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Design of Customer-Oriented Cloud Products

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***Abstract*— Cloud computing is defined as a scalable services consumption and delivery platform that allows enterprises and individual users to start from the small and increase resources only in case of service demand increase. The competitive environment of cloud service providers forces them to differentiate their products in terms of technical and managerial specifications to attract more customer. The framework in this paper proposes QFD methodology in order to analyze customer needs and transform them into measurable product attributes. The aim is to shape cloud products in respect to different customer needs and attributes such as cost and sustainability. The applicability of the proposed methodology is demonstrated via a real life scenario.**

***Index Terms*— Cloud computing; service selection; quality function deployment.**

I. Introduction

Cloud computing is usually defined as a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction [1]. Three classes are used to differentiate cloud services: SaaS (Software as a Service), PaaS (Platform as a Service) and IaaS (Infrastructure as a Service) [1], [2], [3]. In this work, we will evaluate services provided as IaaS.

Due to fierce competition, the service providers in the cloud market are offering diverse range of configurations to satisfy different customer requirements. The decision of the appropriate configuration is usually a challenging task both for the customers and for the service providers. In this paper, we aim at offering a decision support framework for service providers for designing their product offerings. We proposed using Quality Function Deployment (QFD) approach, a common tool that simply intends to analyze customers' needs (CNs) to guarantee satisfaction. The aim of QFD is to use customer feedbacks as for input and to transform this information into product attributes, which represent the characteristics of a product from a technical view. The transformation of information into usable knowledge necessitates the determination of the relationship between CNs and PTRs, and the correlation among CNs and among PTRs. The main output of QFD is the weights for PTRs, which represent the most important characteristics to concentrate on, in order to satisfy customers. Herein, for obtaining the weights, we have utilized Analytic Network Process (ANP) [4]. ANP is a generalization of Saaty's Analytic Hierarchy Process (AHP), which is one of the most widely used multi-criteria decision support tools [5]. ANP and its supermatrix technique is considered as an extension of AHP that can handle a more complex decision structure as the ANP framework has the flexibility to consider more complex interrelationships (outerdependence) among different elements [6, 7].

The paper is structured as follows. Section 2 describes related literature. The methodologies used in the approach are given in Section 3, while Section 4 presents step by step explanation of the research framework. Section 5 reveals the results and the concluding remarks of the case study. Future works and the conclusion are given in Section 6.

II. Related Work

Although there are many applications of QFD with ANP approach, we have concentrated on the applications in cloud computing field. In one of the recent studies, the authors have proposed a model of cloud service selection by aggregating the information from both the feedback from cloud users and objective performance analysis from a trusted third party [9]. They have used a fuzzy simple additive weighting system in order to select the best cloud service. Another work made use of the AHP approach to select most appropriate SaaS product in terms of five criteria (i.e., functionality, architecture, usability, vendor reputation and cost) [10]. Their research is mainly based on subjective assessment. The integrated AHP and fuzzy technique for order preference by similarity to an ideal solution (TOPSIS) approach was used in another cloud service comparison approach [11]. They proposed a standardization process of the performance attributes, but it is not sufficient to deal with real life's more complex cloud services. In another article, fuzzy TOPSIS approach is utilized to help service consumers and providers to analyze available web services with fuzzy opinions [12]. The authors ranked available alternative web services according to group preference. In their work, Ranjan et al. [13] presented a framework (called CloudGenius) which automates the decision-making process based on a model and factors specifically for Web server migration to the Cloud. They used AHP to automate the selection process based on a model, factors, and QoS parameters related to an application. Assuming that each individual parameter affects the service selection process, and its impact on overall ranking depends on its priority in the overall selection process, Garg et al. [11] proposed an AHP based ranking mechanism to solve the problem of assigning weights to features considering interdependence between them, thus providing a much-needed quantitative basis for ranking of cloud services. In their paper, Ergu et al. [14] proposed a framework for SaaS software packages evaluation and selection by combining the virtual team (VT) and the BOCR (benefits, opportunities, costs, and risks) of the analytic network process (ANP). They attempted to solve the complex ANP model by decomposing the tasks to

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different parts, and performed by benefits virtual team (BVT), opportunities virtual team (O-VT), costs virtual team (C-VT), and risks virtual team (R-VT) separately.

