the needs of customer BlogTO.com. The proposed approach and applied case study illustrate how the model should be applied in real world decision processes. Other work such as Iosup et al. (2011), Cunha et al. (2011), Chang et al. (2012), Dasilva et al. (2013) have tried to compare the cloud service providers indicating the performance evaluation of clouds and their result also focuses AWS as chosen cloud computing service.

While we believe that the presented evaluation framework provides value, there are also further points that can be included. This study was based on consensus of opinions and future study can include consideration of different evaluations by the aid of group decision making. Future research could also include the application of the proposed approach to the different cloud service user companies.

REFERENCES

Akioka, S., Muraoka, Y. (2010). HPC Benchmarks on Amazon EC2. IEEE 24th International Conference on Advanced Information Networking and Applications Workshops. p.1024-1034.

Alabool, H., Mahmood, A. (2013). Trust-Based Service Selection in Public Cloud Computing Using Fuzzy Modified VIKOR Method. Australian Journal of Basic and Applied Sciences, 7(9), p.211-220.

Aleem, A., Sprott, C. R. (2013). Let me in the Cloud: Analysis of the Benefit and Risk Assessment of Cloud Platform. Journal of Financial Crime, 20 (1), p.6-24.

Alhamad, M., Dillon, T., Wu, C., Chang, E. (2010). Response Time for Cloud Computing Providers. Real-Time and Stream Applications, p.603-606.

Alshamaila, Y., Papagiannidis, S., Li, F. (2012). Cloud Computing Adoption by SMEs in the North East of England. Journal of Enterprise Information Management, 26 (3), p.250-275.

Awasthi, A., Chauhan, S., Omrani, H. (2011). Application of Fuzzy Topsıs in Evaluating Sustainable Transportation Systems. Expert Systems with Applications, 38, p.12270–12280

Ayub, M., Kabir, J., Alamt, G. (2009). Personnel Selection Method Using Analytic Network Process (ANP) and Fuzzy Concept. In: Proceedings of 2009 12th International Conference on Computer and Information Technology (ICCIT 2009), December 21-23, Bangladesh, p.373-378.

Baykasoğlu, A., Kaplanoğlu, V., Durmuşoğlu, Z.D.U., Şahin, C. (2013). Integrating Fuzzy DEMATEL and Fuzzy Hierarchical TOPSIS Methods for Truck Selection. Expert Systems with Applications, 40, p.899-907.

Baykasoglu, A., Durmusoglu, Z. (2014). A Hybrid MCDM for Private Primary School Assessment Using DEMATEL Based on ANP and Fuzzy Cognitive Map. International Journal of Computational Intelligence Systems, 7-4, p.615-635.

Bayrak, T. (2013). A Decision Framework for SME Information Technology (IT) Managers: Factors for Evaluating Whether to Outsource Internal Applications to Application Service Providers. Technology in Society, 35, p.14-21.

Benlian, A., Hess, T. (2011). Opportunities and Risks of Software-as-a-service: Findings from a Survey of IT Executives. Decision Support Systems, 52, p.232–246.

Bensch, S., Andris, R., Gahm, C., Tuma, A. (2014). IT Outsourcing: An IS Perspective. In: Hawaii International Conference on System Science, 47, p.4210-4219.

Boran, S., Goztepe, K. (2010). Development of a Fuzzy Decision Support System for Commodity Acquisition using Fuzzy Analytic Network Process. Expert Systems with Applications, 37, p.1939-1945.

Buyukozkan, G., Cifci, G. (2012). A Novel Hybrid MCDM Approach Based on fuzzy DEMATEL, Fuzzy ANP and Fuzzy TOPSIS to Evaluate Green Suppliers. Expert Systems with Applications, 39, p.3000–3011.

Buyukozkan, G., Maden, A., (2015). An Integrated Fuzzy MCDM Approach for Evaluation of Cloud Technology Service Provider. Accepted paper for the 9th International Conference on Business Administration (ICBA '15), Dubai, United Arab Emirates, February.

Cao, J., Cao, G., Wang, W. (2012). A Hybrid Model Using Analytic Network Process and Gray Relational Analysis for Bank’s IT Outsourcing Vendor Selection, Models , Methods And Applications, p.994-1013.

Cardoso, J., Sheth, A., Miller, J., Arnold, J. (2004). Quality of Service for Workflows and Web Service Processes, Web Semantics: Science, Services and Agents on the World Wide Web, p.281–308.

Casas, P., Schatz, R. (2014). Quality of Experience in Cloud Services: Survey and Measurements. Computer Networks, In press.

Cavallaro, F. (2010). Fuzzy TOPSIS Approach for Assessing Thermal-Energy Storage in Concentrated Solar Power Systems. Applied Energy, 87, p.496–503.

Chamodrakas, I., Martakos, D. (2012). A Utility-Based Fuzzy TOPSIS Method for Energy Efficient Network Selection in Heterogeneous Wireless Networks. Applied Soft Computing, 12, p.1929–1938.

Chamzini, A., Shariati, S., Yakhchali, S., Zavadskas, E. (2014). Proposing a New Methodology for Prioritising the Investment Strategies in the Private Sector of Iran. Economic Research-Ekonomska Istraživanja, 27-1, p.320-345.

Chang, B., Chang, C.W., Wu, C.H. (2011a). Fuzzy DEMATEL Method for Developing Supplier Selection Criteria. Expert Systems with Applications, 38, p.1850-1858.

