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To Move or Not to Move: An Iterative Four-Phase Cloud Adoption Decision Model for IT Outsourcing Based On TCO

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Abstract- Information technology outsourcing (ITO) of organizations on cloud datacenter promises cost effectiveness over traditional on-premises deployment. In this regard, making sustainable decision toward cloud adoption needs profound understanding of cost implications, and social environmental issues. There are several concerns and challenges policymakers face when they encounter with IT options' dilemma. Although the cloud migration has potentially merits account for reduction in total cost of ownership (TCO), there may exist demerits for especial situation of each industry and organization such as degree of uncertainty on privacy, security and communication delay concerns. This paper introduces an iterative four-phase cloud adoption decision model for IT outsourcing to solve industries' and organizations' concerns and challenges by considering cost implication of each contingent options and applying the net present value (NPV) of each alternative during the period of investment along with non-economic issues analysis. Also, the model leverages Moore law and Delphi panelists' interview to estimate price of IT devices in future and to weight cloud adoption determinants and inhibitors respectively. The new services of Telecommunication Company of Mazandaran province (TCM) which is a large-scale industry in IRAN are used as a case study to evaluate the effectiveness of proposed model for six years of investment. Implementation of the model for TCM shows that it is better to establish private datacenter on-premises and apply hybrid deployment in burst of resource demand.

Keywords- Cloud Computing, TCO, Economies of Scale, Net Present Value.

I. Introduction

Since the demand on computing and storage devices increases, it makes industries and organizations shifting toward cloud elastic services [1]. The users take benefit of computing resources in the form of web service from open competitive multi sourcing cloud market based on their requirement [2]. The service deployments allow customers to deploy the needed services on one or more provider datacenters with different pricing schemes. For instance, a company selects hybrid deployment to cover their flash crowd conditions instead of procurement of underutilized equipment settled on premises [3]. The IT outsourcing may refer to leasing of external provider or delegating the management of complete datacenter to external providers [4]. In succinct words, IT outsourcing can be related to lease-purchase decision as part of IT department of each industry [5]. It is the old dilemma toward long-term investment when a policymaker investigates whether the lease or purchase of an equipment has the sense of economic or not. During decades, variety models have been presented in literature to make logical decisions between alternatives [6-8]. IT of an organizations is not exempted from this rule, and with the emergence of cloud computing over the past ten years it is necessary to investigate IT options. Therefore, different decision models have been published to address this issue [9-13]. TCO for IT organization is divided into two major categories: (i) capital expenditures (CAPEX) including purchasing servers, disks, racks, cables, network devices, basic software licenses, etc. and (ii) operational expenditures (OPEX) include electricity bills, software and hardware maintenance costs, labor salaries, etc. CAPEX is onetime event, but OPEX is dynamic. With the emergence of cloud computing, it is feasible for organization to outsource their resources demand on third-party datacenter and reach the resources whenever needed and pay only for the amount of used resources [9]. By applying TCO approach as a representative of overall cost, it can help system reconfiguration and asset redeployment to reach business objectives with high performance, low costs and low risks [2]. However, cloud adoption is generally not trivial because it depends on wide variety classes of industries, organizations and their actors' objectives [14-15]. Hence, the cost variables and implications have to be modeled till policymakers attain accurate cost estimation based on different deployment options [11]. Consequently, the need for a reference decision model is tangible which helps decision makers to select among deployment options. So, considering only pure cost factors does not yield sustainable decision. To fill the gap, our proposed decision model takes the effect of social and environmental factors on cost model into account, besides, financial economy that is derived from Delphi panelists' interview. Because non-economic factors are qualitative in nature, we apply AHP and Delphi methods to quantify their effects in cache flow. This paper's original contributions are:

1. To apply Delphi method as a strong decision tool in IT management context to determine and to weight cloud adoption determinants and inhibitors along with leveraging AHP method to avoid subjective results.
2. To present a mathematical iterative decision model based on TCO which takes not only cost factors, but also sustainable factors into account which are derived from Delphi panelists' interview.
3. To apply TCO approach to analyze all of contingent IT options for investment in determined life cycle and exploit NPV concept to measure time worth of money.
4. To apply Moore law to estimate price of each IT device in future for investment interval.

Industries and organizations can apply the proposed model by placing their cost variables and their investigated non-economic factors into the model to make sustainable decision. The remainder of this paper is organized as follows. Section two is dedicated to related works. Our proposed iterative four-phase cloud adoption decision model is brought in section three. Section four clarifies our case study. Evaluation is explained in section five. Finally, conclusions and the future work are respectively presented in section six.

II. Related Works

Several cost/decision models have been done in literature to solve cloud adoption and IS outsourcing problems [5, 9, 11-12, 16]. Safari et al. have studied over cloud adoption indicators for small-medium enterprises (SMEs) in both enterprise and individual levels [17]. They have inspired technology, organization and environment (TOE) frameworks from literature of their works which was improved at the individual level. Then, they extracted related factors and posed 13 hypotheses to verify [17]. Afterwards, their expert interviews were assessed by AHP method; all of the posed hypotheses were verified except for one, effect of annual IT revenue factor, out of thirteen [17]. A mathematical decision-making model has been proposed by Martens and Teuteberg [5]. Their model supported by solid economic theories exploited cost and security factors to quantitatively decide which service providers are the optimal option. A cloud adoption framework has been suggested by Khajeh Hosseini et al. and implemented in the form of toolkit [11]. It conceptually presents a framework in terms of technology sustainability, cost model, stakeholder impact; responsibility modeling and requirements to assess whether cloud can cover enterprise day to day and strategic requirements. An identification modeling of a company sustainability to adopt cloud computing was presented by Misra and Mondal [18]. By modeling a company's characteristics, they pointed out that the size of IT resource, data sensitivity, workload criticality, resource usage pattern must be investigated before cloud adoption. Nussbaumer and Xiaodong have propounded a systematic methodology in the form of cloud migration framework to investigate cloud migration for SMEs [19]. After study over factors, they advised that the important step for cloud migration is to understand existing business process of organization. Then the authors introduced service-oriented approach with specific requirement to analyze whether a business process is qualified for cloud migration or not. In the ever-changing business and technology environment, the decision model must be as agile as possible to take effective indicators and dominants into account to reach in sustainable point although opting suitable factors and their weights are challenging tasks [18]. Totally, study over researches reveals that there are some shortcomings in suggested models leading them not to be sustainable decision. The drawbacks are for considering only sheer economic implications or along with limited non-economic factors, lack of weighting to indicators, lack of assessing iterative feedback such as customer satisfaction, new cloud pricing schemes, organizational changes, socio-political factors, especially cloud security risk assessment, and its potentially financial losses. To fill the gap, we present a comprehensive decision model which considers wide range of determinant and inhibitor factors along with their weights to make sustainable decision.