The main contribution of this study over previous cloud service design approaches is that the proposed methodology enables to incorporate customer feedback in more complete and systematic way. The interrelationships between customer feedback and the interrelationships between the technical attributes could be analyzed and used in the design process. Hence, customer attributes with little or no meaning to customer can be identified and more importance to aspects meaning a lot can be given. Moreover, aspects such as cost and sustainability, which are also decisive in a product design process, can be incorporated into the decision-making process.

III. The Methodologies

A. *Quality Function Deployment*

QFD simply incorporates customer feedback into the product/service development process, which gathers information from different functions of the organization and aims a successful product/service in terms of profitability and customer satisfaction. Herein, QFD provides a framework that deals with the gathered information, combine them in a systematic and meaningful way, and transform them into knowledge that could be used in the design process.

QFD methodology encompasses several steps generally referred as matrices that represent the means for information transformation requiring different inputs from different functions and connecting them in a way so that each step's output simply becomes the input for the following one [15]. The initial matrix of QFD is usually referred as house of quality (HOQ). A demonstrative house of quality matrix is shown in Figure 1. As depicted in the figure, house of quality comprises eight elements:

(1) *Customer needs (CNs) (WHATs)*. They are the essential information block that should be incorporated to the development process. They are expressed deliberately in customers' own phrases, so that the main information is retained in its original form.

(2) *Product technical requirements (PTRs) (HOWs)*. They embody the knowledge of product/service in terms of technical attributes. They are used to achieve the goals set by CNs by providing the means to systematically change the product characteristics.

(3) *Relative importance of the CNs*. The information CNs provide, is usually too diversified to deal with simultaneously. Hence, at this stage the most important CNs have to be identified in order to increase the probability of a greater customer satisfaction. In most cases, organizations have to deal with conflicting demands and this usually means that trade-offs have to be made.

(4) *Relationships between WHATs and HOWs*. This relationship element is usually placed in the body of the house of quality and denotes the information to what extent each PTR affects each CN. This step is very important as the transformation of different information occurs. The expected result of this stage is the importance of CNs presented in terms of PTRs.

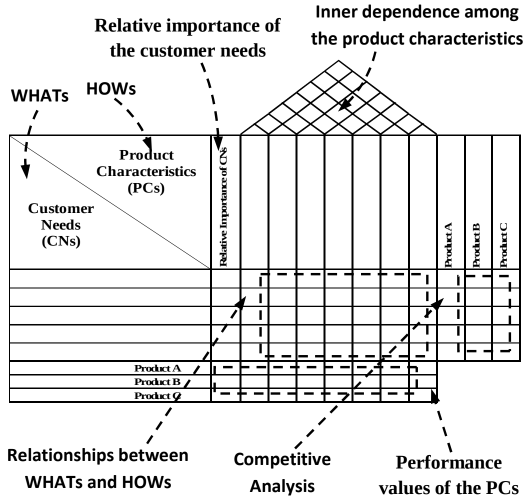

Fig. 3.1. House of quality

(5) *Inner dependencies among the CNs*. The diversification of CNs is a difficult matter that should be solved diligently. At this stage we simply try to determine the interaction among the CNs. The resulting information could be used to measure how much and whether or not CNs support each other.

(6) *Inner dependencies among the PTRs*. The inner dependencies among PTRs are placed in the roof of house of quality and similar to the inner dependencies between CNs, they are used to measure to what extent a change in one feature may affect another.

(7) *Competitive analysis*. The benchmarking process tries to establish improvement directions necessary to achieve total customer satisfaction by including competitors' performance into the decision process.

(8) *Overall priorities and performance values of PTRs*. The performance values of PTRs and the PTRs' final ranking are used to obtain the overall ratings of PTRs. These ratings could help to design the most appropriate product/service.

