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SERVICE QUALITY ANALYSIS AND IMPROVEMENT: DEVELOPMENT OF A SYSTEMATIC FRAMEWORK

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As the service sector is rapidly growing, one of the challenges faced by the service industry is the lack of effective methodologies for quality analysis and improvement. In service industries, the service quality serves as both a customer retention tool and a business differentiator in local and global competition. This paper aims at developing a systematic framework for service quality analysis and improvement. The proposed framework advantageously integrates quality function deployment (QFD) and structural equation modeling (SEM). More specifically, the framework utilizes QFD to collect, organize, and analyze qualitative information. The results of QFD are used as the basis for developing a service quality improvement strategy. Then, SEM is used in building and analyzing quantitative models to devise a detailed strategy for the improvement. The proposed framework is demonstrated through a case study on the asymmetric digital subscriber lines (ADSL) service of a major telecommunication company in Asia. This framework can be utilized for an effective analysis and improvement of service quality not just in the telecommunication industry, but also in any service industry which collects customer satisfaction and service performance data as part of its daily operation.

Significance: Most conventional quality analysis and improvement tools, though effective for the manufacturing industry, cannot be applied directly or efficiently to the service industry. This paper develops a systematic framework for an effective analysis and improvement of service quality. This framework can be utilized in any data-rich service industry.

Keywords: Quality analysis and improvement, Service quality, Telecommunication service, Quality function deployment, Structural equation modeling

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1. INTRODUCTION

Services are defined as economic activities that produce time, place, form, or psychological utilities (Haksever et al. 2000). In recent years, the share of the service sector in the whole economy has been increasing. As an example, in the U.S., the service sector is estimated to produce 76% of the gross domestic product (GDP) in 2000, and is expected to grow to 77% in 2005 (U.S. Department of Commerce 1998). This trend is true not only for developed countries, but also for developing countries. For example, the Hong Kong economy has become increasingly service-oriented since the mid-1980s. The share of the service sector in GDP has increased, from 67% in 1980 to 74% in 1990, and further to 85% in 1999 in Hong Kong (Hong Kong Government 2003), and from 33% in 1990 to 38% in 1998 in Korea (Bank of Korea 2000). In general, the share of the service sector is expected to rise even further due to rapid developments in information technology and globalization.

As the service sector is rapidly growing, one of the challenges faced by the service industry is the lack of effective methodologies for quality analysis and improvement. In service industries, the service quality serves as both a customer retention tool and a business differentiator in local and global competition. However, its business potential can only be realized if there are effective tools to analyze and improve customer satisfaction and service quality.

Most conventional quality analysis and improvement tools, though effective for the manufacturing industry, cannot be applied directly or efficiently to the service industry. This is mainly due to the unique characteristics of services, such as intangibility, inseparability between provision and consumption, perishability, and heterogeneity (Haksever et al. 2000). There are four inherent service quality gaps that present challenges for service quality analysis and improvement (Parasuraman et al. 1985). These gaps include (i) not understanding what customers expect, (ii) wrong service quality specifications, (iii) service performance gap, and (iv) discrepancy between service delivery and expectations. Currently, practitioners attempt to improve service quality mostly by intuition and experience, or simply by trial and error. As a result, the lack of effective quality analysis and improvement methodologies becomes a major obstacle to improving the competitiveness of the service industry.

The objective of this paper is to develop a systematic framework for service quality analysis and improvement. The proposed framework advantageously integrates two well-known methods, namely, quality function deployment (QFD) and structural equation modeling (SEM). More specifically, the framework utilizes QFD to collect, organize, and analyze qualitative information. The results of QFD are used as the basis for developing a service quality improvement strategy. Then, SEM is used in building and analyzing quantitative models to devise a detailed strategy for the improvement.

The developed framework is demonstrated through a case study on the asymmetric digital subscriber lines (ADSL) service. The case study was conducted with one of the major telecommunication companies in Asia. (This company will be referred to as Company K throughout this paper.)

2. BACKGROUND

The case study to be presented in Section 3 was conducted on the asymmetric digital subscriber lines (ADSL) service of Company K. Throughout the case study, the methods of QFD and SEM were employed. This section briefly introduces ADSL and reviews QFD and SEM.

2.1. ADSL Service

ADSL is a newly standardized transmission technology to deliver high-rate digital data over existing ordinary phone-lines. A new modulation technology called discrete multitone (DMT) allows the transmission of high speed data. DMT-based ADSL can be seen as a transition from existing copper-lines to the future fiber-cables. This makes ADSL economically interesting for the local telephone companies. They can offer customers high speed data services even before switching to fiber-optics (Saarela 2003).

2.2. QFD

The purpose of QFD is to translate the desires of the customer into product design characteristics, and subsequently into parts characteristics, process plans, and production requirements associated with its manufacture (Hauser and Clausing 1988). Ideally, each translation uses a chart, called "house of quality" (HOQ), which relates the variables associated with one design phase to the variables associated with the subsequent design phase.