Chang, C., Horng, D., Lin, H. (2011b). A Measurement Model for Experts Knowledge-Based Systems Algorithm using Fuzzy Analytic Network Process. Expert Systems with Applications, 38, p.12009-12017.

Chang, C., Liu, P., Wu, J. (2012). Probability-based Cloud Storage Providers Selection Algorithms with Maximum Availability. In: 41st International Conference on Parallel Processing, p-199-208.

Chang, B., Kuo, C., Wu, C., Tzeng, G. (2015). Using Fuzzy Analytic Network Process to Assess the Risks in Enterprise Resource Planning System Implementation. Applied Soft Computing ,28, p.196–207.

Chen, C.C., Tseng, M.L., Lin, Y.H. (2008). Using Fuzzy DEMATEL to Develop a Causal and Effect Model of Hot Spring Service Quality Expectation. In: Proceedings of the 2008 IEEE, p.1004-1008.

Chen, J., Chen, I. (2010). Using a Novel Conjunctive MCDM Approach Based on DEMATEL, fuzzy ANP, and TOPSIS as an Innovation Support System for Taiwanese Higher Education. Expert Systems with Applications, 37,p.1981–1990.

Chen, L., Hung, C. (2010). An Integrated Fuzzy Approach for The Selection of Outsourcing Manufacturing Partners in Pharmaceutical R&D. International Journal of Production Research, 48-24, p.7483–7506.

Chen, T. (2011). Interval-valued fuzzy TOPSIS Method with Leniency Reduction wnd an Experimental Analysis. Applied Soft Computing, 11, p.4591–4606.

Chen, C., Yan, S., Zhao, G., Lee, B., Singhal, S. (2012). A Systematic Framework Enabling Automatic Conflict Detection and Explanation in Cloud Service Selection for Enterprises. In: IEEE Fifth International Conference on Cloud Computing, p.883-890.

Chiu, D., Agrawal, G. (2010). Evaluating Caching and Storage Options on the Amazon Web Services Cloud. 11th IEEE/ACM International Conference on Grid Computing. p.17-24.

Chu, T., Lin, Y. (2009). An Interval Arithmetic Based fuzzy TOPSIS model. Expert Systems with Applications, 36, p.10870–10876.

Chou, Y.C., Sun, C.C., Yen, H.Y. (2012). Evaluating the Criteria for Human Resource for Science and Technology (HRST) based on an Integrated Fuzzy AHP and fuzzy DEMATEL Approach. Applied Soft Computing, 12, p.64–71.

Chyu, C., Fang, Y. (2014) A Hybrid Fuzzy Analytic Network Process Approach to the New Product Development Selection Problem. Mathematical Problems in Engineering, 2014, p.13.

Cunha, M., Mendonça, N., Sampaio, A. (2011). Investigating the Impact of Deployment Configuration and User Demand on a Social Network Application in the Amazon EC2

Cloud. In: Third IEEE International Conference on Coud Computing Technology and Science, p.746-751.

Dagdeviren, M. Yuksel, I. (2010). A fuzzy analytic network process (ANP) model for measurement of the sectoralcompetititon level (SCL). Expert Systems with Applications, 37, p.1005–1014.

Dargi, A., Anjomshoae, A., Galankashi, M., Memari, A., Tap, M. (2014). Supplier Selection: A Fuzzy-ANP Approach. Procedia Computer Science, 31, p.691-700

DaSilva, C., Trkman, P., Desouza, K., Lindi, J. (2013). Disruptive Technologies: A Business Model Perspective on Cloud Computing. Technology Analysis & Strategic Management, 25 (10), p.1161-1173.

Dorri, M., Kazemipour, H., Peydaei, M. (2014). Proposing a Model for the Selection of Repair & Maintenance Strategy for IT Systems with the Help of DEMATEL&ANP Fuzzy Process. Kuwait Chapter of Arabian Journal of Business and Management Review, 3-6, p.202-218.

Dou, W., Qi, L., Zhang, X., Chen, J. (2013). An Evaluation Method of Outsourcing Services for Developing an Elastic Cloud Platform. J Supercomput, 63, p.1-23.

Ergu, D., Kou, G., Peng, Y., Shi, Y., Shi, Y. (2013). The Analytic Hierarchy Process: Task Scheduling and Resource Allocation in Cloud Computing Environment. Journal of Supercomputing , 64, p.835–848.

Ergu, D., Peng, Y. (2014). A framework for SaaS Software Packages Evaluation and Selection with Virtual Team and BOCR of Analytic Network Process. Journal of Supercomputing, 67, p.219–238.

Fan, W., Yang S., Pei, J. (2014). A Novel Two-stage Model for Cloud Service Trustworthiness Evaluation. Expert Systems, 31, p.136-151.

Fekri, R., Aliahmadi, A., Fathian, M. (2009). Identifying the Cause and Effect Factors of Agile NPD Process with Fuzzy DEMATEL Method: the Case of Iranian Companies. Journal of Intelligent Manufacturing, 20, p.637–648.

Feng, Y., Li, B., Li, B. (2014). Price Competition in an Oligopoly Market with Multiple IaaS Cloud Providers. IEEE Transactions on Computers, 63 (1), p.59-73.

Gantman, S. (2011). IT Outsourcing in the Public Sector: A Literature Analysis. Journal of Global Information Technology Management, 14-2, p.48-83.