III. Proposed Iterative Four-phase Cloud Adoption Decision Model

As policymakers have challenges with service selection problem, we present cloud decision model as can be seen in Figure I.

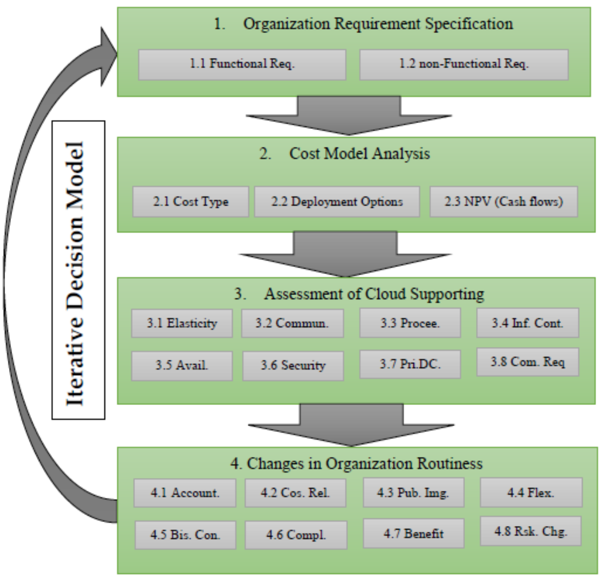

Fig. I. Proposed Iterative Four-Phase Cloud Adoption Decision Model

Phase 1. Organization Requirements Specification (Investigation)

In the investigation phase, the functional and non-functional requirements should be determined for an organization.

. Functional Requirement: it pertains the services to cover company's business functions including software, hardware, business objectives, domain behavioral, and specialist individual requirements. Software requirements are such as applications, mail service, web services, DB service, virtual machines, middleware and etc. Hardware requirements are such as application server (CPU), storage server, disk (storage), RAM, switches, routers, communication links, data transfer (bandwidth), etc., business objectives include acceptable quality of service (in the form of SLA), domain behavioral (usage pattern). Also, individual requirements are technical and non-technical personnel.

. Non-Functional requirement: Desirable level of availability, scalability, reliability, maintainability, recoverability and usage pattern of services and resources must be defined as non-functional requirements.

Phase 2. Cost Model Analysis

In the second phase, CAPEX and OPEX are specified in which these costs must be elaborated in details known as cost types. Then, all feasible deployments must be determined as scenarios to find out the best option (scenario).

. Cost Type: Regardless of any deployment option, total costs (TC) of each investment include fixed costs (FC), variable costs (VC), and potential losses (LS). Note that, nomenclature of parameters in our decision model is elaborated and tabulated in Table I.

Table I. Nomenclature of parameters in our decision model [20].

Symbol	Description	Symbol	Description
S	The number of servers	C_T^{Ls}	The cost of labor for maintaining software per unit ($/hour)
N	The number of network devices	L_T^S	The amount of labor in time interval *T* (hour)
B	The number of basic server software license	C_T^{LH}	The cost of labor for maintaining hardware per unit ($/hour)
K	The number of middleware software license	L_T^H	The amount of labor in time interval *T* (hour)
A	The number of application software license	C_T^{LO}	The cost of labor for other tasks per unit($/hour)
C_j^{Se}	The cost of server *j* ($)	L_T^O	The amount of other labor in time interval *T* (hour)
C_j^{Ne}	The cost of network devices *j* ($)	Q^d	The number of deployments
C_j^{BSS}	The cost of a basic server software license ($)	c_k^{Dep}	adoption cost basis for service *k* deployment ($)
C_j^{MS}	The cost of a basic middleware software license ($)	ζ_{kij}	simplicity parameter of service *k* and sourcing options *i* and *j*
C_j^{AS}	The cost of a basic application software license ($)	w_k	Increasing rate for the sake of multi sourcing complexity
C^{Fa}	The cost of facility space in square meters ($/mm)	C_{ik}^{Dep}	Deployment cost for service *k* with sourcing option *i* ($)
F	The size of the facility space in square meters ($/mm)	$DCV(T)$	Deployment cost vector per time interval *T* ($)
C^{Nee}	Costs for non-electronic equipment ($)	TR_T^{IO}	Total cost of traffic within/across clouds ($)
C^{Ca}	Costs for cabling ($)	C_T^{Sto}	The cost of storage per unit in time interval *T* ($/GB)
C_T^{Ele}	The cost of electricity per unit in time interval *T* ($/KWh)	H_T	The amount of usage storage in time interval *T* (GB)
E_T^{NED}	The amount of electricity usage for non-electronic device in time interval *T*	$C_{j,T}^{Ser}$	Cloud server usage cost for server type *j* in time interval *T* ($/hour)
E_T^{ED}	The amount of electricity usage of electronic device in time interval *T*	S_T^j	The amount of server usage of type *j* in time interval *T* (hour)
C_T^{Int}	The unit cost of internet connectivity usage per unit ($/hour)	$DTM(i,j)$	Data transfer matrix: amount of data transfer between datacenter *i* and *j* (GB)
I_T	The amount of internet usage in time interval *T* (hour)	SP(i)	Service provide *i*
α_i	The output amount of technological loss $L_{i,T}^{TCH}$ during time interval *T*; $\alpha_i \in [0,1]$	TCR(i,j)	Traffic cost rate matrix: shows the cost of data transfer between datacenter *i* and *j* per unit traffic (GB/hour)
β_i	The output amount of organizational changes loss $L_{i,T}^{ORG}$ during time interval *T*; $\beta_i \in [0,1]$	$L_{i,T}^{TCH}$	The basic loss cost due to violating TCH={EL,Com,Down,IC,Av,Sec,Pri,RCom} objectives with sourcing i in time interval *T*
$Income(t)$	Income of year *t*th($)	$L_{i,T}^{ORG}$	The basic loss cost due to disability of ORG={Acc,CRel,PI,Flx,BC,Comp,OTH} changes of objectives with sourcing i in time interval *T*

TC should be calculated for T-year of investment as can be calculated by equation (1):

$$TC_{Investment}(T) = FC(T) + VC(T) + LS(T) \quad (1)$$

whereas FC comprises procurement of servers, network devices, basic server software license, basic middleware, applications, facilities (such as premises or mortgage cost), non-electronic devices (such as cooling systems), cabling for on-premises. The amount of FC is calculated in equation (2) [9]:

$$FC(T) = \sum_j^S C_j^{Se} + \sum_j^N C_j^{Ne} + \sum_j^B C_j^{BSS} + \sum_j^K C_j^{MS} + \sum_j^A C_j^{AS} + C^{Fa}.F + C^{Nee} + C^{Ca} \quad (2)$$