The HOQ chart is the principal tool for QFD. The structure of an HOQ depends on the objective, stage, and scope of the QFD project, and thus different HOQs can have different components. However, there are a set of standard components of an HOQ, including the following: customer attributes (CAs; "what to do") and their relative importance ratings; design characteristics (DCs; "how to do it"); relationship matrix between CAs and DCs; correlation matrix among DCs; computed absolute/relative importance ratings of DCs; and CA and DC benchmarking data (customer and technical competitive analysis, respectively).

QFD was originally developed and used in the manufacturing environment. Since the late 1980s, QFD has also been applied to a variety of service design and improvement problems in, for example, automobile maintenance (Behara and Chase 1993), customer telephone service (Graessel and Zeidler 1993), educational service (Stamm 1992; Burgar 1994; Eringa and Boer 1998; Koura et al. 1998), medical service (Ehrlich and Hertz 1993; Radharamanan and Godoy 1996; Haplin 1998; Kao and Fujimoto 2000), hotel service (Kaneko 1991; Kirk and Galanty 1994), and administrative system (Mann and Halbleib 1992; Berglund 1993).

2.3. SEM

SEM is a comprehensive statistical approach to testing hypotheses about relations among observed and latent variables (Hoyle 1995). The SEM approach involves developing measurement models to define latent variables and then establishing relationships or structural equations among the latent variables.

Confirmatory factory analysis methods reflect measurement models in which observed variables define latent variables. Latent variables are not directly measurable but must be inferred. The loading of each observed variable on a latent variable indicates its correlation with the construct of interest (Bollen 1989; Schumacker and Lomax 1996).

In mathematical terms, a SEM model is represented as (Bollen 1989; Hoyle 1995; Jöreskog and Sörbom 1996):

$$\boldsymbol{\eta} = \mathbf{B}\boldsymbol{\eta} + \boldsymbol{\Gamma}\boldsymbol{\xi} + \boldsymbol{\zeta} \quad \text{and} \tag{1}$$

$$\mathbf{Y} = \boldsymbol{\Lambda}_y\boldsymbol{\eta} + \boldsymbol{\varepsilon}, \ \mathbf{X} = \boldsymbol{\Lambda}_x\boldsymbol{\xi} + \boldsymbol{\delta} \tag{2}$$

with $E(\boldsymbol{\zeta}) = 0$; $E(\boldsymbol{\varepsilon}) = 0$; $E(\boldsymbol{\delta}) = 0$; $Cov(\boldsymbol{\zeta}) = \boldsymbol{\Psi}$; $Cov(\boldsymbol{\varepsilon}) = \boldsymbol{\Theta}_{\varepsilon}$; $Cov(\boldsymbol{\delta}) = \boldsymbol{\Theta}_{\delta}$. Here $\boldsymbol{\zeta}$, $\boldsymbol{\varepsilon}$, and $\boldsymbol{\delta}$ are mutually uncorrelated, and $Cov(\boldsymbol{\xi}) = \boldsymbol{\Phi}$. The quantities $\boldsymbol{\xi}$ and $\boldsymbol{\eta}$ in (1) are the cause-and-effect variables, respectively, such as DCs and CAs that are not directly observed. The quantities **Y** and **X** in (2) are variables that are linearly related to η and ξ through the coefficient matrices Λ_y and Λ_x, and these variables can be measured. As an example in telecommunication industry, the speed perceived by customer is **Y**, and the download speed and upload speed constitute **X**. The covariance matrix

$$\Sigma = \mathrm{Cov}\begin{pmatrix} \mathbf{Y} \\ \mathbf{X} \end{pmatrix} = \begin{bmatrix} \mathrm{Cov}(\mathbf{Y}) & \mathrm{Cov}(\mathbf{Y},\mathbf{X}) \\ \mathrm{Cov}(\mathbf{X},\mathbf{Y}) & \mathrm{Cov}(\mathbf{X}) \end{bmatrix} \quad (3)$$

is a function of the model parameters Λ_x, Λ_y, Γ, $\mathbf{B}$, Φ, Ψ, Θ_ε, and Θ_δ. SEM estimates the model parameters by producing a matrix $\hat{\Sigma}$ that closely approximates the sample covariance matrix **S** via the least squares or maximum likelihood method.

SEM has been originally developed in sociology, psychology, and economics (Bollen 1989; Hoyle 1995; Schumacker and Lomax 1996). Since the mid-1980s, SEM has also been applied to a variety of service-related problems in, for example, telecommunication service (Gerpott et al. 2001; Kim et al. 2004), hotel service (Gundersen et al. 1996; Lemmink et al. 1998; Subramaniam et al. 2002), travel service (Neal et al. 1999; Baker and Crompton 2000; Bigne et al. 2001), and medical service (Raju and Lonial 2002; Li and Benton 2003).