Garg, S., Versteeg, S., Buyya, R. (2012). A Framework for Ranking of Cloud Computing Services. Future Generation Computer Systems, 29, p.1012–1023.

Ghosh, N., Ghosh, S., Das, S. (2014). SelCSP: A Framework to Facilitate Selection of Cloud Service Providers. IEEE Transactions on Cloud Computing, p.2168-7161.

Godse, M., Mulik, S. (2009). An Approach for Selecting Software-as-a-Service (SaaS) Product. In: IEEE International Conference on Cloud Computing, p.155-158.

Gong, C. Liu, J., Zhang, Q., Chen, H.,and Gong, Z. (2010). The Characteristics of Cloud Computing. In: 39th International Conference on Parallel Processing Workshops, p.275-279.

Goo, J., Huang, D., Hart, P. (2008) A Path to Successful IT Outsourcing: Interaction Between Service-Level Agreements and Commitment. Decision Sciences, 39-3, p.469-506.

Ghorbani, M., Velayati, R., Ghorbani, M. (2011). Using Fuzzy TOPSIS to Determine Strategy Priorities by SWOT Analysis. In: 2011 International Conference on Financial Management and Economics, p.135-139.

Grubisic, I. (2013). ERP in Clouds or Still Below. Journal of Systems and Information Technology, 16 (1), p.62-76.

Guneri, A.F., Cengiz, M., Seker, S. (2009). A fuzzy ANP Approach to Shipyard Location Selection. Expert Systems with Applications, 36, p.7992–7999.

He, Q., Luo, L., Hu, Y., Chan, A. (2014). Measuring the Complexity of Mega Construction Projects in China-A Fuzzy Analytic Network Process Analysis. International Journal of Project Management, p.15.

Hiete, M., Merz, M., Comes, T., Schultmann, F. (2012). Trapezoidal Fuzzy DEMATEL Method to Analyze and Correct for Relations Between Variables in a Composite Indicator for Disaster Resilience, OR Spectrum, 34, p.971–995.

Hsua, C., Kuob, T., Chenc, S., Hud, A. (2013). Using DEMATEL to Develop a Carbon Management model of Supplier Selection in Green Supply Chain Management. Journal of Cleaner Production, 56, p.164-172.

Hsu, C.Y., Chen, K.T., Tzeng, G.H. (2007). FMCDM with Fuzzy DEMATEL Approach for Customers' Choice Behavior Model. International Journal of Fuzzy Systems, 9, p.236-246.

Hu, S., Lu, M., Tzeng, G. (2014). Exploring Smart Phone Improvements based on a Hybrid MCDM Model. Expert Systems with Applications, 41, p.4401–4413.

Huang, C., Wan, C., Tzeng, G. (2011). Expatriate Manager Selection for an Overseas Manufacturing Site by Using FMCDM Methods. In: IEEE International Conference on Fuzzy Systems, June 27-30, Taiwan.

Huang, C., Kao, Y. (2012). The Fuzzy DNP Based TAM3 for Analyzing the Factors Influencing the Acceptance of PadFones. In: Proceedings of International Conference on Fuzzy Theory and Its Applications, Nov.16-18, Taiwan.

Huang, C., Liu, C., Tzeng, G. (2012). The Fuzzy DEMATEL Based Impact Derivations for Integrated Market-ing Communications on the High-Technology Brands. In:

Proceedings of International Conference on Fuzzy Theory and Its Applications, Nov.16-18, Taiwan.

Huang, C., Ting, Y. (2012). Derivations of Factors Influencing the Word-of-Mouth Marketing Strategies for Smart Phone Applications by Using the Fuzzy DEMATEL Based Network Process. In: Proceedings of International Conference on Fuzzy Theory and Its Applications National Chung Hsing University, Nov.16-18, Taiwan.

Hung, Y.H., Chou, S.T. , Tzeng, G.H. (2007). Knowledge Management Strategic Planning, IEEE, p.233-238.

Iosup, A., Ostermann, S., Yigitbasi, M., Prodan, R., Fahringer, T., Epema, D. (2011). Performance Analysis of Cloud Computing Services for Many-Tasks Scientific Computing. In: IEEE Transactions On Parallel And Distributed Systems, June, 22(6), p.931-945.

Isalou, A., Zamani, V., Shahmoradi, B., Alizadeh, H. (2013). Landfill Site Selection using Integrated Fuzzy Logic and Analytic Network Process (F-ANP). Environmental Earth Sciences, 68, p.1745-1755.

Jadhav, A., Sonar, R. (2009). Evaluating and Selecting Software Packages: A review. Information and Software Technology, 51, p.555-563.

Jaafari, A., Najafi, A., Melónc, M. (2015). Decision-making for the Selection of a Best Wood Extraction Method: An Analytic Network Process Approach. Forest Policy and Economics, 50, p.200–209.

Jassbi, J., Mohamadnejad, F., Nasrollahzadeh, H. (2011). A Fuzzy DEMATEL Framework for Modeling Cause and Effect Relationships of Strategy Map. Expert Systems with Applications, 38, p.5967–5973.

Jeng, D., Tzeng, G. (2012). Social Influence on the use of Clinical Decision Support Systems: Revisiting the Unified Theory of Acceptance and Use of Technology by the Fuzzy DEMATEL Technique, Computers & Industrial Engineering, 62, p.819–828.

