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A Quantitative Method for Selection of Enterprise Cloud Computing Models

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Abstract Targeting at methodological limitations in the decision-making of enterprise cloud computing adoption, this paper analyzes the main influence factors affecting enterprise cloud computing, builds up their hierarchical structures, and works out 8 key influence factors affecting cloud computing models, based on the structural model theory in system engineering. A quantitative method is provided for the selection of optimal or recommended enterprise cloud computing models, in terms of the relationship valuations among key influence factors, cloud computing models, and the factor weights for a specific enterprise.

Keywords enterprise cloud computing; structural models; selection of cloud computing models; influence factors of cloud computing

1 Introduction

As an emerging technology in information systems development, cloud computing has become very popular for the establishment of enterprise business information systems recently. In the US almost 90% corporations surveyed were applying or experimenting with cloud computing in their business, in accordance with RightScale report[1] in 2014. In China, about 50% corporations surveyed were implementing private clouds according to "China Network World" report last year[2]. The fact shows that cloud computing is going to be the leading architecture and technology in enterprise information systems construction.

However, enterprise cloud computing doesn't go smoothly without problems along the way. The cloud computing paradigms should be enterprise specific, because of corporations' differences in both organizational interior and environment. Therefore one of the important issues in enterprise cloud computing applications is how to select the most appropriate cloud computing models for a specific corporation to satisfy its users' requirements, organizational strategies, management practices, and business processes, with which the enterprise managers must confront in the first place.

Enterprise cloud computing models are multidimensional per se. We are still short of in depth study on multidimensional cloud computing models and their relations with enterprise influence factors, as well as on the methods for selecting the best cloud models to help enterprise professionals in their clouds planning and implementation. A lot of studies are still limited to

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single dimensional models and their influence factors[3–8], such as on service or deployment models, and little attention is paid to an integrated view of the cloud model selection issues. Some researches focus on certain aspects in enterprise business arena[9–13] by exploring the effects of influence factors from certain perspectives including cost-effectiveness, security, cloud providers' services, business models, and sizable corporations, lacking systematic and comprehensive analysis of the main influence factors affecting enterprise cloud computing adoption. For all those contributions, though very valuable and helpful to enterprise cloud computing exploitations, there is no quantitative method put forward to select best cloud computing models.

Targeting at those limitations, the main objective of this article is to provide enterprise management professionals and cloud computing practitioners with a systematic way, by investigating closely the key influence factors and their relations to cloud computing models, to select most appropriate cloud models in enterprise cloud computing adoption. The article works out a paradigm to formulate a quantitative method to deal with these issues, based on the analysis of factors hierarchical structure and the author's own longtime experience in development of enterprise business information systems, in order to assist business professionals and system developers in their cloud computing planning and implementation.

2 Main Influence Factors Affecting Cloud Computing Models

Cloud computing models are affected by many influence factors, which are closely related to the characteristics of cloud models. There are many models in enterprise cloud computing from various perspectives, and their characteristics are quite different.

2.1 Multidimensional Models of Enterprise Cloud Computing

It seems there is a common viewpoint or consensus among researchers of both academic and business world on two classifications of enterprise cloud models: Service cloud models and deployment models. For service models we have[14–16]

- Infrastructure as a service (IaaS),
- Platform as a service (PaaS), and
- Software as a service (SaaS).

For deployment models, we have[16–18]

- Public cloud,
- Community cloud,
- Hybrid cloud, and
- Private cloud.

There are a lot of literature discussing those models and their characteristics. These models are formulated from the perspectives of cloud system architecture, composition and shared resource, without consideration of factors in managerial aspects of enterprise, including business strategy, management, security, process and personnel. Therefore those single dimensional models (models in one dimension like service or deployment) won't be appropriate in many cases to provide us with an effective paradigm or mechanism to depict a clear and complete picture about cloud computing issues, especially when the enterprise management practice is taken into consideration.

Aiming at those limitations Yang put forward a concept of multidimensional models for enterprise clouds[19]. The main idea is to take an integrated view on cloud computing models, as is shown in Figure 1.