3. CASE STUDY: ADSL SERVICE QUALITY ANALYSIS and IMPROVEMENT

The high-speed internet service, based on the ADSL technology, has achieved a remarkable increase in penetration in recent years. For example, in Korea, the number of subscribers in the service increased from 3 million (households) in October 2000 to 4 million in December 2000, and to 7.5 million in December 2001, and to 10 million in November 2002 (Korea National Statistical Office 2003). This figure indicates that almost seven in every ten households are now subscribed to the service. The ADSL service has been one of the major services of Company K since 1999. Currently, Company K has more than five million ADSL service subscribers, and is considered the leader in this market.

Until recently, the companies in this market believed their competitiveness comes from a higher market share, a typical characteristic of telecommunication services. However, as this market moves into a near-saturation stage, the service quality level that was considered good enough in the past is no longer adequate. In order to sustain the leading position in this competitive and lucrative market, Company K should continue to improve the quality of its service effectively.

A systematic framework for strategic service quality analysis and improvement for Company K has been developed and applied in this ADSL case study. The overall framework is shown in Figure 1. The numbers in the parentheses indicate the sections of this paper where the corresponding phases or tasks are explained.

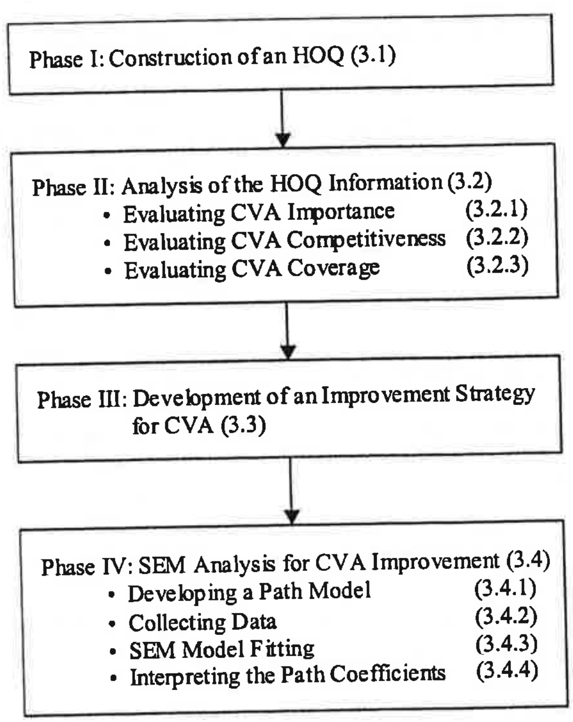

Figure 1. The Proposed Framework of Service Quality Analysis and Improvement.

3.1. Construction of an HOQ

One of the major tasks associated with the construction of an HOQ is the identification of CAs and DCs, among others. Company K has developed and used for a few years a list of desirable service attributes, called customer value added (CVA) items, as part of its total quality management program. The CVA, a well-known concept in the telecommunication industry, is used in measuring the customer satisfaction level of a company vis-à-vis its competitors (Gale 1994). The existing CVA structure served as a basic template in identifying the CAs.

On the other hand, the internal technical quality characteristics (QCs) were employed as the DCs. Note that the CVA items represent the customers' viewpoint, while the QCs are defined by the engineers, and thus measured and controlled within the company. (Hereafter, the terms "CVA" and "QC" are used to indicate the CA and DC of the case study, respectively.)

The initial sets of CVA items and QCs were identified and then refined through a series of focus group sessions. The focus group consisted of several staff members of Company K, both from management and technical divisions, and several researchers of a national research institute specializing in customer satisfaction management in telecommunication industry. An independent facilitator conducted the focus group sessions. The results from the focus group evolved to a three-level hierarchy of twelve CVA items and a two-level hierarchy of fourteen QCs. The CVA items and QCs are shown in Tables 1 and 2, respectively, along with brief descriptions. The focus group also developed the relationship and correlation matrices of the HOQ. The CVA benchmarking information was obtained from a group of thirty customers — ten customers from Company K and ten customers each from two of its major competitors. The completed HOQ is given in Figure 2. Several sections of the HOQ are shaded due to confidentiality.

Table 1. CVA Items of the ADSL Case Study

Level 1	Level 2	Level 3	Description
Network	Speed	CVA1: Guarantee of speed	Provide the network transmission speed as stated in the contract
		CVA2: Minimization of speed variability	Minimize the time-to-time variability in network transmission speed
	Availability	CVA3: Availability	Maximize the network availability during connection
		CVA4: Ease of connection	Maximize the network accessibility for connection
Customer Service	Subscription	CVA5: Ease of subscription	Provide prompt and convenient service for subscription/unsubscription
		CVA6: Accuracy	Perform the promised subscription/ unsubscription tasks accurately at the designated time
	Customer Support	CVA7: Access	Provide easily accessible service
		CVA8: Responsiveness	Provide the service timely and willingly
		CVA9: Reliability	Perform the service consistently and dependably
		CVA10: Security	Protect the customer's privacy
	Billing/Charge	CVA11: Adequacy of charge	Charge the service in keeping with its value
		CVA12: Flexibility of charge options	Provide flexible charge options

3.2. Analysis of the HOQ Information

Based on the information contained in the HOQ, three types of analyses were performed to extract some useful insights. The results of these analyses will be employed as the basis for developing an improvement strategy later in Section 3.3. The purpose, procedure, and result of each analysis are described next.