Also, VC comprises electrical utility cost, internet charge, human salaries for software, hardware and other specialist costs, deployment cost, data transfer and bandwidth usage cost, storage costs and virtual server costs for the sake of cloud usage. The amount of VC is calculated in equation (3) [9]:

$$\begin{aligned} VC(T) = C_T^{Ele}.(E_T^{NED} + E_T^{ED}) + C_T^{Int}.I_T \\ + C_T^{Ls}.L_T^S + C_T^{LH}.L_T^H + C_T^{LO}.L_T^O \\ + C_{ik}^{Dep}.Q^d.DCV(T) + TR_T^{IO} \\ + C_T^{Sto}.H_T \\ + \sum_j^{SerType} C_{j,T}^{Ser}.S_T^j \end{aligned} \quad (3)$$

Meanwhile TR_T^{IO} is calculated in equation (4) [9]:

$$TR_T^{IO} = \sum_{i=1}^{M}\sum_{j=1}^{M} DTM(i,j).TCR(SP(i),SP(j)) \quad (4)$$

Moreover, losses (LS) comprise of technological loss and environmental costs in light of disability of cloud competence after cloud adoption scenario. So, losses are calculated by equation (5):

$$LS(T) = L_{Tech}(T) + L_{ORG}(T) \quad (5)$$

The elements of $L_{Tech}(T)$ and $L_{ORG}(T)$ are elaborated in the third and fourth phases.

. Deployment Options: This part illustrates outsourcing of organization's business functions on different sourcing. So, the effect of deployment options is investigated in the second phase. Deployment cost is calculated by equation (6):

$$C_{ik}^{Dep} = c_k^{Dep}.(1 - \zeta_{kij}).w_k \qquad \forall\, k,i,j \quad (6)$$

$$w_k = \ln(I)\ with\ I \neq 1 \quad (7)$$

Deployment parameters $C_{ik}^{Dep}, c_k^{Dep}\ and\ \zeta_{kij}$ are adoption costs for service *k* with sourcing option *i*, adoption cost basis for service *k*, simplicity parameter of service *k* and sourcing options *i* and *j* respectively and w_k is depending on *I* in a logarithmical way, under linear growth. The last term shows that the cost rises if the company selects from different sourcing of set *I* [5]. In equation (6), the term ζ_{kij} is near zero if there exists no experience for outsourcing split service whereas developing company-specific API increases implementation efforts on outsourcer side. On the other hand, ζ_{kij} is near 1 if there exists an implementation experience [5].

. NPV of Cash flows: In economic finance, it is essential key to perceive the time value of money. So, logically, the biggest NPV is the best option.

Phase 3. Assessment of Cloud Supporting

In the third phase, cloud computing which supports elasticity, communication, processing, infrastructure control, availability, security, privacy, and data confidentially and regularly comply with requirement must be well understood in details. Afterwards, the potential losses should be taken into account for decision model due to failure of their mission. In this line, the term $L_{i,T}^{TCH}$ is used as the basic unit amount of technological loss in our decision model where the superscript and subscript indices respectively indicate to the type of loss and due to provider_i disability to provision determined services during the time interval *T*. Also the coefficients α_i , *i*=1,...,8 (cf. Table I), the output amount of technological losses, and the basic unit amount of technological losses are attainable with AHP and Delphi approaches and company background experiences [5, 16, 21-23].

. Elasticity: Elasticity is the seductive and cost-efficient feature of cloud computing such as EC2 instances in which each organization stimulates to adopt it. Provider failure to deliver on-demand service makes $\alpha_1.L_{i,T}^{EL}$ amount of loss in cash flows during time interval *T*.

. Communication: It shows the feasibility of the bandwidth within and across the clouds for applications and workloads; especially communication link circumstance is a crucial feature for communication-intensive workloads. So, the amount of $\alpha_2.L_{i,T}^{Com}$ loss incurred to cash flows on behalf of communication failures.

. Processing: Processing of Amazon EC2 provides an option of using either small or large server instances depending on the amount of CPU capacity and memory required. However, this could be changed for larger instances if the performance is recognized to be unacceptable. However, the amount of $\alpha_3.L_{i,T}^{Down}$ loss is accounted for cash flows due to processing downtime.

. Infrastructure control: The system health, safety and soundness will be periodically checked involving checking error logs, backup logs, server load levels, communication links etc. by the organization IT support team. The amount of $\alpha_4.L_{i,T}^{IC}$ loss is accounted for long-term downtime because of cloud infrastructure in no longer under control of IT company team [24-25].

. Availability: It is the proportion of time for which a system can perform its function [25]. Also, the availability is related to reliability, a service that is on 24x7 but goes constantly offline which is useless. The amount of $\alpha_5.L_{i,T}^{Av}$ loss is accounted for availability loss.

. Security: As a third-party cloud computing are known multi-tenancy for the sake of maximizing infrastructure utilization, it allows multiple VMs relevant to different customers to be simultaneously assigned for execution on the same physical server and multiplexing resources upon same physical server by isolation/disjoint fashion between virtual machines [26-27]. The amount of $\alpha_6.L_{i,T}^{Sec}$ loss is accounted for all types of security attacks and detriments.

. Privacy and data confidentiality: The emergence of cloud computing makes individuals and organizations motivated to outsource their data off-premises for the sake of its cost-efficient feature. Practically the data owner and service provider are not in the same trusting level. For the sake of providing data privacy and protection of data owner from eavesdropping, the typical approach is to encrypt data then outsource it. The amount of $\alpha_7.L_{i,T}^{Pri}$ is considered as costs and losses due to data vagueness process and data leakage.

. Comply with requirement regularly: The ability of compliance with customer requirement regularly depends on service deployment, design model and management of resources. Then, the detriment amount $\alpha_8.L_{i,T}^{RCom}$ is accounted for cloud disability to comply with requirement.