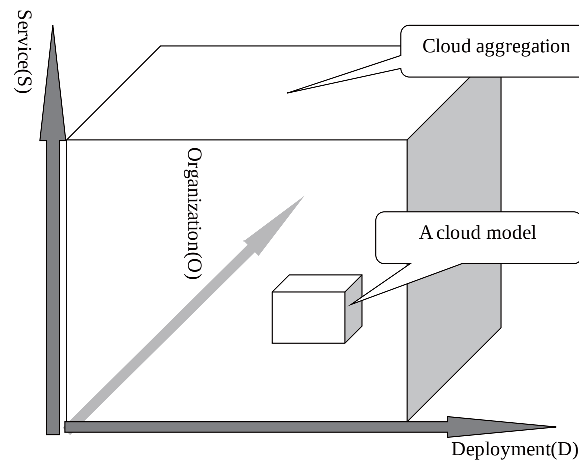

Figure 1 Multidimensional models of enterprise cloud computing[19]

In Figure 1 cloud service and deployment are viewed as two dimensions, and a third one is also added: organization dimension, which concerns mainly with enterprise managerial characteristics.

We name the paradigms formulated by combination of service dimension and deployment dimension as 2-dimensional cloud computing models. The 3-dimensional cloud computing models are the paradigms when the organization dimension is incorporated, as is shown by the cube in the picture. For 2-dimensional cloud models we have 12 paradigms[19]:

- Infrastructure as a service deployed by private cloud (IaaS-Private),
- Platform as a service deployed by private cloud (PaaS-Private),
- Software as a service deployed by private cloud (SaaS-Private),
- Infrastructure as a service deployed by hybrid cloud (IaaS-Hybrid),
- Platform as a service deployed by hybrid cloud (PaaS-Hybrid),
- Software as a service deployed by hybrid cloud (SaaS-Hybrid),
- Infrastructure as a service deployed by community cloud (IaaS-Community),
- Platform as a service deployed by community cloud (PaaS-Community),

- Software as a service deployed by community cloud (SaaS-Community),
- Infrastructure as a service deployed by public cloud (IaaS-Public),
- Platform as a service deployed by public cloud (PaaS-Public), and
- Software as a service deployed by public cloud (SaaS-Public).

In this article the organization dimension is not used literally. It's only for depiction of influence factors affecting enterprise cloud computing adoption, and how these factors are related to the selection of 2-dimensional cloud models. Namely the enterprise cloud models applied in the selection method are actually two dimensional.

2.2 Main Influence Factors in Cloud Computing

What are the influence factors, along the organizational dimension, affecting enterprise cloud computing adoption? To answer this question many authors made a lot of studies on the issue of influence factors from various perspectives. A set of main influence factors is put forward, as shown from Table 1 to Table 5, based on the analysis of articles[3–13, 16, 20–22] and this author's own longtime experience in enterprise business information systems development including cloud computing.

38 influence factors are shown in these tables, which are divided into 5 categories, concerning with cloud systems quality indices, security measures, management practices, resources provided and technological features.

Table 1 Main factors affecting cloud computing: Quality indices

Factor (No)	Description
Usefulness (1)	Satisfy users requirements, be user friendly and easily operational, and have an intuitive interface
Maintainability (2)	Be not too complicated, have structural robustness, be easy to add functions, debug and upgrade
Scalability (3)	Be extensible or elastic for applications, processing power, data storage and network connections
Flexibility (4)	Be capable of managing resource and service use in real time, according to users actual needs
Reliability (5)	Have low downtime, run smoothly and stably without big performance fluctuations
Integration (6)	Be capable of integrating with business processes and legacy systems, eliminating info islands
Standardization (7)	Conform to industrial standards, follow business process optimization, and adopt the best practices
Performance (8)	Have high performance, quick responses, more available functions, and high configurability
Cost effectiveness (9)	Have low development cost, short implementation cycle, easy deployment, low conversion and maintenance cost

Table 2 Main factors affecting cloud computing: Security measures

Factor (No)	Description
Regular security audits (10)	Have security plan and implementation policy, conduct audits periodically to find, evaluate and cope with potential risks
Leaders security consciousness (11)	Top leaders are involved in security planning, policy formulation and management, have security knowledge and mentality
CSO in charge (12)	Conduct chief security officer (CSO) or CIO responsibility system for security management
Incident analysis and provisions (13)	Have regulations for security incidents discovering, reporting, analysis and countermeasures provisioning
Security regulations and operations (14)	Have security guidelines and provisions of using and operating the system applications, and procedures of coping with contingencies
Employee education & training (15)	Have a policy of employee security related training, educate them to conform security regulations and rules, esp. for new employees
Security standards adoption (16)	Be aware of and conduct security norms and standards, such as ISO/IEC 27001:2013, GB/T 22081-2008
Data access control (17)	Have data protection measures and rules for sensitive information accessing, using, and privileges authenticating