B. *Analytic Network Process (ANP)*

ANP has its origins in the widely used multi-criteria decision making tool, the Analytic Hierarchy Process (AHP). AHP simply decomposes a problem into several levels in such a way that they form a hierarchy, where each element is supposed to be independent [16]. AHP incorporates both qualitative and quantitative approaches to a decision problem [17]. But AHP cannot deal with interconnections and inner dependencies among decision factors at the same level [18]. In order to deal with this shortcoming, ANP is developed by replacing hierarchies with networks and is used as an effective tool in those cases where the interactions among the elements of a system form a network structure [18].

The interactions among the elements in ANP are evaluated using pairwise comparisons. Accordingly, a supermatrix is obtained, representing the influence among the elements. It is raised to limiting powers to calculate the overall priorities, and thus the cumulative influence of each element on every other element is obtained [19]. The supermatrix of a hierarchy with three levels is as follows:

$$\mathbf{W} = \begin{array}{r} \\ \text{Goal(G)} \\ \text{Criteria(C)} \\ \text{Alternatives(A)} \end{array} \begin{array}{c} \begin{array}{ccc} G & C & A \end{array} \\ \begin{pmatrix} 0 & 0 & 0 \\ \mathbf{W}_{21} & 0 & 0 \\ 0 & \mathbf{W}_{32} & \mathbf{I} \end{pmatrix} \end{array}$$

where $\mathbf{W}_{21}$ is a vector that represents the impact of the goal on the criteria, $\mathbf{W}_{32}$ is a matrix that represents the impact of the criteria on each of the alternatives, and I is the identity matrix.

When a network consists of only two clusters apart from the goal, namely criteria and alternatives, the matrix manipulation approach proposed by [20] can be employed to deal with dependence of the elements. It is used herein to incorporate the dependencies inherent in QFD process into the analysis.

IV. Research Framework

A. Proposed Model

The proposed decision support framework aims at helping cloud service providers in shaping a cloud product that will consider quality along with cost and sustainability. The main objective is to balance different and mostly contradicting goals. The research methodology is based on the framework proposed by Karsak et al. [21], in which the authors combined QFD methodology with ANP to suggest improvement directions for product technical attributes. They proposed to improve the design of a pencil by incorporating customer feedback into the design process. Their methodology ended up with a goal programming approach that includes cost, extendibility and manufacturability aspects. The main difference of our methodology compared to the one of Karsak et al. is that we construct a house of quality specifically designed for cloud computing based on the work of Garg et al. [8] and extend this house of quality with cost and sustainability goals.

As required by ANP, we use the following supermatrix representation. We modify it to deal with the CNs and PTRs and with their relationships as required in the QFD methodology:

$$\mathbf{W} = \begin{array}{r} \\ \text{Goal (G)} \\ \text{Criteria (C)} \\ \text{Alternatives (A)} \end{array} \begin{array}{c} \begin{array}{ccc} G & C & A \end{array} \\ \begin{pmatrix} 0 & 0 & 0 \\ \mathbf{w}_1 & \mathbf{W}_3 & 0 \\ 0 & \mathbf{W}_2 & \mathbf{W}_4 \end{pmatrix} \end{array}$$

where $\mathbf{w_1}$ is a vector representing the impact of the goal, namely a product/service that will satisfy the customers, $\mathbf{W_2}$ is a matrix that denotes the impact of the CNs on each of the PTRs, $\mathbf{W_3}$ and $\mathbf{W_4}$ are the matrices that represent the inner dependencies of the CNs and PTRs, respectively.

As suggested by Karsak et al. [21], when a network consists of only two clusters apart from the goal, namely criteria and alternatives, the matrix manipulation approach proposed by [20] can be employed to deal with dependence of the system elements. Thus, the interdependent priorities of the CNs ($\mathbf{w_C}$) are computed by multiplying $\mathbf{W_3}$ by $\mathbf{w_1}$, and similarly the interdependent priorities of the PTRs ($\mathbf{W_A}$) are obtained by multiplying $\mathbf{W_4}$ by $\mathbf{W_2}$. Overall priorities of the PTRs ($\mathbf{W_{ANP}}$) are obtained by multiplying $\mathbf{W_A}$ and $\mathbf{W_C}$. The resulting weights represent overall ratings of PTRs with the goal of obtaining a higher customer satisfaction. But, cloud computing market with its fierce competition and increasing pricing pressure coming especially from incumbents necessitates a quality product with a cost conscious design. Therefore, we once again rated PTRs, but this time with the goal of reducing total cost. The calculations are done in the same way by using pairwise comparisons. Recently, more and more cloud service providers have paying attention to the sustainability and especially to green computing approaches. They have using them as part of their marketing campaigns. Hence, we believe that a proper cloud product should also take into considerations the sustainability issues, in addition to cost and quality issues. Hence with pairwise comparisons we obtained overall ratings for PTRs with the goal of improving sustainability. These three sets of weights are combined by simple additive weighting. The main steps and information processed in each are summarized as follows:

