# Measuring the Customer Satisfaction Efficiency of Mobile Phone Manufacturers in an Emerging Market: A Super-Efficiency DEA Approach

**Ekrem Tatoglu[1*], Erkan Bayraktar[2], Ali Turkyilmaz[3]**
**1 Department of International Trade and Business**
**Bahcesehir University, Besiktas, Istanbul 34349 Turkey.**
**2 Industrial Engineering Department**
**Bahcesehir University, Besiktas, Istanbul 34349 Turkey.**
**3 Department of Industrial Engineering**
**Fatih University, Buyukcekmece, Istanbul, 34500, Turkey.**
**[*]EMAIL: ekremt@bahcesehir.edu.tr**

**Abstract:** Relying on a super-efficiency data envelopment analysis (DEA) approach, this paper compares the customer satisfaction efficiency of companies operating in Turkish mobile phone sector. The constructs of customer satisfaction index model are treated as inputs and outputs indicators of DEA analysis. These outputs and inputs are obtained using partial least squares analysis. Drawing on the perceptual responses of 652 mobile phone users, the super-efficiency scores reveal that from a total of seven mobile phone companies operating in Turkey Nokia and LG features as the most efficient companies in terms of CS efficiency, while Sonny Ericsson and Motorola rank as the two least efficient companies.

**Keywords:** Customer satisfaction, DEA, super-efficiency, PLS, mobile phone sector.

## I. Introduction

The principal focus of this study is on evaluating customer satisfaction (CS) efficiency of incumbent firms operating in Turkish mobile phone sector. As of 2009, the top five mobile phone manufacturers are namely Nokia, Samsung, LG, Motorola and Sony Ericsson and together they account for nearly 75 per cent of overall market sales. In terms of market share, Nokia has been undisputedly the market leader (36.4% of sales) with Samsung featuring second (19.5%) and LG ranking third (10.1%) (*Patron Turk*, 2010).

The methodology used to evaluate the relative CS efficiency of mobile phone manufacturers in this study is known as super-efficiency data envelopment analysis (DEA). This method has recently been proposed as an alternative to the traditional DEA approach for efficiency analysis due to its rigor, usefulness and computational easiness (Nahra et al., 2009). The traditional DEA technique has long been applied extensively in the field of operations research and management science across a wide range of industries as well as in not-for-profit organizations (Wu et al., 2009), but there has been relatively little diffusion into the field of marketing and related disciplines. The super efficiency DEA approach adopted in this study illustrates how differences in CS efficiency between incumbent firms can be ascertained empirically and will thus help management to determine policy and action scientifically.

## II. Research Framework

Within the existing literature on customer satisfaction research, various customer satisfaction models were developed based on a cumulative view of satisfaction. To this end, various customer satisfaction indices (CSIs) were developed with most prominent of those being Swedish customer satisfaction barometer (SCSB), the American customer satisfaction index (ACSI) and European customer satisfaction index (ECSI). Of these CSIs, we have adopted the ECSI model as the framework for our CS efficiency model in this study. The ECSI model is a structural model based on the assumptions that customer satisfaction is caused by a number of factors such as perceived quality, perceived value, expectations of customers, and image of a firm. These factors are the antecedents of overall customer satisfaction (Turkyilmaz and Ozkan, 2007). The all four antecedents of customer satisfaction may also have direct effects on customer loyalty (Johnson et al., 2001). Each construct in the ECSI model is a latent construct which is operationalized by multiple indicators (Fornell, 1992; Chien et al., 2003).

Figure 1 shows the causal relationships between customer satisfaction and other latent constructs. In our CS efficiency model, all four antecedents of customer satisfaction which include image, customer expectations, perceived quality and perceived value were treated as input variables, while the two constructs of customer satisfaction and customer loyalty were considered as output variables.