Table 3 Main factors affecting cloud computing: Management practices

Factor (No)	Description
Top leaders support (18)	Top leaders support cloud computing adoption, and have certain knowledge and mentality of business information systems
Optimization of business processes (19)	Have normalized organization structures and business practices, like optimizing business processes, for instance, by business process reengineering (BPR)
Collaboration of departments (20)	Have effective collaborations between various levels of managers and consensus among them towards cloud computing
Long run strategic plan (21)	Have long-term strategic plan for enterprise business informayion systems development and exploitation
Project management (22)	Have well organized and structured project team, and team leaders have sufficient knowledge, experience and competence in IT systems development
Communication and users involvement (23)	The related managers/leaders have sufficient ability of articulation for new systems adoption, getting employees understood and involved in the project

It seems not practical to use all 38 influence factors in the analysis and selection of cloud computing models, especially for enterprise managers or management professionals. To take them all into account is even not necessary or helpful in most cases, because it could blur the key issues in the adoption of cloud computing and make us distracted by those trivial ones. Therefore, we should simplify and reduce these influence factors and find the most important ones, or the key influence factors, in order to provide enterprise planners and implementers with a simple, intuitive and formal way for the decision of selecting best cloud computing models.

Table 4 Main factors affecting cloud computing: Resources provided

Factor (No)	Description
Developers (24)	Have knowledge of software engineering, skills and experience in business information systems development
Time schedule (25)	Time availability for cloud systems development and deployment
Project budgets (26)	Budgets availability for the cloud computing adoption project
Systems development environment (27)	The availability of related hardware, software, networks and documents for the cloud computing systems development
Cloud providers credibility (28)	Cloud providers reputation, their strategic and management practice, and their accountability
Cloud providers services (29)	Cloud services provided by providers, their competitive advantages for the services going to be applied
Network facilities (30)	Cloud providers have sufficient network resources for customers like bandwidth, IP addresses, routing paths, and so on
Favorite from cloud providers (31)	Cloud providers extra or preferential services including licensing, security facilities, and other specialties

Table 5 Main factors affecting cloud computing: Technological features

Factor (No)	Description
On-demand self-service (32)	Consumer can unilaterally customize computing capabilities, such as server time, network storage and applications
Broad network access (33)	Capabilities are available over the network that can be accessed through standard mechanisms and heterogeneous client platforms
Resource pooling (34)	The providers computing resources are pooled to serve multiple consumers, with different physical and virtual resources dynamically assigned and reassigned to them according to consumer demand
Rapid elasticity (35)	Capabilities can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward conforming to demand
Measured service (36)	Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level appropriate to the type of service
Security technology applications (37)	Security investment on technologies is allocated including the adoption of security applications such as firewall, encryption, intruder detection, and access control
Continuous system updating and patching (38)	Plan and policy are set up to continuously update, patch and backup systems, to keep the systems up to date and alleviate security holes, performance regressions, and other issues

Not all these influence factors are independent and they are related in some way, if we take a close look at their relations. Some factors are dominant comparing to others, and certain factors are only effective when others are in position and effective. For example, top leaders support is dominant in undertaking cloud computing, and employees security training is only possible when top leaders have security consciousness. Therefore, if we manage to have a way to find out the most important factors that have dominant positions, control roles and more impact on factors effectiveness, those factors could be viewed as key influence factors and used as arguments for the analysis in selection of cloud computing models, while the other factors could just be omitted safely without losing the expected rationality and usefulness in question. The structural model theory in system engineering can serve as a tool to deal with that issue to simplify and reduce the influence factors.

3 Structural Model of Main Influence Factors

A model, which will help to find out the key influence factors in cloud computing adoption and serve as a quantitative method, is worked out by using system engineering theory, in terms of influence factors' hierarchical structure. The basic hypothesis is that the factors in higher levels are more influential and effective than lower level ones, because they have more impact on factor system.

3.1 System Structural Model

A digraph representing all influence factors, expressed by a set F, and their dependencies can be drawn up. F has n elements corresponding to all influence factors.

$$F = [F_1, F_2, \cdots, F_n]. \tag{1}$$

We can establish the adjacency matrix A expressing factor dependencies in accordance with the digraph, and its reachability matrix can be calculated by

$$R = I \cup A \cup A^2 \cup \cdots \cup A^n = (I \cup A)^n, \tag{2}$$

where I is a $n \times n$ identity matrix, A and R are Boolean matrices.