In this part, the technological losses for the sake of cloud disability to cover aforementioned requirements are calculated by equation (8):

$$L_{Tech}(T) = \alpha_1.L_{i,T}^{EL} + \alpha_2.L_{i,T}^{Com} + \alpha_3.L_{i,T}^{Down} + \alpha_4.L_{i,T}^{IC} + \alpha_5.L_{i,T}^{Av} + \alpha_6.L_{i,T}^{Sec} + \alpha_7.L_{i,T}^{Pri} + \alpha_8.L_{i,T}^{RCom} \quad (8)$$

Phase 4. Changes in Organization Routines

With cloud migration, organizational changes are inevitable and should be taken into consideration [45]. Merits and demerits of radical/slow shift to cloud must be analyzed in organizational perspective. Potential losses within organizational changes are taken into account in our decision model such as previous phase (cf. phase 3), i.e., notation $L_{i,T}^{ORG}$ is the basic unit amount of organizational changing loss and the coefficient β_i i=1,…,7 , the output amount of organizational changing loss, and the basic unit amount of environmental loss are attainable with AHP, Delphi approaches and company background experiences [5, 16, 21]. Noticeable organizational changes are as below:

. Accounting: Accounting will change because hardware and network infrastructure is not procured upfront. So, the amount of $\beta_1.L_{i,T}^{Acc}$ is considered as accounting changes with potential loss in cash flows.

. Customer Relationship: Other changes by adopting technology such as cloud services are related to enterprise's sales, marketing, support, then managing them by its feedback is known as customer relationship management changes. Therefore, the amount of $\beta_2.L_{i,T}^{CRel}$ is taken into account for customer relationship loss.

. Public Image: Users cannot endure the situation out of non-available, unreliable, untrustworthy and non-efficient services. These phenomena have bad effect on public image which leads losing user adhering. Hence, the amount of $\beta_3.L_{i,T}^{PI}$ is considered as a bad public image loss.

. Flexibility: New changes regarding to cloud migration must have flexibility for both organization staff and customers. Flexibility is more relevant to availability and scalability of services especially in the case of expanding new product market fortune made by cloud technology. So, the amount of $\beta_4.L_{i,T}^{Flx}$ loss is taken into account for poor flexibility.

. Business Continuity: Three principles including integrity, availability and confidentiality of information security guarantee business continuity (BC). Then the amount of $\beta_5.L_{i,T}^{BC}$ loss is added into model to show hinder of business continuity.

. Compliance: Compliance will change because the geographic location of data will not be exactly known in the cloud; this is as a long-term implication for enterprises concerned with data privacy [28-30]. So, compliance loss is formed in $\beta_6.L_{i,T}^{Comp}$ which is accounted in decision model.

. Benefit: As cloud computing is geographically distributed over all of the world, it makes facilities such as edge network (causing data storage, processing and retrieval is sent to closer servers and raises reliability), scalability , content delivery, new fortune for new product marketing, and security benefit(tracking, auditing, logging and reporting).

. Risks and Challenges: To find out the risks and challenges is far from obviousness, so one should excavate underneath, hype the organization relationships and CRM for profound understanding implication costs (monetary and nonmonetary) and benefit bonanza. Other losses such as phobia amongst stakeholders, vendor lock-in problem, lost IT authority, inefficient personnel and information system (IS) redeployment etc. are formed in $\beta_7.L_{i,T}^{OTH}$ which is taken into account in decision model. Also, in this part, policymakers can develop the model.

Consequently, the incurred losses due to organizational changes of cloud adoption are calculated by equation (9):

$$L_{ORG}(T) = \beta_1.L_{i,T}^{Acc} + \beta_2.L_{i,T}^{CRel} + \beta_3.L_{i,T}^{PI} + \beta_4.L_{i,T}^{Flx} + \beta_5.L_{i,T}^{BC} + \beta_6.L_{i,T}^{Comp} + \beta_7.L_{i,T}^{OTH} \quad (9)$$

Finally, NPV of scenario's in T-year investment is calculated by equation (10) as below:

$$NPV_{T-year\ of\ Investmenrt}(Scenario) = -FC(T) + \sum_{t=0}^{T} \frac{(Income(t) - VC(t) - LS(t))}{(1+I_K)^T} + \frac{SV}{(1+I_K)^T} \quad (10)$$

Also, the SV parameter is the asset's salvage value after T years (cf. in Table I) [31].

Remarks (Some crucial points): One of the important things to mention is that our proposed phases need to be reevaluated iteratively. Indeed, after predetermined time interval passes the policymakers and decision makers must reevaluate the current circumstance of pricing scheme of cloud providers, customer satisfaction, cash flows and new organization policies such as security concerns to make the sustainable decision.

IV. Case Study

In this paper, TCM new services in IRAN has been used as a case study, but currently TCM has commodity cluster servers to provide their routine services; then it only focuses on problem of outsourcing the new services based on new requirement [32]. In other words, it should make decision whether move to cloud or not. TCM intends to present new online services to its initial 10,000 customers of Mazandaran province for six-year investment.

The new services are as below:

. **Public services**: including software, music, movie and sport events downloading.

. **News services**: that needs vast storage capacity to store documents.
. **Server hosting**: includes web hosting and host renting.
. **Mail Service**: that makes facility such as mailbox for customers.
. **Backup service**: that needs backup servers and huge amount of storage.

Regarding aforementioned services, TCM should provide services such as user archive, user panel, web site, blogs, upload, download and other related services. To this end, it approximately needs 60 TB as storage along with applications to cover requirements per year, so it must initially be hosted on two storage servers and run application server; storage servers which need RIAD controller to integrate hard drivers; so, the amount storage are shared between services. For instance, to cover 2000 users' emails if it considers 2GB storage space for each user's panel it approximately needs 4TB storage space. According to previous projects in TCM, the number of users and related services have been increasing a trend of approximately twice a year [32]. So, TCM can provide e.g. twelve HP midrange storage servers and six HP midrange application servers for six-year investment to cover the requirements, we consider three enterprise class application servers and three enterprise storage servers such as HP enterprise class [33-34]. For this paper's case study nature, we concentrate on IaaS cost. In other words, decision makers must select between purchasing storage disks, processing time and bandwidth such as in traditional ways versus leasing storage and virtual processors from online market of cloud storage services such as Amazon S3 or EBS services and VMs besides enough bandwidth for data transfer; so, it is known as functional requirement. In our case study, for workload nature, the only environmental factors are availability, communication for users in terms of the rate of server downtime and bandwidth feasibility along with data privacy for users' email data which are known as non-functional requirement.

V. EVALUATION

The proposed model will be started by the first phase which was determined in the case study section. Then, the next phases are done in forthcoming sections. The definitions of scenarios and NPV are used in the second phase. The third and fourth phases are determined by Delphi panelists.

A. Scenarios Definition

To evaluate our decision model, we define several options in following second phase.

$Option_1$: Gradual purchase: In this option, requested asset will be gradually procured.

$Option_2$: Lease: In this option, all the requested asset will be leased from cloud without considering any cloud side effects (i.e., two epochs of three-year reservation instances).

$Option_3$: Lease-Sustainability: In this option, all the requested asset will be leased from cloud by considering cloud elasticity and potential losses into account (i.e., two epochs of three-year reservation instances).