3.2.1. Evaluating CVA Importance

The relative importance of the CVA items was obtained from the group of customers mentioned in Section 3.1. For each of the thirty respondents, an interview was conducted to solicit pairwise comparisons of the CVA items for an AHP analysis (Armacost et al. 1994). The individual responses were aggregated via a geometric mean, after a homogeneity test. The obtained importance of the network-related CVA items are shown in Figure 2 in the column, entitled "IMPORTANCE."

As shown in Figure 2, the importance values of the "network" CVA items (i.e., CVA1 through CVA4) are 0.338, 0.241, 0.169, 0.063, respectively, which sum to 0.811. The total importance value of the "network" CVA items 0.811 is more than four times higher than that of the "customer service" CVA items 0.189 (1 – 0.811). This indicates that the customer satisfaction or dissatisfaction is determined primarily by the "network" CVA items.

Among the "network" CVA items, the guarantee of speed (CVA1) and the minimization of speed variability (CVA2), both of which are speed-related, rank the first and the second, respectively. The speed is a very important attribute of the ADSL service because the download/upload of multimedia files and network games has become a major need of the internet users in Korea (Kim et al. 2001). In addition to CVA1 and CVA2, the availability (CVA3) turned out to be another highly important CVA item. These three CVA items collectively account for 74.8% (0.338 + 0.241 + 0.169) of all the CVA items in importance.

Table 2. QCs of the ADSL Case Study

Level 1	Level 2	Description	Measurement Unit
Network Quality	QC1: Download speed	Network transmission speed in downloading	Megabits per second (MBPS)
	QC2: Upload speed	Network transmission speed in uploading	Megabits per second (MBPS)
	QC3: Packet transfer delay	Round trip time of a packet in a ping test	Milliseconds (MS)
	QC4: Packet loss rate	Percentage of packets lost in a ping test	Percentage (%)
	QC5: Connection success rate	Percentage of successful connections	Percentage (%)
Customer Service Quality	QC6: In-time installation rate	Percentage of installation/reinstallation completed in time	Percentage (%)
	QC7: Early defect rate	Defect rate in the 1st month after installation	Percentage (%)
	QC8: Defect report rate	Number of defect calls per 100 subscribers	Percentage (%)
	QC9: Defect rate	Number of defects per 100 subscribers	Percentage (%)
	QC10: Defect repair rate	Percentage of defects repaired within 12 hours	Percentage (%)
	QC11: Time to announce trouble	Time elapsed from the perception of a network failure to an announcement	Minutes
	QC12: Response rate	Percentage of repair requests responded within 15 seconds	Percentage (%)
	QC13: Error rate in billing	Percentage of errors in billing	Percentage (%)
	QC14: Error correction rate in billing	Percentage of errors in billing corrected in time	Percentage (%)

3.2.2. Evaluating CVA Competitiveness

The purpose of this analysis is to understand the position of a company vis-à-vis its competitors in the market. This analysis, performed for each individual CVA item, can be done based on the concept of either attribute value added (AVA) or attribute improvement potential (AIP). The AVA is defined as the ratio of the customer satisfaction levels of our company vs. its major competitor, while the AIP refers to the gap between the current and the target satisfaction levels of our company.

The target satisfaction level may be set in many different ways, depending on the purpose of the analysis. Here, the authors suggest the following three ways of setting the target satisfaction level, namely, the target level being equal to the level of a hypothetical ideal company (type I), the current level of the targeted company (type II), or the average level of the companies in the market except our company (type III).

In this case study, the CVA competitiveness of Company K was evaluated using the AIP with the type II target level. It turned out that Company K is competitive (i.e., equal to or better than the targeted company) with respect to the guarantee of speed (CVA1), and not competitive with respect to all other CVA items.