The hierarchical structures of the factor system can be formulated, in accordance with the reachability matrix R[23]. Suppose F_i's reachable set is $RS(F_i)$, and its antecedent set is $AS(F_i)$, then for factors at the lowest level, we have

$$RS(F_i) = RS(F_i) \cap AS(F_i). \tag{3}$$

So we can get the lowest level factors according to Equation (3). Then these factors are discarded temporarily from the factor system, and we compute the rest factors with the same process again to get next lowest level factors. Suppose the factor sets at different levels are expressed by L_1, L_2, $\cdots$, L_k, and $L_0 = \Phi$, we have

$$L_j = \{F_i \in F - F_0 - F_1 - \cdots - L_{j-1} | RS_{j-1}(F_i) \cap AS_{j-1}(F_i) = RS_{j-1}(F_i)\}, \tag{4}$$

where $j = 1, 2, \cdots, k$, k is number of the structure levels. To continue the computation according to Equation (4), until all factors are discarded, namely $L_0 = \Phi$ is reached, then we have all factor sets at different levels.

$$\prod\nolimits_2 (F) = [L_1, L_2, \cdots, L_k]. \tag{5}$$

We select certain levels of factors from bottom (the highest level) up as the key factors of the factor system. For example, we select h levels starting from bottom, then the key factors are

$$\prod\nolimits_2^{\text{Key}} (F) = [L_k, L_{k-1}, \cdots, L_{k-h+1}]. \tag{6}$$

3.2 The Key Influence Factors Affecting Adoption of Cloud Computing Models

If we analyse the relations between influence factors put forward in Section 2.2, a digraph can be formulated as Figure 2 (the numbers represent corresponding factors, please refer to Tables 1 to 5). The dependencies are drawn from a project including 3 students under author's instruction, and verified by consulting with 4 management professionals (conducted in a survey, see section 4.1).

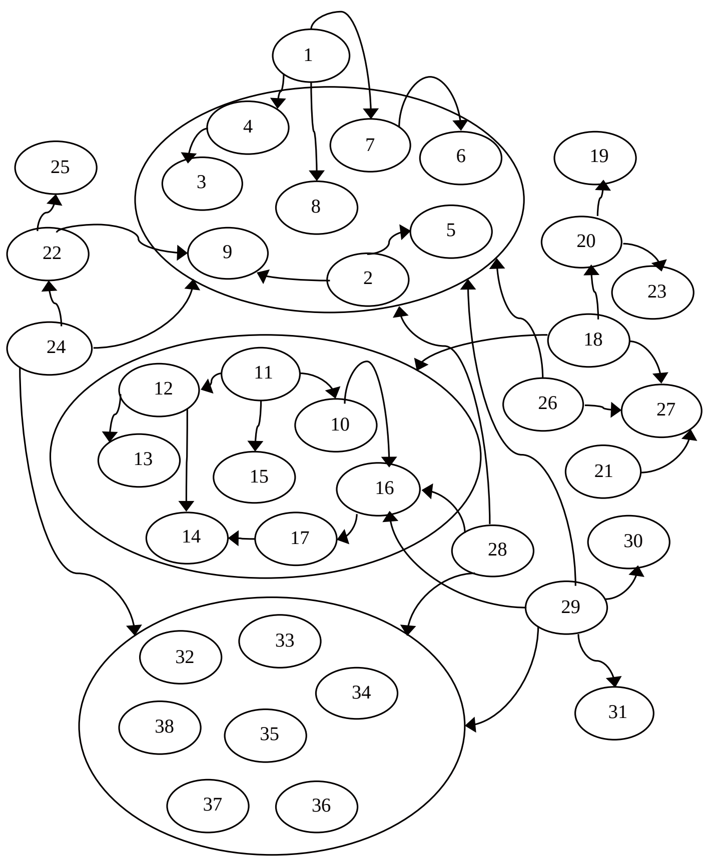

Figure 2 Digraph of influence factors

Then we can obtain the adjacency matrix A, shown in Figure 3, and calculate the reachability matrix R by Equation (2), as shown in Figure 4. Because there is no strong coupling between factors, and all links are unilateral, so we have

$$RS(F_i) \cap AS(F_i) = F_i \tag{7}$$

According to Equation (4), Equation (7), and the procedures described in section 3.1, we can get all levels of influence factors. The result is as follows.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
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Figure 3 Adjacency matrix(A) of influence factors