Jiang, J., Chen, Y., Chen, Y., Yang, K. (2011). TOPSIS with Fuzzy Belief Structure for Group Belief Multiple Criteria Decision Making. Expert Systems with Applications, 38, p.9400–9406.

Ju, Z. (2011). Fuzzy-ANP based Research on the Risk Assessment of Runway Excursion. In: The Tenth International Symposium on Operations Research and Its Applications (ISORA 2011), August 28–31, China, p.350-358.

Jung, G., Mukherjee, T., Kunde, S., Kim, H., Sharma, N., Goetz, F. (2013) CloudAdvisor: A Recommendation-as-a-Service Platform for Cloud Configuration and Pricing. In:IEEE Ninth World Congress on Services, p.456-463.

Junior, F., Osiro, L., Carpinetti, L. (2014). A Comparison Between Fuzzy AHP and Fuzzy TOPSIS Methods to Supplier Selection. Applied Soft Computing, 21, p.194–209.

Jula, A., Sundararajan, E., Othman, Z. (2014). Cloud Computing Service Composition: A Systematic Literature Review. Expert Systems with Applications, 41, p.3809-3824.

Kang, H., Lee, A., Yang, C., (2012). A fuzzy ANP model for supplier selection as applied to IC packaging. Journal of Intelligent Manufacturing, 23, p.1477–1488.

Kang, J., Sim, K. (2011). Ontology and Search Engine for Cloud Computing System. In: International Conference on System Science and Engineering, China, June. p. 276-281.

Kang, J., Sim, K. (2010). Cloudle: A Multi-criteria Cloud Service Search Engine, In: IEEE Asia-Pacific Services Computing Conference, p.339-346.

Kannan, G., Pokharel, S., Kumar, P. (2009). A Hybrid Approach Using ISM and Fuzzy TOPSIS for the Selection of Reverse Logistics Provider. Resources, Conservation and Recycling, 54, p.28–36.

Kannan, D., Jabbour, A., Jabbour, C. (2014). Selecting Green Suppliers based on GSCM Practices: Using fuzzy TOPSIS Applied to a Brazilian Electronics Company. European Journal of Operational Research, 233, p.432–447.

Karim, R., Ding, C., Miri, A. (2013). An End-to-end QoS Mapping Approach for Cloud Service Selection. In: IEEE Ninth World Congress on Services, p.341-348.

Kelemenis, A., Ergazakis, K., Askounis, D. (2011). Support Managers' Selection Using an Extension of Fuzzy TOPSIS. Expert Systems with Applications, 38, p.2774–2782.

Kim, Y., Chung, E., Jun, S., Kim, S. (2013). Prioritizing the Best Sites for Treated Wastewater Instream Use in an Urban Watershed using Fuzzy TOPSIS. Resources, Conservation and Recycling, 73, p.23– 32.

Kossmann, D., Kraska, T., Loesing, S. (2010). An Evaluation of Alternative Architectures for Transaction Processing in the Cloud. In: SIGMOD'10, June 6-11, USA, p.579-590.

Krohling, R., Campanharo, V. (2011). Fuzzy TOPSIS for Group Decision Making: A Case Study for Accidents with Oil Spill in the Sea. Expert Systems with Applications 38, p.4190–4197.

Kumar, G., Maiti, J. (2012). Modeling Risk Based Maintenance Using Fuzzy Analytic Network Process. Expert Systems with Applications, 39, p.9946–9954.

Kuo, M., Liang, G. (2011). A Novel Hybrid Decision-Making Model for Selecting Locations in a Fuzzy Environment. Mathematical and Computer Modelling, 54, p.88-104.

Kuyucu, A. (2011). The Playground of Cloud Computing in Turkey. Procedia Computer Science, 3, p.459-463.

Lee, Y.C., Li, M.L., Yen, T.M., Huang, T.H. (2011). Analysis of Fuzzy Decision Making Trial and Evaluation Laboratory on Technology Acceptance Model. Expert Systems with Applications, 38, p.14407–14416.

Lee, W., Huang, A.,Chang, Y., Cheng, C. (2011). Analysis of decision making factors for equity investment by DEMATEL and Analytic Network Process. Expert Systems with Applications, 38, p.8375–8383.

Lee, S., Park, S., Lim, G. (2013). Using Balanced Scorecards for the Evaluation of “Software-as-a-service”. Information & Management, 50, p.553–561.

Lee, Y., Tang, N., Sugumaran, V., (2014). Open Source CRM Software Selection using the Analytic Hierarchy Process. Information Systems Management, 31, p. 2–20.

Lenk, A., Menzel, M., Lipsky, J., Tai, S. (2011). What are you paying for? Performance benchmarking for Infrastructure-as-a-Service offerings. IEEE 4th International Conference on Cloud Computing, p.484-491.

Li, A., Zong, X., Kandula, S., Yang, X., Zhang, M. (2011). CloudProphet: Towards Application Performance Prediction in Cloud. In: SIGCOMM, August 15–19, Toronto, Canada. p.426-427.

Li, A., Yang, X., Kandula, S., Zhang, M. (2011). Comparing Public Cloud Providers. IEEE Internet Computing, Marc-April, p.50-53.

Li, Z., O’Brien L., Zhang, H., Cai, R. (2012). On a Catalogue of Metrics for Evaluating Commercial Cloud Services. In: ACM/IEEE 13th International Conference on Grid Computing, p.164-173.