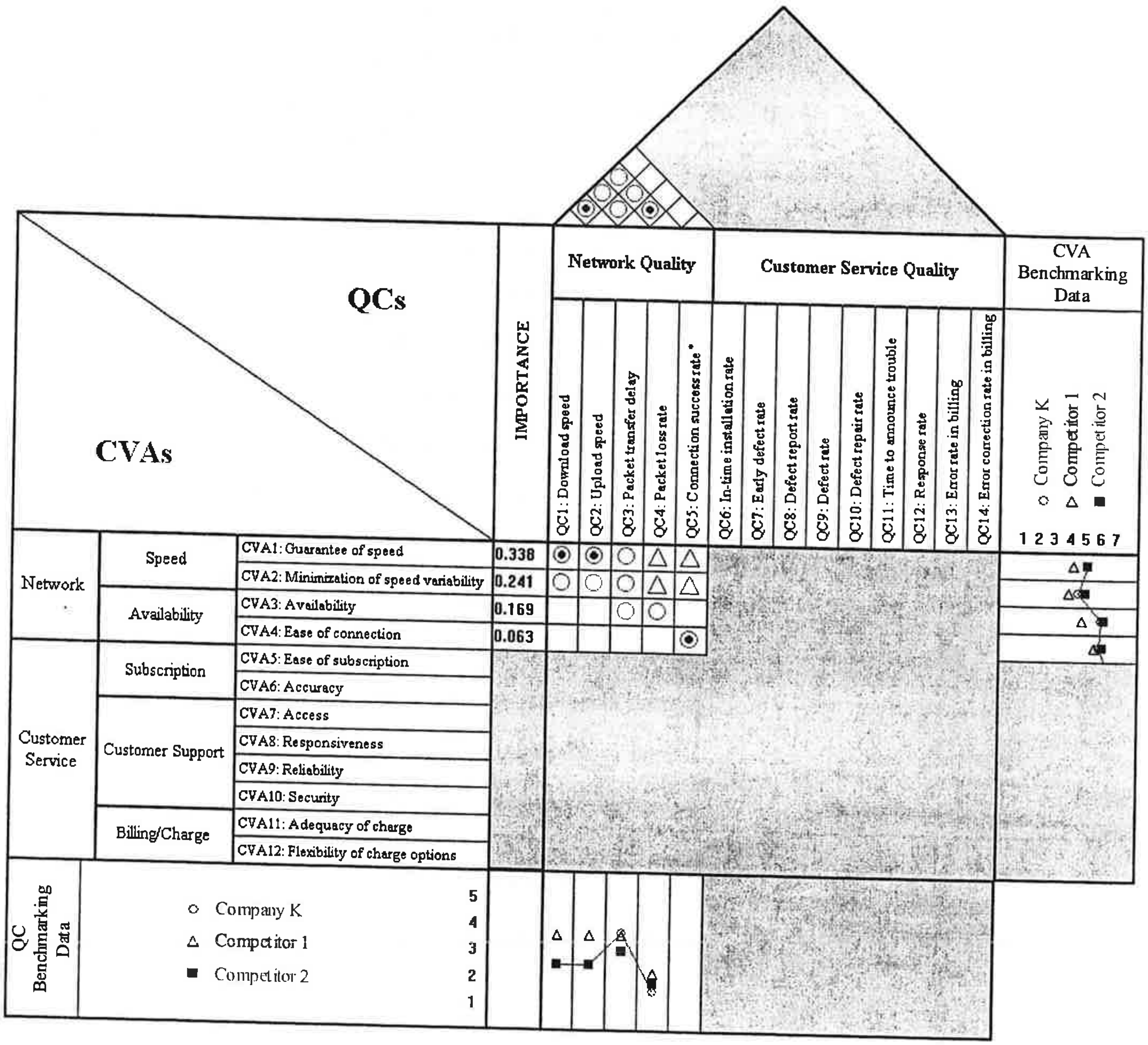

Figure 2. The HOQ for the ADSL Case Study

3.2.3. Evaluating CVA Coverage

The relationship matrix in an HOQ indicates which QCs affect which CVA items. Assuming the given set of QCs is comprehensive, all the QCs affecting a given CVA item can be identified from the HOQ. Ideally, the variation in the customer perception on a CVA item is properly explained by the variation in the performance on the related QCs. If, however, the given set of QCs is not comprehensive (i.e., some important QCs are missing), the explanation power would not be enough. Consequently, the customer perception on a CVA item cannot be effectively improved even if the performance on the related QCs is improved.

The CVA coverage is defined as the degree to which a CVA item is explained by the given set of QCs. That is, if a CVA item has a high coverage, the customer perception on the CVA item can be improved just by improving the performance on the given, related QCs. If not, improving the existing QCs only would not be enough. Instead, new QCs affecting the CVA item should be identified and improved.

In this case, the standardized coverage index (SCI) (Kim et al. 2003) was employed to evaluate the CVA coverage. The SCI is a value between 0 and 1, with 0 representing no coverage and 1 a complete coverage. The SCI value of 0.6 was considered good enough and thus was used as a threshold value for CVA coverage in this case. Three CVA items, namely, the security (CVA10), the adequacy of charge (CVA11), and the flexibility of charge options (CVA12) turned out to have SCI values below the threshold value of 0.6.