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1	1	0	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
26	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
28	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1	1	1	1
29	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	1
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Figure 4 Reachability matrix(R) of influence factors

$$L_1 = [F_3, F_5, F_6, F_8, F_9, F_{13}, F_{14}, F_{15}, F_{19}, F_{23}, F_{25}, F_{27}, F_{30}, F_{31}, F_{32}, F_{33}, F_{34}, F_{35}, F_{36}, F_{37}, F_{38}],$$
$$L_2 = [F_2, F_4, F_7, F_{12}, F_{16}, F_{17}, F_{20}, F_{21}, F_{22}],$$
$$L_3 = [F_1, F_{10}, F_{24}, F_{26}, F_{28}, F_{29}],$$
$$L_4 = [F_{11}], \quad L_5 = [F_{18}].$$

Commonly by thumb rule we can select no more than 10 influence factors as the key influence factors (7±2, 7 is the "magic number"). The factors in the last 3 levels are selected as the key factors, so we have 8 key influence factors in all.

$$\prod\nolimits_2^{key}(F) = [L_5, L_4, L_3] = [F_{18}, F_{11}, F_1, F_{10}, F_{24}, F_{26}, F_{28}, F_{29}]. \tag{8}$$

3.3 Comments on the Key Influence Factors in Cloud Computing

In accordance with Table 1 to Table 5 and Equation (8), the key influence factors are

F_{18}: Top leaders support,

F_{11}: Leaders security consciousness,

F_1: Usefulness,

F_{10}: Regular security audits,

F_{24}: Developers,

F_{26}: Project budgets,

F_{28}: Cloud providers creditability, and

F_{29}: Cloud providers services.

We know from the factor descriptions that the key influence factors concern mainly with

- Enterprise top managers mentality and involvement in cloud computing adoption,
- Cloud computing systems to satisfy users requirements,
- The knowledge, skills and competence of developers and available budgets,
- Enterprise security regulations and practices, and
- Cloud providers accountability and service quality.

Most key influence factors are related to enterprise management practices. We could draw a conclusion from the results that the enterprise adoption of cloud computing is actually more a problem of enterprise business management, rather than that of application technology, from the viewpoint of key influence factors.

4 Selection of Enterprise Cloud Computing Models

There are 12 2-dimensional cloud models as we discussed in section 2.1. But which models are best or most suitable for an enterprise? We can answer this question if we know the relationships between enterprise cloud computing influence factors and the cloud models, as well as the weights of those factors for a specific corporation.

4.1 The Relationships Between Cloud Models and Influence Factors

The relationships between cloud models and influence factors are enterprise specific. But there is some kind of stability or consistency in the relationships revealed by a survey conducted by a project instructed by the author, regarding to what are the effects of key influence factors on cloud computing models. There are 28 professionals (high profile seniors relatively) from 5 corporations surveyed by questionnaires and interviews, the survey profile is described as Table 6. In the survey the management professionals were mainly interviewed, and their questionnaires were filled with help of the survey project members, because of their lacking IT specific knowledge. At the meantime we also consulted them with dependencies among influence factors.

Table 6 Profile of the survey

Profession	Number	Form of survey
Top level manager	2	2 Interviews
Department leader	4	2 Questionnaires, 2 interviews
System analyst and software engineer	22	22 Questionnaires (3 not valid)

We got 21 valid questionnaires having questions regarding how strong are the 8 key influence factors affecting enterprise models, with Likert scales (5 to 1): Very strong, strong, medium, certain, and small. The results (averages rounded to integers) are summarized as relationship matrix in Table 7 (The 4 interviews were evaluated by the team based on their talks).