Li, Z., O'Brien, L., Zhang, H., Cai, R. (2012). Towards a Taxonomy of Performance Evaluation of Commercial Cloud Services. In: IEEE Fifth International Conference on Cloud Computing, p.344-351.

Li, Z., O'Brien L., Zhang, H., Cai, R., Flint, S. (2013). On Evaluating Commercial Cloud Services: A Systematic Review. The Journal of Systems and Software, 86, p.2371-2393.

Lin, L., Hsu, T. (2011). Designing a Model of FANP in Brand Image Decision-making. Applied Soft Computing, 11, p.561–573.

Lin, R. (2013). Using Fuzzy DEMATEL to Evaluate the Green Supply Chain Management Practices. Journal of Cleaner Production, 40, p.32-39

Lin, C., Wu, W. (2008). A Causal Analytical Mmethod for Group Decision-making Under Fuzzy Environment Expert Systems with Applications, 34, p.205-213.

Lin, C., Hsieh, M., Tzeng, G. (2010). Evaluating Vehicle Telematics System by Using a Novel MCDM Techniques with Dependence and Feedback, Expert Systems with Applications, 37, p.6723–6736.

Lin, R.J., Chen, R.H., Nguyen, T.H. (2011). Green Supply Chain Management Performance in Automobile Manufacturing Industry Under Uncertainty, Procedia - Social and Behavioral Sciences, 25, p.233 – 245.

Liou, J., Chuang, Y. (2010). Developing a Hybrid Multi-criteria Model for Selection of Outsourcing Providers. Expert Systems with Applications, 37, p.3755-3761.

Liou, H., Wang, S., Hsu, C., Yin, L. (2011). A hybrid model for selection of an outsourcing provider. Applied Mathematical Modelling, 35, p.5121–5133.

Liou, J.J.H., Yen, L., Tzeng, G.H. (2008). Building an Effective Safety Management System for Airlines. Journal of Air Transport Management, 14, p.20–26.

Liu, C., Tzeng, G., Lee, M. (2012). Improving Tourism Policy Implementation e The use of Hybrid MCDM models. Tourism Management, 33, 413-426.

Liu, C., Tzeng, G., Lee, M., Lee, P. (2013). Improving Metro–Airport Connection Service for Tourism Development: Using hybrid MCDM Models. Tourism Management Perspectives, 6, p.95–107.

Liu, H., You, J., Zhen, L., Fan, X. (2014). A Novel Hybrid Multiple Criteria Decision Making Model for Material Selection with Target-Based Criteria. Materials and Design, 60, p.380–390.

Lo, C., Chen, D., Tsai, C., Chao, K. (2010). Service Selection Based on fuzzy TOPSIS Method. In: IEEE 24th International Conference on Advanced Information Networking and Applications Workshop, p.368-372.

Losup, A., Ostermann, S., Yigitbasi, M. (2011). Performance Analysis of Cloud Computing Services for Many-Tasks Scientific Computing. IEEE Transactions on Parallel and Distributed Systems, 22 (6), p.931-945.

Low, C., Chen, Y. (2012). Criteria for the Evaluation of a Cloud-Based Hospital Information System Outsourcing Provider. Journal of Medical Systems, 36, p.3543–3553.

Lu, M., Lin, S., Tzeng, G. (2013). Improving RFID Adoption in Taiwan's Healthcare Industry Based on a DEMATEL Technique with a Hybrid MCDM model. Decision Support Systems, 56, p.259–269.

Mahdevari, S., Shahriar, K., Esfahanipour, A. (2014). Human Health and Safety Risks Management in Underground Coal Mines Using fuzzy TOPSIS. Science of the Total Environment, 488–489, p.85–99.

Martens, B, Teuteberg, F. (2012). Decision-making in cloud computing environments: A cost and risk based approach. Information System Front, 14, p.871–893.

Matin, H. (2011). The Application of Fuzzy TOPSIS Approach to Personnel Selection for Padir Company, Iran. Journal of Management Research, 3(2).

Mell, P., Grance, T. (2011). The NIST Definition of Cloud Computing. Special Publication, p.800-145.

Menzel, M., Schönherr, M., Tai, S. (2013). MC2/2: criteria, Requirements and a Software Prototype for Cloud Infrastructure Decisions. Softaware-Practice And Experience, 43, p.1283-1297.

Mohammad, A, Mcheick, H. (2011). Cloud Services Testing: An Understanding. Procedia Computer Science, 5, p.513–520.

Ni, J., Qi, L., Yan, C. (2012). A Selection Strategy Supporting Service Outsourcing in Cloud Platform. In: Second International Conference on Cloud and Green Computing, p.726-729.

Nuhodzic, R., Macura, D., Bojovic, N., Milenkovic, M. (2010) Organizational Design of a Rail Company using Fuzzy ANP. African Journal of Business Management, 4-8, p.1494-1499.

Ooi, B., Chan, H., Cheah, Y. (2011). Resource Selection Using Fuzzy Logic for Dynamic Service Placement and Replication. Tencon. p.128-132.

Ouedraogo, M., Mouratidis, H. (2013). Selecting a Cloud Service Provider in the Age of Cybercrime. Computers & Security, 38, p.3-13.

Oussalah, M. (2002). On the Compatibility Between Defuzzfication and Fuzzy Arithmetic Operations. Fuzzy Sets and Systems, 128, p.247–260.