Although we can consider two conditions for cloud pricing schemes' variations [11]:

1. Increasing 15% service cost for electricity and personnel cost as $Option_4$.
2. Decreasing 15% service cost for Moore law and competitive market as $Option_5$.

Note that, in $Option_1$ which we considered a gradual procedure, we make time series of IT device prices based on Moore law to estimate exact resource price in upcoming years [35]. Moreover, in this paper, AWS is selected owing to its pervasiveness and better cost-benefit in the market although it does not lose the model generality; it means that policymakers can apply and try the model over other present providers. The Amazon provides instances in the form of VM including operating system, server type and specifications such as the vector (Linux-based, t2.small, 1vCPU, 2GB RAM) in which all of resources are deployed thereon. The pricing metrics are $/h for running hours of processing, $/GB/month for storage and etc. based on exact usage [36-37]. Also, in the leasing scenarios, after three years company re-contracts with a provider, it benefits new technological services between the years of fourth to sixth. For now, TCM intends to present new online services to its initial 10,000 customers for six-year investment and anticipates earning on an average of $80 per year individually. Moreover, we estimate each user's downloads about 60GB annually along with appropriate bandwidth; that's why TCM considers 155Mb/sec legal to multiplex bandwidth at most among its users with infinite download capacity. Although users typically use 10Mb/sec in average, so it approximately charges $1785 per month, namely $21420 annually for bandwidth usage [32]. The proposed decision model in this paper helps policymakers to evaluate all of the alternatives for six years as its life cycle, then it selects the scenario with the greatest NPV of cash flow whether to move or not to move to cloud. Moreover, the last scenario's cash flow is affected by cloud server downtime, bandwidth infeasibility prediction and data leakage derived from data history. The services such as StackDriver and Amazon CloudWatch are used to view application and service monitoring in Amazon environment [38-39].

B. NPV of Scenarios

In our case study, in the first option (gradual purchase), asset's net present value will be calculated by equation (11) as follows:

$$NPV_T\,(Option_1) = -C_0^{GP} + \sum_{t=0}^{T} \frac{(Income^{GP}(t) - VC^{GP}(t) - E_t)}{(1+I_R)^t} + \frac{SV}{(1+I_R)^T} \quad (11)$$

Since our case study has its own infrastructure, fixed costs are just included to purchase application server, storage server, disk storage, and disk controller as network devices. So, FC(T)= $C_0^{GP} = \sum_j^N C_j^{Se} + \sum_j^N C_j^{Ne}$. Also, gradual purchase of equipment on-premises does not threaten the company, therefore the term LS(t) is omitted from equation. Moreover, the term C_0^{GP} as CAPEX is the onetime initial purchase capital cost, $Income^{GP}(t)$ is the annual profit resulting from the gradual purchasing asset in year t , $VC^{GP}(t)$ as OPEX is the asset's expected annual operating cost at year t as observed in equation (12). Note that, other parameters do not interfere in the calculation because they are not related to case study's requirements.

$$VC^{GP}(t) = \alpha.(C_t^{Ls}.L_t^S +.C_t^{LH}.L_t^H) + C_t^{Ele}(x_t.P_S+y_t.P_C + Z_t.P_D + P_D * \lceil V_t \rceil_\Omega) * 365 * 24 + TR_t^{IO} \quad (12)$$

The amount of $VC^{GP}(t)$ includes cost of human effort salary, equipment electric utility consumption, bandwidth usage and data transfer cost. I_R is the firm's cost of capital, defined as the interest rate of its outstanding debt used to finance the purchase, T is the asset's productive life in years, E_t as CAPEX is the asset's gradual purchase (capital) cost of year t [42]. Since purchasing the requirements is growing annually then E_t depends to variable time t. The amount of E_t is attainable via equation (13).

$$E_T = (1.03 * \lceil V_T \rceil_\Omega - \lceil V_{T-1} \rceil_\Omega) * \Omega * K * e^{-0.438T} + 1.05 * S_0 * e^{-0.173T} \quad (13)$$

In equation (13), the first expression is the amount of requested disk cost and the second one is the amount of requested server cost at year T*th* respectively. In this line, the cost analytical estimation is predicted via historical data by regression methods [31, 37]. According to equation (13), a cost of the same amount of resource is cheaper in upcoming years. Also, *SV* is the asset's salvage value after *T* years. The amount of *SV* in this case study comprises of storage salvage value (*SSV)* and disk salvage value (*DSV)* as observed in equation (14).

$$SV = SSV + DSV \quad (14)$$

Servers and Disk salvage value will be gained in the end of usage time. Servers and Disk price data were derived from Pricewatch.com on a weekly basis regardless of manufacturer or model [37]. The empirical results and regression analysis from mentioned website data history [31, 37] determine the value of the term *DSV* and *SSV* as the end of life salvage value which are attainable by equations (15) and (16) as below:

$$DSV = \gamma * \Omega * \lceil V_T \rceil_\Omega * K * e^{-0.438T} \quad (15)$$

$$SSV = \gamma * S_0 * e^{-0.173T} \quad (16)$$

Also, S_0 is an initial asset value and $\lceil V \rceil_\Omega$ is an operator returning the minimum number of Ω-sized disk drives needed to store *V* GB of data. Moreover, nomenclature of scenarios' parameters in our decision model is tabulated in Table II.

Table II. Nomenclature of scenarios' parameters in our decision model [20].

Symbol	Description	Symbol	Description
SV	the asset's salvage value after T years ($)	γ	Used disk depreciation factor on salvage ([0.0, 1.0])
I_R	interest rate	Ω	Size of purchased disk drives (GB)
I_K	Capital of cost	$\lceil V \rceil_\Omega$	minimum number of Ω-sized disk drives needed to store *V* GB of data
α	the proportion of the human operator cost required to maintain the system/data at year *t*	C_0^{GP}	Initial costs ($) in purchase gradual scenario
β	the proportion of the human operator cost required to maintain the data on the leased storage at year *t*	$Income^{GP}($	The annual profit resulting from the gradually purchased asset in year *t*
P_S	Server power consumption (kWh)	$VC^{GP}(t)$	The amount of variable costs of year *t* in purchase gradual scenario
P_C	Disk controller power consumption (kWh)	E_t	The asset's gradually purchase (capital) cost of year *t* ($)as a type of CAPEX
P_D	Disk drive power consumption (kWh)	$Income^L(t$	The annual profit resulting from the leasing scenario in year *t*
x_t	The number of purchased server in year t	$VC^L(t)$	The amount of variable costs of year *t* in leasing scenario
y_t	The number of purchased Disk Controller in year t	$TR_t^{IO/L}$	Data transfer and Bandwidth usage Cost in/out from cloud DC to internet($)
z_t	The number of purchased Disk driver in year t	L_T	Expected annual per-GB lease of storage payment ($/GB/year)
X	The number of purchased Disk Controller in onetime scenario	V_t	Expected storage requirement in year *t* (GB)
Y	The number of purchased Disk Driver in onetime scenario		