Table 7 The relationship matrix for 2-dimensional cloud models and key influence factors

Model/Factor	F_{18}	F_{11}	F_1	F_{10}	F_{24}	F_{26}	F_{28}	F_{29}
IaaS-Private	1	5	5	5	2	2	1	1
PaaS-Private	2	4	5	4	3	3	1	1
SaaS-Private	2	3	4	4	4	4	1	1
IaaS-Hybrid	2	5	5	5	3	2	2	2
PaaS-Hybrid	3	4	5	4	4	3	2	2
SaaS-Hybrid	3	3	4	4	5	4	2	3
IaaS-Community	3	5	4	4	3	3	2	3
PaaS-Community	3	4	3	3	4	4	3	3
SaaS-Community	4	3	2	3	5	5	4	4
IaaS-Public	4	4	4	4	4	3	3	4
PaaS-Public	5	3	3	3	5	4	4	5
SaaS-Public	5	2	2	2	3	5	5	5

4.2 Selection of Cloud Models

Here is an example showing how to use the relationship matrix for best cloud models selection. For a specific enterprise the key influence factors' importance or weight can be evaluated by relevant experts, management professionals or consultants. Suppose the vector of key influence factor weights W is

$$W = [W_1, W_2, W_3, W_4, W_5, W_6, W_7, W_8]^{\mathrm{T}},$$

where W_1 to W_8 correspond to F_{18}, F_{11}, F_1, F_{10}, F_{24}, F_{26}, F_{28}, and F_{29}. Suppose the relationship matrix is C, which is 12×8 matrix having values taken from Table 7, $AV()$ means evaluation function, CM is a vector of 12 cloud models, then we have

$$AV(CM) = \begin{vmatrix} AV(\mathrm{IaaS-Private}) \\ AV(\mathrm{PaaS-Private}) \\ AV(\mathrm{SaaS-Private}) \\ AV(\mathrm{IaaS-Hybrid}) \\ AV(\mathrm{PaaS-Hybrid}) \\ AV(\mathrm{SaaS-Hybrid}) \\ AV(\mathrm{IaaS-Community}) \\ AV(\mathrm{PaaS-Community}) \\ AV(\mathrm{SaaS-Community}) \\ AV(\mathrm{IaaS-Public}) \\ AV(\mathrm{PaaS-Public}) \\ AV(\mathrm{SaaS-Public}) \end{vmatrix} = C * W. \tag{9}$$

Suppose the vector of best or recommended cloud models are in CM_{opt}, which have maximum value of $AV()$, and can be obtained by the following equation:

$$CM_{\mathrm{opt}} = CM_m | AV(CM_m) = \max(AV(CM_i)). \tag{10}$$

For example, a corporation has weights vector

$$W = [3, 4, 4, 3, 3, 4, 5, 5]^{\mathrm{T}}.$$

The best or recommended cloud model(s) can be found by Equation (9) and Equation (10).

$$\begin{aligned} &AV(CM) = C * W = [82, 85, 84, 98, 101, 105, 103, 104, 116, 115, 124, 116]^{\mathrm{T}}, \\ &CM_{\mathrm{opt}} = [\mathrm{PaaS-Public}]. \end{aligned}$$

Namely, the best cloud model for the corporation is “platform as a service deployed by public cloud” in the enterprise cloud computing adoption.

4.3 Some Comments and Discussions

There are some limitations about the evaluation data in Table 3. The sample is relative small, and the survey is limited to small and medium size enterprises (SME) with low maturity on IT applications in China. For sizable corporations, or some corporations with high level of IT internal drivers or special demand on some aspects of cloud computing systems, such as more security and high performance, the data in Table 3 may not be appropriate or some of them even not correct. For different categories of enterprises we could have different relationship matrices, which would be drawn up as needed in the planning stage of cloud computing adoption.

Another issue is that in some special cases certain important influence factors may be omitted, because they are in lower levels. To deal with this issue we could add those omitted important factors to the key influence factor set and reformulate and reevaluate the relationship matrix accordingly.

The quantitative method is mainly a theoretical exploration, empirical studies could be also needed to show its effectiveness in practice.

5 Conclusions

Enterprise cloud computing adoption is affected by many factors. The importance of different factors to enterprise cloud models is different, therefore we can find the most important or key influence factors in terms of their impact on the factor system by structural models in system engineering.

This article puts forward a relative formal and quantitative method for enterprise professionals to select most appropriate cloud computing models for their business. At first, we find out the main influence factors in cloud computing, through multidimensional cloud models with the concept of organizational dimension, extensive literature reviews, and our experience. Next, a structural model expressing factor system hierarchy is drawn up, by which we figure out the key influence factors by choosing certain highest levels of factors. Finally, we work out a quantitative method to select the best or recommended cloud models, by means of the relationship matrix representing the factors effectiveness or strength on cloud models and the key influence factor weights expressing factors' importance to a specific corporation.

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