3.3. Development of an Improvement Strategy for CVA

Based on the findings of the analyses described in Section 3.2, an improvement strategy for the ADSL service quality was developed. The strategy is formulated based on three criteria, namely, CVA importance, CVA competitiveness, and CVA coverage. Each CVA item was evaluated with respect to the three criteria, either low or high. If a CVA item has a high importance, it should be immediately improved or maintained at a high level, depending on its current competitiveness level. If a CVA item has a low competitiveness, it should be improved, either immediately or in the long-run, depending on its importance. If a CVA item has a high CVA coverage, its satisfaction level can be enhanced by improving the existing related QCs. Otherwise, a new set of QCs should be developed first to increase the CVA coverage to a reasonable level, and then those QCs should be improved.

All these ideas can be combined and represented as a cube having eight cells in a three-dimensional space, called an improvement strategy space. The improvement strategy space is presented in Figure 3, where the CVA items of this case study are placed in the appropriate cells. Based on the improvement strategy space analysis, the following conclusions can be drawn:

- CVA1 is high in all three criteria. Its current competitiveness should be maintained.
- CVA2 and CVA3 are high in CVA importance and CVA coverage but low in CVA competitiveness. These CVA items should be improved immediately by improving the existing related QCs.
- The other CVA items are low in both CVA importance and CVA competitiveness. These CVA items need to be improved, although not urgent. In addition, CVA10, CVA11, and CVA12 need an improvement in CVA coverage as well.
- None of the CVA items is low in CVA importance but high in CVA competitiveness in this case study. If there were such a CVA item, it should be checked whether excessive resources are being allocated to the CVA item. The potential benefit to other CVA items that can be obtained by relaxing its competitiveness should also be examined.

3.4. SEM Analysis for CVA Improvement

Once a CVA item is chosen for improvement, a detailed strategy for the improvement should be devised. That is, the question of "which QC(s) should be changed, in which direction, and by how much?" should be answered. This certainly requires a quantitative, cause-and-effect relationship between the CVA item and the related QCs. SEM is employed in this case study in building and analyzing such quantitative models.

3.4.1. Developing a Path Model

The minimization of speed variability (CVA2) and the availability (CVA3), which need immediate improvements, were chosen for the SEM analysis. The guarantee of speed (CVA1), although not requiring an immediate improvement, was also included in the SEM analysis due to its high importance. A path model linking the three CVA items and the related QCs (i.e., download speed (QC1), upload speed (QC2), packet transfer delay (QC3), and packet loss rate (QC4)) was developed based on the relationship and correlation matrices of the HOQ in Figure 2. The connection success rate (QC5), which is expected to have a weak relationship with CVA1 and CVA2, was not included in the model because it is currently unmeasurable. The resulting path diagram is given in Figure 4. In this figure, a straight arrow represents a cause-and-effect relationship between a QC and a CVA item, and a curved two-headed arrow represents an association between two QCs. And ζ_i denotes the error associated with CVAi (i = 1, 2, 3).