Step 1. QFD starts with the determination of the CNs, which are customers' perceptions and linguistic assessments in respect to the product/service. The PTRs, the tools of the company used to satisfy these CNs, are also identified in this step. The CNs and the PTRs used in this study are based on the work of Garg et al. [8]. Our main motivation for this choice was that they established a comprehensive list of attributes, which could be categorized as CNs and PTRs. We used their attributes and classified their quality related attributes as CNs and their performance related attributes as PTRs.

Step 2. As mentioned in previous section, the most important CNs have to be determined in order to make the necessary tradeoffs. Herein, we have used pairwise comparisons as suggested by ANP. As a result, we have obtained $\mathbf{w_1}$.

Step 3. In this step, assuming that there is not any dependence among PTRs, the degrees of relative importance of PTRs with respect to each CN are identified. As a result, we have obtained $\mathbf{W_2}$.

Step 4. It is not possible to assume that CNs are independent in real life scenarios. Therefore, we have used ANP to determine the inner dependence among CNs. Once again, we have used pairwise comparisons and have obtained $\mathbf{W_3}$.

Step 5. Similarly, as PTRs may affect each other, we have determined inner dependencies among them. The resulting matrix is $\mathbf{W_4}$.

Step 6. At this stage we transformed customer requirements into measurable technical requirements. For this transformation, we have initially calculated interdependent priorities of CNs ($\mathbf{W_C}$) and also interdependent priorities of PTRs ($\mathbf{W_A}$) and have combined them to obtain the overall priorities of PTRs with the quality oriented mindset.

Step 7. The effect of PTRs on the cost of the cloud product is calculated using pairwise comparisons. Initially, $\mathbf{w_1}$ and $\mathbf{W_2}$ is recalculated with the goal of reducing the cost of the product. Then the overall priorities of PTRs are calculated by combining $\mathbf{W_C}$ and $\mathbf{W_A}$. The effect of PTRs on the sustainability is calculated in the same way, using pairwise comparisons with the goal of improving

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sustainability of the service provider.

Step 8. The overall ratings of PTRs considering quality, cost and sustainability goals are calculated using simple additive weighting by combining the overall ratings for each goal.

V. CASE STUDY

As a demonstrative example, we have used the data provided in the work of Garg et al. [8]. They aimed to select the best cloud service provider using real world data. They rated Amazon EC2, Windows Azure and Rackspace in their work.

Step 1. The CNs are defined using the work of Garg et al. [8]. Customers are required to determine the relative importance ratings of the following criteria: accountability (CN1), capacity (CN2), elasticity (CN3), availability (CN4), service stability (CN5), serviceability (CN6), on-going cost (CN7), service response time (CN8) and security (CN9).

The PTRs are also chosen from the work of Garg et al. [8]: accountability performance (PTR1), CPU capacity (PTR2), memory capacity (PTR3), disk (PTR4), time (PTR5), availability (PTR6), upload time (PTR7), CPU stability (PTR8), memory stability (PTR9), free support (PTR10), type of support (PTR11), virtual machine cost (PTR12), inbound data cost (PTR13), outbound data cost (PTR14), storage cost (PTR15), service response time range (PTR16), service response time average value (PTR17) and security performance (PTR18).