Ozdagoglu, A. (2012). A Multi-criteria Decision-making Methodology on the Selection of Facility Location: Fuzzy ANP. International Journal of Advanced Manufacturing Technology, p.5987-803.

Ozgen, A., Tanyas, M. (2011). Joint Selection of Customs Broker Agencies and International Road Transportation Firms by a Fuzzy Analytic Network Process Approach. Expert Systems with Applications, 38, p.8251-8258.

Park, J., Jeong, H. (2013). The QoS-based MCDM System for SaaS ERP Applications with Social Network, Journal of Supercomputin, 66, p.614–632.

Peng, J., Zhang, X., Lei, Z., Zhang, B., Zhang, W., Li, Q. (2009). Comparison of Several Cloud Computing Platforms. In: Second International Symposium on Information Science and Engineering, p.23-27.

Peng, K.,Tzeng, G. (2012). Improving Tourism Policy Implementation: The use of Hybrid MCDM Models. Tourism Management, 33, p.41-426.

Petcu, D. (2014). Consuming Resources and Services from Multiple Clouds. In: Journal of Grid Computing, 12, p.321-345.

Qu, L., Kang, R., Long, J. (2009). A Fuzzy ANP Model for Evaluating Materiel Support Plan in Development Phase. In: Proceedings of 2009 IEEE International Conference on Grey Systems and Intelligent Services, November 10-12, China, p.809-813.

Qu, C., Buyya, R. (2014). A Cloud Trust Evaluation System using Hierarchical Fuzzy Inference System for Service Selection. In: EEE 28th International Conference on Advanced Information Networking and Applications, p.850-858.

Rad, M., Badashian, A., Meydanipour, G., Delcheh, M., Alipour, M., Afzali, H. (2009). A Survey of Cloud Platforms and Their Future. In: ICCSA, pp.788–796.

Razmi, J., Rafiei, H., Hashemi, M. (2009). Designing a Decision Support System to Evaluate and Select Suppliers using Fuzzy Analytic Network Process. Computers & Industrial Engineering, 57, p.1282-1290.

Razmi, J., Sangari, M., Ghodsi, R. (2009). Developing A Practical Framework For ERP Readiness Assessment Using Fuzzy Analytic Network Process. Advances in Engineering Software, 40, p.168–1178.

Rehman, Z., Hussain, O., Hussain, F. (2014). Parallel Cloud Service Selection and Ranking Based on QoS History. International Journal of Parallel Programming, 42, p.820–852.

Ren, L., Zhang L., Tao F., Zhao, C. (2013). Cloud Manufacturing: From Concept to Practice. Enterprise Information Systems.

Ren, L., Zhang, L., Tao F., Zhao C. (2013). Cloud Manufacturing: From Concept to Practice. Information Systems. p.186-209.

Rimal, B. P., Choi, E. (2012). A Service-oriented Taxonomical Spectrum, Cloudy Challenges and Opportunities of Cloud Computing, International Journal of Communication Systems, 25, p.796–819.

Ristova, E., Gecevska, V. (2011). AHP Methodology and Selection of an Advanced Information Technology due to PLM Software Adoption. In: XV International Scientific Conference on Industrial Systems (IS'11), Novi Sad, Serbia, September 14-16.

Roszkowsk, E., Wachowicz, T. (2015). Application of fuzzy TOPSIS to Scoring the Negotiation Offers in Ill-Structured Negotiation Problems. European Journal of Operational Research, 242, p.920–932.

Rouhani, S., Ghazanfari, M., Jafari, M. (2012). Evaluation Model of Business Intelligence for Enterprise Systems Using Fuzzy TOPSIS. Expert Systems with Applications, 39, p.3764–3771.

Samantra, C., Datta, S., Mahapatra, S.S. (2014). Risk Assessment in IT Outsourcing Using Fuzzy Decision-making Approach: An Indian Perspective. Expert Systems with Applications, 41, p.4010-4022.

Sangjae, L., Park, S. B., Lim, G. G. (2013). Using balanced scorecards for the evaluation of ‘‘Software-as-a-service’’. Information & Management, 50, p.553–561.

Saripalli, P., Pingali, G. (2011). MADMAC: Multiple Attribute Decision Methodology for Adoption of Clouds. IEEE 4th International Conference on Cloud Computing, p.316-323.

Sebesta, M., Vorisek, J. (2010). On ICT Services Management and Outsourcing.In: 2nd International Conference on Software Technology and Engineering(ICSTE), 1, p.288-296.

Sebesta, M. (2013). On ICT Services Outsourcing in the Context of Small and Medium Enterprises. Procedia-Social and Behavioral Sciences, 81, p.495-509.

Sebesta, M. (2010). Towards a Framework for Effective Outsourcing Practice within the New Application Service Provisioning Trends. IEEE, p.553-560.

Sevkli, M., Oztekin, A., Uysal, O., Torlak, G., Turkyilmaz, A., Delen, D. (2012). Development of a Fuzzy ANP based SWOT Analysis for the Airline Industry in Turkey. Expert Systems with Applications, 39, p.14-24.

Shafiee, M. (2015). A Fuzzy Analytic Network Process Model to Mitigate the Risks Associated with Offshore Wind Farms. Expert Systems with Applications, 42, p.2143–2152.

Shen, K., Yan, M., Tzeng, G. (2014). Combining VIKOR-DANP Model for Glamor Stock Selection and Stock Performance Improvement. Knowledge-Based Systems, 58, p.86–97.