Similarly, the equation (17) calculates NPV of a leased asset's as $Option_2$:

$$NPV_T(Option_2) = \sum_{t=0}^{T} \frac{(Income^L(t) - VC^L(t))}{(1+I_R)^t} - \sum_{T=0}^{N} \frac{L_T}{(1+I_K)^T} \quad (17)$$

Whereas $VC^L(t)$ is:

$$VC^L(t) = \beta.C_t^{Ls}.L_t^S + TR_t^{IO/L} \quad (18)$$

For simplicity, we assume that annual profit in all scenarios are equal. In this equation, the lease's financing rate is generally regarded as smaller than the cost of capital, I_K, because of the involved payment structure's predictability [2, 31], we take them equal into account for simplicity. Also, in the leasing scenarios, after three years the company re-contracts with provider to benefit new technology services between the years of fourth to sixth.

Phase 3 (Assessment of Cloud Supporting) and Phase 4 (Changes in Organization Routines): Cloud disability in terms of elasticity, communication, availability and privacy for phase 3 along with compliance and public image are brought in $Option_3$. Moreover, $Option_3$ is similar to

$Option_2$ except for placing the amount of losses owing to cloud adoption disabilities as equation (19) indicates:

$$NPV_T(Option_3) = \sum_{t=0}^{T} \frac{(Income^L(t) - VC^L(t) - LS(t))}{(1+I_R)^t} - \sum_{T=0}^{N} \frac{L_T}{(1+I_K)^T} \quad (19)$$

Wherein LS(T) = $L_{Tech}(T) + L_{ORG}(T)$= $\alpha_2 . L_{i,T}^{Com}$ + $\alpha_5 . L_{i,T}^{Av}$ + $\alpha_7 . L_{i,T}^{Pri}$+ $\beta_2 . L_{i,T}^{CRel}$ based on new services' non-functional requirements. Also, customer relationship is affected by communication and availability drawbacks. Coefficient and base loss are attained by AHP and Delphi methods in organization interview (cf. Table II) such as the methods presented in [5, 16, 21]. To set up Delphi panel we considered heterogeneous groups of practitioners 10 persons of customers, 10 providers, 5 academia and 5 NGOs to use diverse set of experts. Each of them has more than 5 years of experiences in IT and cloud computing context. Also, all of communications happened via email. We used follow-up interview for deep understanding and findings. This methodology is very appropriate of this study and provides good opportunity to attain a wide range of cloud adoption determinants and inhibitors. The following four research questions (RQ) are conducted for this research:

RQ1: Which issues do the enterprise policymakers face when adopting cloud computing services?
RQ2: What are the weight and the relative importance of each issue?
RQ3: Why are these issues important?
RQ4: Which of the issues can be omitted from model based on case study's non-functional requirements?

The result of AHP and Delphi methods proves that factors such as communication delay, availability, privacy and customer relationship are the most effective issues in TCM case study. Other factors, on the other hand, can be omitted owing to their marginal effect on TCM. So, the coefficients α_2, α_5, α_7 and β_2 are set to 0.395, 0.403, 0.315 and 0.221 accordingly. According to investigation over Amazon data history in [38-39] and different level interview between organization executives, each basic loss, $L_{i,T}^{CRel}$, is approximately set into 0.0006 of annual income derived from AHP and Delphi methods [21-23].

C. Experimental Results

To calculate CAPEX of the first option, one HP midrange application server and two storage servers along with Disk space and an enterprise-class RAID disk controller must be procured to integrate disk drivers such as Seagate RAID disk controller. The cost of a midrange HP application server (e.g. a HP ProLiant DL360e Gen8 with quad-core 2.4 GHz, 4GB RAM and 2TB hard), storage server (e.g. a HP ProLiant ML310e Gen8 with quad-core 2.4 GHz, 4GB RAM and four 3.5 inch ports to apply up to 32 TB hard drives configured with RAID controller) and Seagate RAID disk controller are $1000, $1500 and $1000 in IRAN respectively [33-34, 43]. The enterprise-class disk controller supports up to 100 TB disk drives capacity, also TCM must procure 4X8TB disk drivers e.g. SATA disk drives, each of which costs $260, for each four-port storage server to cover 60TB capacity needed in the first year; aforementioned asset will be approximately duplicated in each forthcoming year. To take OPEX ,power consumptions 0.8 kWh, 0.7 kWh and 0.01 kWh are considered for each server, RAID disk controller and disk driver respectively with electric utility cost, C^{Ele} =$ 0.02 per kWh; then disk salvage depreciation factor is 0.1 for its end life usage [33-34, 43-44]. Also, annual human operator salary is about $15,000 and human effort to manage data/system in the case of purchase is about 90 percent of full-time personnel salary whereas it is 80 percent in the case of leasing as the personnel focuses on data management only, although it depends on the situation of case study. So, coefficients α, β and γ are set to 0.9, 0.8 and 0.5 respectively. Here, data transfer and bandwidth usage are taken into account as OPEX, therefore TCM considers at most 155Mb legal to multiplex bandwidth among its users with infinite download capacity so it charges approximately $1785 per month, namely $21420 per year as OPEX [32]. Amazon EC2 provides a wide selection of instance types; it is optimized to fit different use cases. Instance types comprise of varying combinations of CPU, memory, storage, and networking capacity and give the flexibility to choose the appropriate mix of resources for everyone's applications. Each instance type includes one or more instance sizes, allowing organizations to scale their resources to the requirements of their target workload such as general purpose T2, M3, Compute optimized C4, GPU G2, etc. [36]. Aforementioned instances, which are worthy for the cases provided the organization, stands in the inception way such as startup companies, but for the case studies with existing infrastructure such as TCM, the best remedy is to excerpt between individual instances. Therefore, for our case study to provide storage instance in the lease case from Amazon web service, there are some options such as standard S3, Glacier storage, EBS and DDS. Except for Glacier storage, the rest are high performance and expensive to charge, but the best option is high-scalable EBS with trade-off between speed and price as it is suitable for large files such as videos and movies; that's why we consider Amazon EBS for investigation. Moreover, S3 and EBS provide a simple web service interface such as standard-based REST and SOAP web services interfaces that you can use to store and retrieve by means of PUT and GET requests any amount of data, at any time, from anywhere on the web [36]. Using this web service, developers can easily build applications that make use of Internet storage. Since EBS is highly scalable and you only pay for what you use, developers can start a bit and grow their application as they wish, with no compromise on performance or reliability. It is designed to be highly flexible: Store any type and amount of data that you want; read the same piece of data a million times or only for emergency disaster recovery; build a simple FTP application, or a sophisticated web application such as the Amazon.com retail web site. EBS frees developers to focus on innovation, not figuring out how to store their data [40-41]. In addition, in the scenario of leasing option, the same amount of servers, i.e. eighteen virtual servers, storage and bandwidth will be leased from Amazon Web Service (AWS) [36]. As our case study needs vast amount of data storage and download communication, the EBS instance is selected. Despite S3 instance, the cost of data in/out to storage with