Step 2. The relative importance of the CNs are determined by asking the following questions: 'Which CN should be emphasized more in establishing the best cloud product?'. We used the same weights for CNs as obtained by Garg et al. [8]. The resulting importance weights are given as:

$$\mathbf{w_1} = \begin{pmatrix} 0.05 & 0.06 & 0.04 & 0.14 & 0.04 & 0.02 & 0.3 & 0.3 & 0.05 \end{pmatrix}^T$$

Step 3. Assuming that PTRs are independent, they are compared with respect to each CN, which results in the column eigenvectors regarding each CN. For instance, one of the possible questions at this stage can be: 'What is the relative importance of "CPU stability" when compared to "upload time" on controlling "service stability"?'; yielding to the weights presented in Table 1. Similarly, the degree of relative importance of PTRs for the remaining CNs are calculated and presented in Table 2.

Table I. Relative importance weights of the PTRs for "service stability"

Service stability (CN5)	Relative importance weights
PTR7	0.3
PTR8	0.4
PTR9	0.3

Step 4. In this step, we identify the inner dependence among the CNs by considering each CNs effect on others by using pairwise comparisons. The resulting vectors are summarized in Table 3.

Table II. The column eigenvectors with respect to each CN

$\mathbf{W_2}$	CN1	CN2	CN3	CN4	CN5	CN6	CN7	CN8	CN9
PTR1	1	0	0	0	0	0	0	0	0
PTR2	0	0.5	0	0	0	0	0	0	0
PTR3	0	0.3	0	0	0	0	0	0	0
PTR4	0	0.2	0	0	0	0	0	0	0
PTR5	0	0	1	0	0	0	0	0	0
PTR6	0	0	0	1	0	0	0	0	0
PTR7	0	0	0	0	0.3	0	0	0	0
PTR8	0	0	0	0	0.4	0	0	0	0
PTR9	0	0	0	0	0.3	0	0	0	0
PTR10	0	0	0	0	0	0.7	0	0	0
PTR11	0	0	0	0	0	0.3	0	0	0
PTR12	0	0	0	0	0	0	0.6	0	0
PTR13	0	0	0	0	0	0	0.1	0	0
PTR14	0	0	0	0	0	0	0.1	0	0
PTR15	0	0	0	0	0	0	0.2	0	0
PTR16	0	0	0	0	0	0	0	0.5	0
PTR17	0	0	0	0	0	0	0	0.5	0
PTR18	0	0	0	0	0	0	0	0	1

Table III. The inner dependence matrix of CNs

$\mathbf{W_3}$	CN1	CN2	CN3	CN4	CN5	CN6	CN7	CN8	CN9
CN1	1.00	0	0	0	0	0	0	0	0
CN2	0	0,65	0.14	0	0	0	0	0	0
CN3	0	0,12	0.57	0	0	0	0	0	0
CN4	0	0	0	0.45	0	0	0	0	0
CN5	0	0	0	0	0.56	0	0	0.33	0
CN6	0	0	0	0.29	0.32	0.67	0	0.10	0
CN7	0	0.23	0.29	0	0	0.29	1.00	0	0
CN8	0	0	0	0.14	0	0	0	0.57	0
CN9	0	0	0	0.12	0.12	0	0	0	1.00

Step 5. Similar to step 4, in this step we determine the inner dependence among the PTRs with respect to CNs. The resulting eigenvector of all the pairwise comparisons among PTRs are build using similar pairwise comparisons. Due to space limitations, the resulting matrix is not given.

Step 6. This step includes obtaining overall priorities of the PTRs. First, we obtain the interdependence priorities of the CNs and PTRs by multiplying the weights obtained in previous steps. Overall priorities of the PTRs ($\mathbf{W_{ANP}}$) are obtained by multiplying $\mathbf{W_A}$ and $\mathbf{W_C}$. The resulting weights representing quality-oriented product design are given in Table 4.

The ANP analysis results indicate that the most important cloud service attribute for the customer is "VM cost", followed by, "Service response time range" and "CPU capacity".

Table IV. Overall quality-oriented priorities of the PTRs

W_{ANP}	**PTR1**	**PTR2**	**PTR3**	**PTR4**	**PTR5**	**PTR6**	**PTR7**	**PTR8**	**PTR9**
	0.073	0.084	0.045	0.034	0.028	0.041	0.026	0.064	0.050
	PTR10	**PTR11**	**PTR12**	**PTR13**	**PTR14**	**PTR15**	**PTR16**	**PTR17**	**PTR18**
	0.043	0.022	0.161	0.033	0.037	0.050	0.093	0.062	0.054

Step 7. In this step, the effect of PTRs on the cost of the cloud product is calculated using pairwise comparisons with the goal of reducing the total cost. The resulting weights are given in Table 5.