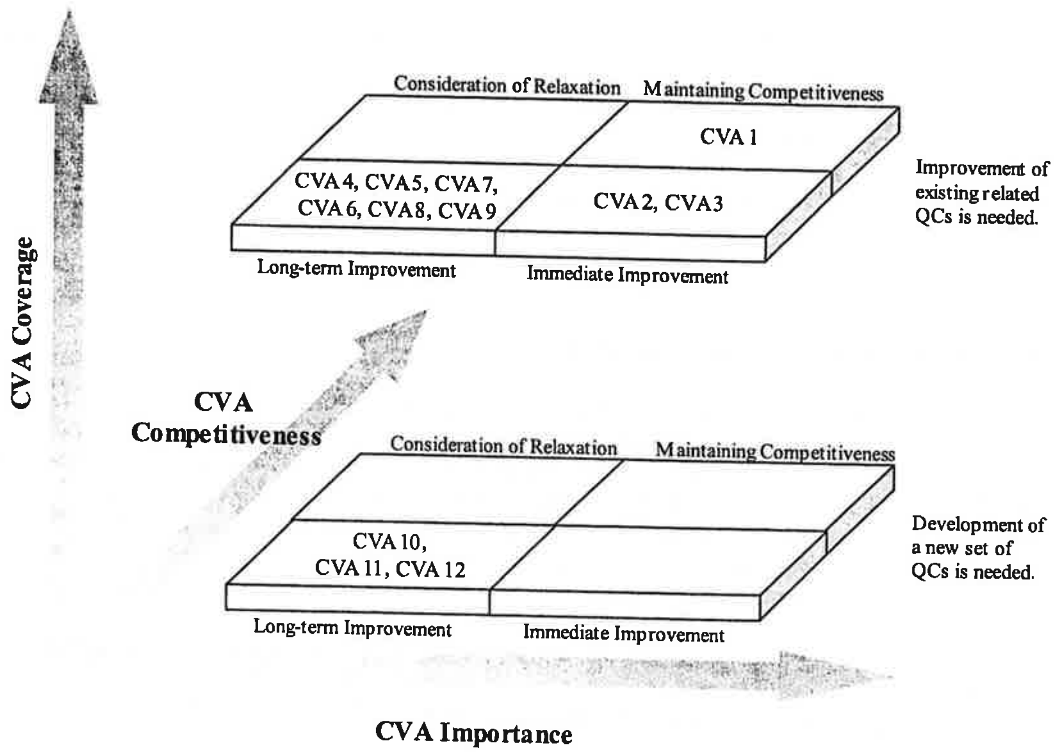

Figure 3. CVA Items of the ADSL Case Study in the Improvement Strategy Space

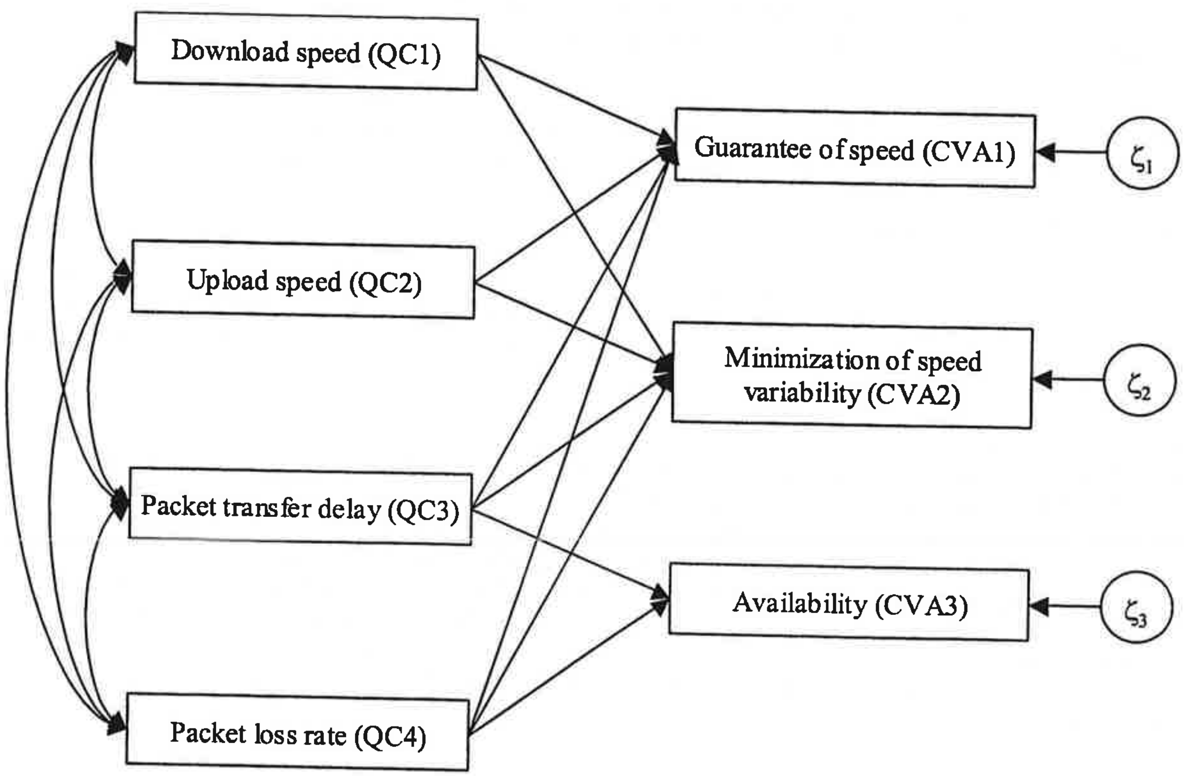

Figure 4. The Path Diagram of the Selected CVA items for Improvement

3.4.2. Collecting Data

The data for the SEM analysis were collected through a survey from the current users of Company K's very high-speed digital subscriber lines (VDSL) service, which is a slightly advanced version of the ADSL service. The survey was conducted through a website designed for benchmarking tests on telecommunication services over the internet. The customer satisfaction level on each of the CVA items was evaluated by the user visiting the website. The performance of the QCs was automatically measured during the visit so that the CVA evaluation and the QC performance values were synchronized. As a result, a total of 912 valid data were collected over a 9 month period, from March 2003 to November 2003.

3.4.3. SEM Model Fitting

In this case study, AMOS 4.0 was used for the SEM model fitting (Arbuckle and Wothke 1999). The model fit indices of the initial model were unacceptable. To improve the model fit, a path from QC1 to CVA3 and correlations among ζ_i's, which are theoretically sound, were added to the initial path model. The revised model turned out to be quite acceptable (p-value = 0.149, GFI = 0.999, AGFI = 0.982, RMSR = 0.043). (For the standards on the significance level in SEM, see Kline (1998).) The resulting estimated (unstandardized) path coefficients are summarized in Table 3.