Siegel, J., Perdue, J. (2012). Cloud Services Measures for Global Use, The Service Measuremet Index. In: Service Research and Innovation Institute Global Conference. p.411-415.

Silas, S., Rajsingh, E., Ezra, K. (2012). Efficient Service Selection Middleware using ELECTRE Methodology for Cloud Environments. Information Technology Journal, 11(7), p.868-875.

Singh, R., Benyoucef, L. (2011). A fuzzy TOPSIS Based Approach for E-Sourcing. Engineering Applications of Artificial Intelligence, 24, p.437–448.

Sinrat, S., Atthirawong, W. (2013). A Conceptual Framework of an Integrated Fuzzy ANP and TOPSIS for Supplier Selection Based on Supply Chain Risk Management. In: Proceedings of the 2013 IEEE, p.1607-1611.

Su, C.H., Tseng, H.L., Tzeng, G.H. (2012). Improving Cloud Computing Service in Fuzzy Environment-Combining Fuzzy DANP and fuzzy VIKOR with a New Hybrid FMCDM Model. International Conference on Fuzzy Theory and Its Applications, p.30-35.

Sultan, N. A. (2011). Reaching for the “cloud”: How SMEs can Manage. International Journal of Information Management, 31, p.272–278.

Sun, C., Lin, G. (2009). Using Fuzzy TOPSIS Method for Evaluating the Competitive Advantages of Shopping Websites. Expert Systems with Applications, 36, p.11764–11771.

Sun, M., Zang, T., Xu, X., Wang, R. (2013). Consumer-Centered Cloud Services Selection Using AHP. In: International Conference on Service Science.

Sun, L., Dong, H., Hussain, F., Hussain, O., Chang, E. (2014). Cloud Service Selection: State-of-the-art and Future Research Directions. Journal of Networkand Computer Applications, 45, p.134–150.

Tabriz, A., Rajabani, N., Farrokh, M. (2014). An Integrated Fuzzy DEMATEL-ANP-TOPSIS Methodology for Supplier Selection Problem. Global Journal of Management Studies and Researches, 1-2, p.85- 99.

Tadic´, Zecˇevic´, Krstic´ (2014). A Novel Hybrid MCDM Model based on Fuzzy DEMATEL, Fuzzy ANP and fuzzy VIKOR for city logistics concept selection. Expert systems with applications. 41, p.8112–8128.

Tam, M., Tummala, V. (2001). An Application of the AHP in Vendor Selection of Telecommunications System. Omega, 29, p.171-182.

Tansel, Y., Yurdakul, M. (2010). Development of a Quick Credibility Scoring Decision Support System Using Fuzzy TOPSIS. Expert Systems with Applications, 37, p.567–574.

Taylan, O., Bafail, A., Abdulaal, R., Kabli, M. (2014). Construction Projects Selection and Risk Assessment by Fuzzy AHP and Fuzzy TOPSIS Methodologies. Applied Soft Computing, 17, p.105–116.

Torlak, G., Sevkli, M., Sanal, M., Zaim, S. (2011). Analyzing Business Competition by Using Fuzzy TOPSIS method: An example of Turkish Domestic Airline Industry. Expert Systems with Applications, 38, p.3396–3406.

Tsai, W., Leu, J., Liu, J., Lin, S., Shaw, M. (2010). A MCDM approach for sourcing strategy mix decision in IT projects. Expert Systems with Applications, 37, p.3870-3886.

Tsai, W., Kuo, H. (2011). Entrepreneurship Policy Evaluation and Decision Analysis for SMEs. Expert Systems with Applications, 38, p.8343–8351

Tsai, W., Chou, W., Leu, J. (2011). An Effectiveness Evaluation Model for the Web-Based Marketing of the Airline Industry. Expert Systems with Applications, 38, p.15499–15516

Tseng, M. (2009). A Causal and Effect Decision Making Model of Service Quality Expectation using Grey-fuzzy DEMATEL Approach. Expert Systems with Applications, 36, p.7738–7748.

Tseng, M., Lin, Y. (2009). Application of Fuzzy DEMATEL to Develop a Cause and Effect Model of Municipal Solid Waste Management in Metro Manila, p.519–533.

Tseng, M. (2011). Using a Hybrid MCDM Model to Evaluate Firm Environmental Knowledge Management in Uncertainty. Applied Software Computing, 11, p.1340–1352.

Ukor, R., Carpenter, A. (2011). Service Selection and Horizontal Multi-sourcing in Process-oriented Capability Outsourcing. Journal of Software Evolution and Process, 24, p.259-283.

Uygun, Ö., Kaçamak, H., Ayşim, G., Şimşir, F. (2013). Supplier Selection for Automotive Industry Using Multi-Criteria Decision Making Techniques. TOJSAT: The Online Journal of Science and Technology, 3-4, p.126-137.

Uygun, O., Kacamak, H., Kahraman, U. (2014). An Integrated DEMATEL and Fuzzy ANP Techniques for Evaluation and Selection of Outsourcing Provider for a Telecommunication Company. Computers & Industrial Engineering. In press

Vinodha, S., Gauthama, S., Ramiyaa, R., Rajanayagam, D. (2010). Application of Fuzzy Analytic Network Process for Agile Concept Selection in a Manufacturing Organisation. International Journal of Production Research, 48-24, p.7243–7264.