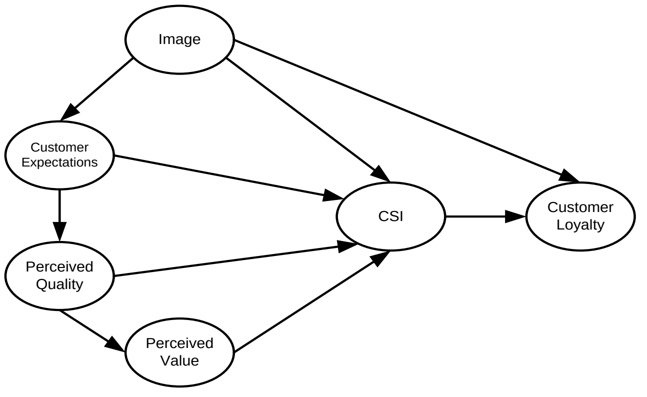


Figure 1 Customer Satisfaction Model

## II. Methodology

**Survey Instrument and Data Collection**

The constructs of the CSI model are unobservable (latent) variables indirectly described by a block of observable variables which are called manifest variables or indicators. The constructs and their constituent items are shown in Table 1.

A survey instrument, developed to measure the manifest variables, was prepared in Turkish. The final questionnaire contained 23 questions pertaining to the CSI. A 10-point measurement scale was used where 1 denotes a very negative view and 10 indicates a very positive view. Relying on 10-point scales enables customers to make better discriminations (Fornell et al., 1996).

Table 1 The Latent Variables and Their Observable Indicators in the CS Model

| Latent Variables | Observable (Manifest) Variables |
|---|---|
| *Image (IM)* | IM1: Being reliable<br>IM2: Being professional<br>IM3: Social contributions to society<br>IM4: Customer relations<br>IM5: Innovative and forward looking<br>IM6: Adding value to user (prestige) |
| *Expectations (EXP)* | EXP1: Expectations for fulfillment of personal need<br>EXP2: Expectations for overall quality<br>EXP3: Expectations for product quality<br>EXP4: Expectations for service quality |
| *Perceived quality (PQ)* | PQ1: Overall quality<br>PQ2: Product quality (technical)<br>PQ3: Service quality<br>PQ4: Customer Services<br>PQ5: Appropriateness to intent of use |
| *Perceived value (PV)* | PV1: Price/Performance<br>PV2: Performance/Price |
| *Customer loyalty (CL)* | CL1: Repurchase intention<br>CL2: Recommendation to others<br>CL3: Price tolerance |
| *Customer satisfaction (CS)* | CSI1: Overall satisfaction<br>CSI2: Fulfillment of expectations<br>CSI3: Compare with ideal |

The CSI model was implemented in Turkish mobile phone sector since the fierce competition in this industry results in a dynamic product innovation and an increasing demand for the products.

Data were gathered based on an interview based survey. The survey was conducted to randomly chosen 700 mobile phone owners (18 years old and above) within the greater metropolitan city of Istanbul. Among all collected data set, 652 were found satisfactory for data analysis. Occasional missing data on variables was handled by replacing them with the mean value. Our sample respondents were categorized in terms of their choice of a particular mobile phone company. A total of seven mobile phone companies were identified, which constituted the subject of our analysis in terms of CS efficiency. These companies were namely Motorola, Nokia, Panasonic, Samsung, BenQ, Sony Ericsson and LG.

**The Data Envelopment Analysis (DEA) Model**

Data envelopment analysis (DEA) is a linear programming based model and assesses the comparative efficiency of homogeneous organizational units, such as bank branches, schools, tax offices, and hospitals. DEA provides a means to assess the relative efficiencies of multi-input multi-output production units (Cook and Seiford, 2009). The efficiency score is usually denoted as either a number between 0 and 1 or 0 and 100 percent. The efficiency score of 1 or 100 percent of a decision making unit (DMU) shows that DMU is efficient relative to other units in the research sample. In addition to providing meaningful scalar efficiency values, DEA is designed to determine the sources and estimate the amounts of inefficiencies that might present in the various output and input vectors (Charnes et al., 1978).

The relative performance measurement of DEA is a two-staged process (Mercan et al., 2003):

(i) Determining the best performing DMUs that produce greatest output with the least input. Assigning a DEA performance-index value of unity (1) to such DMUs and placing them on the efficient frontier.
(ii) Determining the DEA performance-index values for all other DMUs in the set. Such values are represented by the distance of the less efficient units from the above defined efficient frontier. The DMUs in this subset use more inputs given an output level or produce less output for a specific level of inputs.

DEA determines the most productive DMU, the amount of excess resources used by inefficient DMUs, the amount of excess capacity or ability to increase service outputs in less-productive units, the set of best-practice service units the most similar to the less-productive units (Sherman and Ladino, 1995).