PUT and GET commands as I/O cost is included in the price of volumes. In this regard, Amazon EBS general purpose SSD (gp2) volumes are selected; the volume lease cost is $.0.12 GB per month in Asian pacific (i.e. Singapore) [36, 41]. Also, C3.Xlarge instance is selected as virtual servers. The contract will be adjusted for three years; then the re-contract will be done for the rest three years of investment. All data transfer in Amazon is considered free. Figure II, illustrates the results of simulation related to proposed model in comparison with Safari et al.'s work, which published in 2015, for all different scenarios in six-year interval. The number in X-coordinate of sub-plot is for number of options.

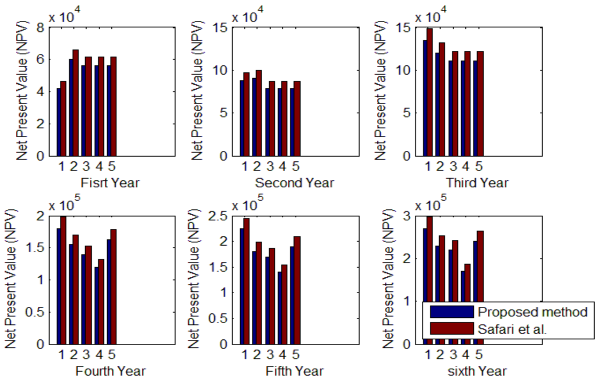

Fig. II. Comparison of NPV related to all scenarios in life cycle

Although scenario with positive NPV is a promising option, our proposed model calculates less NPV in comparison with Safari et al.'s work which did not consider technical and security parameters. Because current proposed model takes wide spectrum inhibitor factors into account such as technical and security relevant factors; the reason why the NPV calculated by our work is nearly exact and consequently is less than that of other state-of-the-art calculates. Moreover, two approaches have proportionally the same treatment in all scenarios as shown in the figure II. However, for the proposed model, the result of implementation shows that gradual purchase is always better than that of in onetime purchase case because in onetime purchase, the company loses to take benefit of new computing technology with economic sense based on Moore law, despite other industries, that's why we do not concentrate on onetime purchase option. Leasing infrastructure from Amazon is beneficial from the outset; it is because of exemption to procure assets with high rate of CAPEX for enterprises in comparison with purchase case in inception years, so except for procuring the devices and related equipment the remaining costs are low, that's why the NPV of gradual purchase will be higher in forthcoming years in comparison with lease option due to economies of scale. It is obvious that in the first year the NPV of Op1 is the lowest owing to procurement of servers and related devices as CAPEX. The NPV of Op2 is the most for the sake of omitting the CAPEX and cloud potential losses. The last three options' NPV are the same till the fourth year of investment the time for re-contract services. Moreover, the last three options' NPV are worse than Op2 because of considering cloud losses. In the same way, NPV of Op2 is still the best in the second year; the reason is clear, but the first option's NPV, Op1, is near that of Op2 in comparison with the first year. It is because of income raising in second year after outcome of CAPEX in the first year. For third year, TCM's income rising due to its increasing customers and services delivery in Op1 on one hand and high cloud service cost for leasing in Op2 on another hand. The first two options are better than the last same options because considering cloud losses levels off the NPV of three last options. The outset of fourth year is to re-contract; we considered two alternatives as Op4 and Op5; the former is %15 increase whereas the latter is %15 decrease in cloud price schemes. It is straightforward to detect that NPV of Op5, Op3 and Op4 are in decreasing order from fourth year to sixth year of investment. Sub-figure related to fourth year illustrates that Op5 is better option than all leasing options. Also, Op5 outperforms Op2 because leasing option does not consider cloud losses. It dubbs that cloud decreasing scheme is promising for companies which are not mission-critical. On the other hand, as opposed to our case, if a case study is mission-critical, the set of cloud disability placed in the model levels off the NPV's option; so it makes a company hesitated to adopt cloud services. Moreover, Op5 does not outperform Op1 since a large-scale company such as TCM takes benefit of economies of scale; it is well depicted in the end of life cycles. As mentioned earlier, the Op5 after Op1 is the best between leasing options for fifth year of investment. It shows that cloud losses can be negligible as it has not drastic affection on NPV. For the sixth year, it has the same result as the fifth year. It means that the large-scale companies are reluctant to ship their IT equipment to third-party because they will lose their IT authority, security, privacy, speed, and other positive features. On the other hand, leasing option namely Op5 considers cloud potential losses along with decreasing pricing scheme; however, it is better than others after Op1. It shows that pricing scheme is a promising parameter that provided the weight of cloud losses and is low in the case study. Otherwise, the cloud losses due to its disabilities will definitely have negative effect on cash flow. As emphasized earlier, our decision model considers social and environmental factors in addition to economical one. As such, we enumerated dozen factors effecting cloud adoption services. Afterwards, we concentrte on sheer economic factors, i.e. monetary along with technological factors such as cloud avaiability, communincation feasibility and organizational changes such as compliance with requirement as well. We have caculated economic factors directly and no-economic factors by the interview of Delphi panelists then we have taken both into account. According to our model (cf. Figure I), cloud elasticity is beneficial for companies with sporadic usage pattern in which they can contract with provider to reserve VMs for covering their requirment at their investment term; it also can swith off VMs or bid resources whenever resource usage levels off in seasonal resource underutilization such as summers or during christmas holidays for universities. But in our case study, resource need surges in two periods i.e. Norouz eve and during summer season that are flash crowd in IRAN. In these conditions, company needs to buy on-demand instances. Althought buying the resources on-demand are expensive in comparison with reserve scheme, revenue from users takes over the costs due to service delivery to the large number of TCM's customers. The high rate of cloud unavailability makes customers change their provider because it is important for user whenver and wherever he/she wants to connect for getteing desirable services. Also, the communication speed is very important for QoS in terms of delay and performance. Privacy, data jurisdiction, and data leakage have low negative effect on our reputation and business of our case study because typical users' data are intrinsically not security-intensive despite case studies such as in banks, healthcare systems, military, etc. Availability, communication, privacy and compliance are in decreasing order according to the importance of our case study as coefficient results of interview show in (cf. Table II). In the case of disparate interview results, we have potentially placed losses on derived data history by applying AHP and Delphi methods; however, owing to cloud disability in terms of technical and organizational factors in our decision model shows sustainability of proposed model. Figure II depicts NPV of different five options' cach flows separately. Also, Figure III integratedly illustrates all options' competence during investmet term. It shows that cloud usage seems to be beneficial from the outset. It implies that cloud leasing instances have sense of economy for short-term investment; for example, less than two years. On the other hand, in Op5 decreasing price schemes along with considering losses after the third year is slightly better than Op2 which only considers sheer economic. However, Op5 is ranked behind Op1 after third year. In long-term investment especially for large enterprises such as TCM, it is better to establish private datacenter on-premises to reduce the cost according to economies of scale as Op1 after the third year of investment which is the best option.