Vujanovic, D., Momcˇilovic´, V., Bojovic´, N., Papic, V. (2012). Evaluation of Vehicle Fleet Maintenance Management Indicators by Application of DEMATEL and ANP. Expert Systems with Applications, 39, p.10552-10563.

Walterbusch, M., Martens, B., Teuteber, F. (2013). Evaluating Cloud Computing Services from a Total Cost of Ownership Perspective. Management Research Review, 36 (6), p.613-638.

Wang, R.C., Chuu, S.J. (2004). Group Decision-making Using a Fuzzy Linguistic Approach for Evaluating the Flexibility in a Manufacturing System. European Journal of Operational Research, 154, p.563–572.

Wang, J., Cheng, C., Cheng, H. (2009). Fuzzy Hierarchical TOPSIS for Supplier Selection. Applied Soft Computing, 9, p.377–386.

Wang, T., Lee, H. (2009). Developing a fuzzy TOPSIS Approach Based on subjective Weights and Objective Weights. Expert Systems with Applications, 36, p.8980–8985.

Wang, Y., Tzeng, G. (2012). Brand Marketing for Creating Brand Value Based on a MCDM Model Combining DEMATEL with ANP and VIKOR methods. Expert Systems with Applications, 39, p.5600-5615.

Wang, F., He, W. (2014). Service Strategies of Small Cloud Service Providers: A Case Study of a Small Cloud Service Provider and its Clients in Taiwan. International Journal of Information Management, In press.

Wang, S., Liu, Z., Sun, Q., Zou, H., Yang, F. (2014). Towards an Accurate Evaluation of Quality of Cloud Service in Service-oriented Cloud Computing. In: Journal of Intelligent Manufacturing, 25, p.283–291.

Wang, Y. (2014). The Evaluation of Financial Performance for Taiwan Container Shipping Companies by Fuzzy TOPSIS. Applied Soft Computing, 22, p.28–35.

Whaiduzzaman M., Gani A., Anuar N., Shiraz M., Haque M., Haque I. T. (2014). Cloud Service Selection Using Multicriteria Decision Analysis. The Scientific World Journal, 2014.

Willcocks, L., Venters, W., Whitley, E. (2013). Cloud Sourcing and Innovation: Slow Train Coming?. Strategic Outsourcing: An International Journal, 6 (2), p.184-202.

Wu, Y., Cegıelski, C., Hazen, B., Hall, D. (2013). Cloud Computing in Support of Supply Chain Information System Infrastructure: Understanding When To Go To The Cloud. Journal of Supply Chain Management, p.25-41.

Wu, W. (2008). Choosing Knowledge Management Strategies by Using a Combined ANP and DEMATEL Approach. Expert Systems with Applications, 35, p.828-835.

Zadeh, L.A. (1965). Fuzzy Sets. Information and Control, 8, p.338-353.

Wu, W., Lee, Y. (2007). Developing Global Managers' Competencies Using the Fuzzy DEMATEL Method. Expert Systems with Applications, 32, p.499–507.

Yang, Yu., Shieh, H., Tzeng, G. (2013a). A VIKOR Technique based on DEMATEL and ANP for Information Security Risk Control Assessment. Information Sciences, 232, p. 482-500.

Yang, J., Lin, W., Dou, W. (2013b). An Adaptive Service Selection Method for Cross-Cloud Service Composition, Concurrency and Computation: Practice And Experience. Concurrency Computation, 25, p.2435–2454.

Yazır, Y., Matthews, C., Farahbod, R., Neville, S., Guitouni, A., Ganti, S., Coady, Y. (2010). Dynamic Resource Allocation in Computing Clouds using Distributed Multiple Criteria Decision Analysis. In: IEEE 3rd International Conference on Cloud Computing. p.91-98.

Yiming, C., Yiwei, Z. (2011). SaaS Vendor Selection Basing on Analytic Hierarchy Process. In: Fourth International Joint Conference on Computational Sciences and Optimization, p.511-515.

Zeng, W., Zhao, Y., Zeng, J. (2009). Cloud Service and Service Selection Algorithm Research. In: *GEC'09*, June 12–14, Shanghai, China. p.1045-1048.

Zhao, L., Ren, Y., Li, M., Sakurai, K. (2012). Flexible Service Selection with User-specific QoS Support in Service-oriented Architecture. Journal of Network and Computer Applications, 35, p.962–973.

Zhu, Y., Hu, H., Ahn, G., Yau, S. (2012). Efficient Audit Service Outsourcing for Data Integrity in Clouds. The Journal of Systems and Software, 85, p.1083-1095.

Zouggari, A., Benyoucef, L. (2011). Multi-criteria Group Decision Supplier Selection Problem using Fuzzy TOPSIS Based Approch. EUSFLAT-LFA 2011, July, Aix-les-Bains, France.

BIOGRAPHICAL SKETCH

Ayça Maden was born in Mersin, in 1990. She graduated from Adnan Menderes Anatolian High School in 2008. She holds a B.S. degree in Industrial Engineering from Kocaeli University. In 2012, she graduated from Kocaeli University ranking the second degree in the department and she was accepted for M.S. study in Logistics and Financial Management in Galatasaray University. She works as a research assistant in Piri Reis University in the department of Business Administration and Economics. Based on the study of this master thesis, a paper untitled "An Integrated Fuzzy MCDM Approach for Evaluation of Cloud Technology Service Provider" is for the 9th International Conference on Business Administration (ICBA '15), Dubai, United Arab Emirates on February 22-24, 2015.