An input oriented envelopment model of DEA may be defined as follows:

$$Min\ \theta_o - \varepsilon(\sum_{i=1}^{n} e_{io} + \sum_{j=1}^{m} d_{jo}) \qquad (1)$$

*Subject to*

$$\sum_{r=1}^{k} \lambda_r x_{ir} + e_{io} = \theta_o x_{io} \qquad i = 1,..., n; \qquad (2)$$

$$\sum_{r=1}^{k} \lambda_r y_{jr} - d_{jo} = y_{jo} \qquad j = 1,2,...,m \qquad (3)$$

For all $i, j, r$ $\qquad e_{io}, d_{jo}, \lambda_r \geq 0 \qquad (4)$

*Where:*

$$\sum_{\substack{r=1 \\ r \neq o}}^{k} \lambda_r y_{jr} - d_{jo} = y_{jo}$$

$\theta_o$ : Efficiency score of o[th] DMU,
$x_{ir}$ : Observed value of input $i$ for the DMU $r$,
$y_{jr}$ : Observed value of output $j$ for the DMU $r$,
$e_{io}$ , $d_{jo}$ : The amounts of excess input $i$ and deficit output $j$ for DMU $o$ respectively,
$\varepsilon > 0$ : Predefined non-Archimedean element,
$\lambda_r$ : Dual variable utilized to construct a composite ideal DMU to dominate DMU $o$.
$k$ : Number of decision making units.
$m$ : Number of outputs.
$n$ : Number of inputs.

The objective function (1) assesses the efficiency score ($\theta_o$) of the university according to respondent under consideration. Within the same objective function in case the university is efficient ($\theta_o$ = 1), all-zero slack values (output deficits and input excesses) are also enforced for full-efficiency. Constraint (2) ensures that the input $i$ for respondent $o$ is a linear combination of the inputs for each university according to respondents ($r$) and the excess input of $i$. Constraint (3) states that the optimal output of $j$ for a university according to respondent $o$ is a linear combination of the outputs for each university ($r$) minus its slacks. In the optimal solution of model (1-4), DMU according to respondent $o$ is efficient if $\theta_o = 1$ and $e_{io} = d_{jo} = 0$ for all $i$ and $j$ (Cooper et al., 2004). If $\theta_o = 1$ but either $e_{io}$ or $d_{jo}$ is non-zero, the firm $o$ is called weakly efficient. The universities found efficient in the solution of the model (1-4) form the efficiency frontier which is called as reference set for universities according to respondent $o$.

**Super-Efficiency Model**

Andersen and Petersen (1993) developed a new procedure the so-called super-efficiency DEA for ranking efficient DMUs as an alternative to traditional DEA model. Since its first introduction, super-efficiency DEA models have gained an increasing recognition in the management science literature. The basic idea in that model is to compare the DMU under evaluation with a linear combination of all other units in the sample, the DMU itself is excluded. It is amenable to reason that an efficient DMU may increase its input vector proportionally while preserving efficiency. The DMU obtains in that case an efficiency score above 1. So that super-efficiency DEA approach provides an efficiency rating of efficient units like rating of inefficient units (Andersen and Petersen, 1993).

For the super-efficiency DEA, the constraints (2) and (3) on the linear programming model (1-4) are modified as follows:

$$\sum_{\substack{r=1 \\ r \neq o}}^{k} \lambda_r x_{ir} + e_{io} = \theta_o x_{io} \qquad i = 1,..., n; \qquad (5)$$

$$j = 1,2,...,m \qquad (6)$$

The only difference between super-efficiency DEA and the original DEA approach is the limitation of the efficiency of unit $o$, the unit under evaluation, to maximum value 1. Therefore, the technical efficiency scores for the efficient units will be greater than or equal to 1 using the super-efficiency DEA (Nahra et al., 2009).

Apart from its clear advantages, there is an issue of infeasibility related to super-efficiency model. In order to avoid the problem of infeasibility inherent in the super-efficiency model, a number of authors have suggested some alternative techniques. For instance, Khodabakhshi (2007) proposed a super-efficiency model based on improved outputs which is similar to an output-oriented version of the Andersen and Petersen’s model including convexity constraint, and rank DMUs by this approach. Tone (2002) offered a slacks-based model; Lovell and Rouse (2003) used an equivalent standard DEA model, and Bogetoft and Hougaard (2004) had theirs based on potential slack to evaluate the super-efficiency scores.