The results show that the download speed (QC1) has highly significant (positive) effects (p-value = 0.000) on all three CVA items. The upload speed (QC2) also has highly significant (positive) effects (p-value = 0.000) on the guarantee of speed (CVA1) and the minimization of speed variability (CVA2). The packet loss rate (QC4) has moderately significant effects on all the CVA items (CVA1, p-value = 0.039; CVA2, 0.096; CVA3, 0.091). Note that the path coefficients associated with the packet loss rate are negative because it is a smaller-the-better type QC. The packet transfer delay (QC3), however, has no significant effects on any of the CVA items (CVA1, p-value = 0.585; CVA2, 0.791; CVA3, 0.611).

Table 3. Estimated Path Coefficients

Path (from)		(to)	Estimated Coefficient (p-value)
Download speed (QC1)	→	Guarantee of speed (CVA1)	0.134 (0.000)
Download speed (QC1)	→	Minimization of speed variability (CVA2)	0.130 (0.000)
Download speed (QC1)	→	Availability (CVA3)*	0.107 (0.000)
Upload speed (QC2)	→	Guarantee of speed (CVA1)	0.187 (0.000)
Upload speed (QC2)	→	Minimization of speed variability (CVA2)	0.120 (0.000)
Packet transfer delay (QC3)	→	Guarantee of speed (CVA1)	0.002 (0.585)
Packet transfer delay (QC3)	→	Minimization of speed variability (CVA2)	-0.001 (0.791)
Packet transfer delay (QC3)	→	Availability (CVA3)	0.002 (0.611)
Packet loss rate (QC4)	→	Guarantee of speed (CVA1)	-0.018 (0.039)
Packet loss rate (QC4)	→	Minimization of speed variability (CVA2)	-0.015 (0.096)
Packet loss rate (QC4)	→	Availability (CVA3)	-0.019 (0.091)

* Added path in the revised path model

3.4.4. Interpreting the Path Coefficients

The obtained coefficients can be utilized for both the descriptive and the prescriptive analysis purposes. Here, the descriptive analysis is to understand the impact of a QC change on the improvement of the related CVA items. For example, an increase in the performance of the download speed (QC1) by one unit (i.e., 1 MBPS) leads to an increase in the customer satisfaction level of the guarantee of speed (CVA1) by 0.134, the minimization of speed variability (CVA2) by 0.130, and the availability (CVA3) by 0.107, out of a 7-point measurement scale. The impacts of other QCs can be interpreted in a similar manner. In contrast, the prescriptive analysis is to form alternative implementation strategies to achieve an improvement target of a specific CVA item. As an example, suppose an increase in the current customer satisfaction level of the guarantee of speed (CVA1) by 1 is desired. This target should be achieved by improving the current performance of the relevant QCs. As shown in Table 3, the increase of QC1, QC2, and QC4 by one unit each improves CVA1 by 0.134, 0.187, and -0.018, respectively. Based on these marginal contribution rates, several alternative strategies can be formed: for example, (i) increasing the current performance of QC1 by 7.46 MBPS; or (ii) increasing the current performance of QC2 by 5.35 MBPS; or (iii) increasing the current performance of QC1 by 3.46 MBPS and that of QC2 by 2.87 MBPS; or (iv) increasing the current performance of QC1 and QC2 by 3.00 MBPS each and that of QC4 by 2.06%; and the like.

In addition to the four alternatives mentioned above for an illustrative purpose, one can devise infinitely many alternatives, at least mathematically, to achieve the given target. Among the alternatives, the analyst needs to select the optimal strategy considering other factors, such as technical and financial feasibility. In principle, the choice of the best alternative can be posed as an optimization problem which simultaneously considers the cause-and-effect relationships and various technical and financial constraints. This topic will be investigated in future studies.

4. CONCLUSIONS

This proposed systematic framework for service quality analysis and improvement advantageously integrates two well-known methods, namely, QFD and SEM. The framework's demonstration through a case study on the ADSL service of a major telecommunication company in Asia proved to be most informative. The QFD analysis provided the CVA evaluation results, including CVA importance, CVA competitiveness, and CVA coverage. The results of the QFD analysis were used as the basis for developing an improvement strategy for the CVA items. Then, SEM was employed to build and analyze the quantitative, cause-and-effect relationships between QCs and CVA items. The results of the SEM analysis were interpreted both the descriptive and prescriptive perspectives. This framework can be utilized for an effective analysis and improvement of service quality not just in the telecommunication industry, but also in any service industry which collects customer satisfaction and service performance data as part of its daily operation. Moreover, the proposed framework can, and should be applied periodically, as opposed to an one-time application only. Thus, the proposed framework can serve as a basis for a company-wide customer satisfaction guarantee system.

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