Table V. Overall priorities of the PTRs with the goal of reducing cost

W_{ANP}	**PTR1**	**PTR2**	**PTR3**	**PTR4**	**PTR5**	**PTR6**	**PTR7**	**PTR8**	**PTR9**
	0.101	0.090	0.045	0.033	0.042	0.023	0.006	0.036	0.024
	PTR10	**PTR11**	**PTR12**	**PTR13**	**PTR14**	**PTR15**	**PTR16**	**PTR17**	**PTR18**
	0.019	0.027	0.145	0.031	0.055	0.057	0.045	0.034	0.190

The analysis results indicate that the most important cloud service attribute is "Security performance", followed by, "VM cost" and "Accountability", when the cloud product is designed with the goal of reducing cost.

The effect of PTRs on the sustainability is calculated using pairwise comparisons with the goal of improving sustainability of the service provider. The resulting weights are given in Table 6.

Table VI. Overall priorities of the PTRs with the goal of improving sustainability

W_{ANP}	**PTR1**	**PTR2**	**PTR3**	**PTR4**	**PTR5**	**PTR6**	**PTR7**	**PTR8**	**PTR9**
	0.063	0.114	0.050	0.033	0.125	0.041	0.008	0.030	0.023
	PTR10	**PTR11**	**PTR12**	**PTR13**	**PTR14**	**PTR15**	**PTR16**	**PTR17**	**PTR18**
	0.036	0.053	0.159	0.047	0.054	0.057	0.027	0.021	0.057

The analysis results indicate that the most important service attribute is "VM Cost", followed by, "Time" and "CPU capacity", when the cloud product is shaped with the goal of improving sustainability.

Step 8. The importance of quality, cost, sustainability for the service provider is determined using pairwise comparisons. The resulting relative importance ratings for each goal are summarized in Table 7.

Table VII. Relative importance weights for quality, cost and sustainability goals

Goals	Relative importance weights
Quality	0.41
Cost	0.33
Sustainability	0.26

The overall ratings for PTRs are calculated using simple additive weighting by combining overall ratings of PTRs for each goal. The resulting weights are depicted in Table 8.

Table VIII. Overall ratings for PTRs

W_{ANP}	**PTR1**	**PTR2**	**PTR3**	**PTR4**	**PTR5**	**PTR6**	**PTR7**	**PTR8**	**PTR9**
	0.080	0.094	0.046	0.033	0.058	0.035	0.015	0.046	0.034
	PTR10	**PTR11**	**PTR12**	**PTR13**	**PTR14**	**PTR15**	**PTR16**	**PTR17**	**PTR18**
	0.033	0.032	0.155	0.036	0.047	0.054	0.060	0.042	0.099

The analysis results indicate that overall the most important cloud service attribute is "VM cost", followed by, "Security Performance" and "CPU capacity".

We believe that incorporating dependence issues using ANP and including cost and sustainability issues into the analysis enables to analyze such a complex decision problem in a more complete manner.

VI. Conclusion

Cloud computing is rapidly gaining importance and more and more service providers are entering the market. As the market gets crowded, service providers are seeking ways to differentiate their products in order to attract their prospective customers. Cloud products have heterogeneous technical and managerial specifications. Therefore, it is a challenging task to design a product, which will satisfy the customers. Moreover, due to fierce competition service providers have to find ways to reduce their costs. We also wanted to incorporate sustainability measure into the design process, as the concept is also becoming very popular.

In this paper, we proposed that QFD, which simply intends to analyze customers' needs and transform this subjective information into measurable product attributes, could be used to shape the most capable cloud service. QFD was chosen as the decision support tool, as it provides a systematic way to combine different sources of data, both subjective like customer expectations and sustainability measures, and also objective like product attributes and cost analysis results.

Possible extensions of this work could enrich the list of CNs and also PTRs based on Cloud Service Measurement Index Consortium's measurement indexes [22] and also ISO/IEC 25010:2011 standard.

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