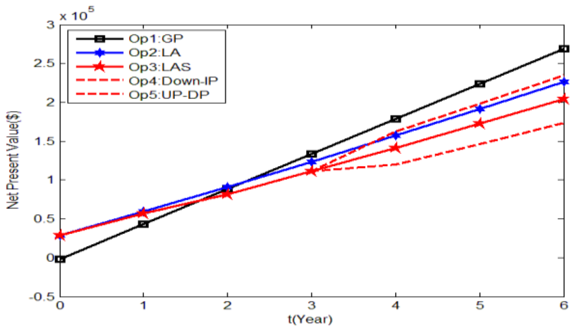

Fig. III. Net Present Value Comparison between all Options in Estimated Life Span.

Moreover, in long term investment, it is suspicious to radical adoption especially for mission-critical applications because the company losses their IT authority. Overall, cloud services are appropriate for startup companies, SMEs with low sensitive applications especially for short-term investment. For TCM, it is better to use cloud services from the scratch and envisage to establish private datacenter for upcoming years; it can cover flash crowd on resource demand by applying hybrid deployment. Then, the policymakers can iteratively decide what to do for future business affairs by applying cloud experience into the model.

VI. Conclusions and Future Direction

Since cloud computing is a promising paradigm for IT solution, industries and organizations face cloud adoption challenges. It needs investigating benefits and drawbacks of its adoption; that's why we have proposed a decision model helping policymakers and investors to evaluate options. The paper's contribution has been done based on AHP, Delphi methods, Moore laws and economic theories. We applied AHP to opt the most effective issues of determinants and inhibitors along with determining their weights which are qualitative in nature. Moreover, a Delphi method as the complementary tool is used to quantify parameters and to avoid subjective results. The Delphi panelists and participants were selected from heterogeneous groups such as individual customers, providers, academia, and NGOs to use diverse experiences. In our case study, calculations were based on local zone parameters such as device price, electric utility cost and expert human salary. Totally, regarding IaaS demand, results of model implementation show that developing private datacenter, as purchasing alternative, is a better choice for long term investment according to the economies of scale provided the cloud pricing scheme has fixed or decreasing trend. Also, TCM as a large scale industry can adopt hybrid deployment besides own datacenter to handle flash crowd. In a word, TCM can provide additional computing resources via cloud computing to avoid in overloaded situation. On the other hand, leasing option as moving to cloud is a better choice for short term investment. Moreover, the technological factors such as service availability, communication and privacy feasibility have drastic effect on TCM cash flows. However, the practicality of our model depends on several factors such as nature, culture, capabilities and case study's circumstance of the adopters along with articulating technological, organizational, and political issues. Other approaches, on the other hand, rigorously focused on economic factors and less on other non-economic factors which lead to non-sustainable decision. In this line, our model is more reliable in comparison to other approaches; as a result, sustainable decision can be made. We envisage extending our model and proving its applicability in our future work with two different ways. First of all, we will quest over mission-critical applications to investigate all of the mentioned issues to observe their effectiveness on final decision. Second, we will show the sustainability of our proposed decision model by using inductive and deductive approaches with statistical distribution over problem parameters to argue about data sensitivity.

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چکیده- برونسپاری فناوری اطلاعات سازمان به مراکز ابر در برابر فناوری اطلاعات سنتی از لحاظ هزینه به کارائی امیدبخش تر است. در این راستا، اخذ یک تصمیم پایدار برای پذیرش رایانش ابری نیاز به درک عمیق از هزینه ها، موضوعات محیطی و اجتماعی دارد. چالش‌ها و دغدغه های زیادی در سر راه سیاستگزاران در مواجه با انتخاب بین گزینه های مختلف فناوری اطلاعات وجود دارد. اگرچه مهاجرت به ابر به دلیل کاهش کل مجموع هزینه مالکیت (TCO)، به صورت بالقوه مزایائی دارد ولی همچنان ضعف هائی با توجه به شرایط خاص صنعت یا سازمان پذیرنده ابر مثل دغدغه های پذیرنده ابر در برابر میزان درجه عدم قطعیت روی خلوت خصوصی داده، امنیت و تأخیر ارتباطات شبکه ای وجود دارد. این مقاله، یک مدل تصمیم چهار گذره ی پذیرش رایانش ابری برای برونسپاری فناوری اطلاعات ارائه می دهد تا دغدغه ها و چالش های سازمان ها و صنایع پذیرنده را با درنظر گرفتن هزینه های تحمیلی هر گزینه محتمل با به کارگیری مفهوم ارزش خالص فعلی (NPV) مربوط به هر راه حل محتمل در دوره سرمایه گذاری به همراه تحلیل موضوعات غیر اقتصادی حل کند. همچنین، این مدل از قانون مور و مصاحبه تیم دلفی به ترتیب برای تخمین قیمت ابزار فناوری اطلاعات در آینده و وزن دادن به پارامترهای تعیین کننده و بازدازنده بهره می برد. جهت ارزیابی عملکرد مدل پیشنهادی، سرویس های جدید شرکت مخابرات استان مازندران به عنوان یک صنعت مقیاس بزرگ در ایران به عنوان یک مورد مطالعه در مدت سرمایه گذاری شش ساله در نظر گرفته شد. پیاده سازی مدل برای شرکت مخابرات، نشان می دهد بهترین گزینه تأسیس یک مرکز داده ای خصوصی و استفاده از استقرار ترکیبی ابر در زمان اوج درخواست لحظه ای منابع کامپیوتری است.

واژه‌های کلیدی: رایانش ابری، مجموع هزینه مالکیت، اقتصاد مقیاس، ارزش خالص فعلی