## III. Analysis and Findings

The data analysis was conducted in three steps. First, Partial Least Squares (PLS) method was applied in order to determine the relative weights of exogenous and endogenous latent variables that would be later used as input and output variables in our CS efficiency model. Second, the traditional DEA approach was implemented to identify the ranking of mobile phone companies in terms of CS efficiency. Finally, a super-efficiency DEA approach was used for ranking efficient mobile phone companies as an alternative to the traditional DEA method.

**Estimation of SEM**

Customer satisfaction model is designed as a structural equation model (SEM) which is a comprehensive statistical approach for testing hypothesized relationships between observed and latent variables.

The structural model of the present model is analyzed using PLS method. Before starting to analyze the path model, unidimensionality of each reflective construct in the proposed model was checked. There are three tools available for the unidimensionality check of a construct: Principal component analysis of the construct, Cronbach's alpha, and Dillon-Goldstein's ρ.

For the data set, Cronbach's alpha and Dillon-Goldstein's ρ values of each construct were found to be greater than 0.80. From principal component analysis, first eigenvalue was noted to be greater than 1 and second eigenvalue is less than 1 for each construct. These results lead to an acceptance of the unidimensionality of all constructs. The outer model estimation results are provided in Table 2.

Table 2 Outer Model Results

| Latent variable | Manifest variable | Outer weight | Communality |
|---|---|---|---|
| *Image* | IM1 | 0.137 | 0.684 |
| | IM2 | 0.121 | 0.708 |
| | IM3 | 0.051 | 0.307 |
| | IM4 | 0.079 | 0.538 |
| | IM5 | 0.101 | 0.621 |
| | IM6 | 0.102 | 0.645 |
| *Customer expectations* | EXP1 | 0.174 | 0.713 |
| | EXP2 | 0.170 | 0.742 |
| | EXP3 | 0.118 | 0.614 |
| | EXP4 | 0.164 | 0.733 |
| *Perceived quality* | PQ1 | 0.152 | 0.733 |
| | PQ2 | 0.149 | 0.773 |
| | PQ3 | 0.100 | 0.610 |
| | PQ4 | 0.101 | 0.606 |
| | PQ5 | 0.130 | 0.534 |
| *Perceived value* | PV1 | 0.214 | 0.924 |
| | PV2 | 0.226 | 0.933 |
| *Customer satisfaction* | CS1 | 0.344 | 0.953 |
| | CS2 | 0.144 | 0.785 |
| | CS3 | 0.066 | 0.561 |
| *Customer loyalty* | CL1 | 0.140 | 0.813 |
| | CL2 | 0.155 | 0.844 |
| | CL3 | 0.099 | 0.592 |

Reliability and validity of the proposed CSI model was assessed by checking unidimensionality of the constructs, individual item reliability, convergent validity and discriminant validity. All test results satisfy the crucial requirements for validity and reliability of structural model.

**Efficiency Analyses**

Exogenous latent variables (independent variables) of the PLS model which are labeled *image* (IM), *expectation* (EXP), *perceived quality* (PQ), and *perceived value* (PV) are considered as inputs for DEA analysis. Two individual variables of endogenous latent variables of the PLS model *customer satisfaction* (CS), *customer loyalty* (CL) were determined as outputs for the DEA analysis. These inputs and outputs were used in the evaluation of the CS efficiency of mobile phone companies.

Table 3 DEA Results

| DMU No. | DMU Name | Efficiency Score | RTS | Benchmarks |
|---|---|---|---|---|
| 1 | Motorola | 0.906 | Increasing | Nokia (0.509), Samsung (0.069), LG (0.112) |
| 2 | Nokia | 1.000 | Constant | 1.000 |
| 3 | Panasonic | 1.000 | Constant | 1.000 |
| 4 | Samsung | 1.000 | Constant | 1.000 |
| 5 | BenQ | 1.000 | Constant | 1.000 |
| 6 | Sony Ericsson | 0.972 | Increasing | Nokia (0.282), Panasonic (0.230), BenQ (0.442) |
| 7 | LG | 1.000 | Constant | 1.000 |

According to the traditional DEA results, 2 out of 7 mobile phone companies were identified as inefficient. These are namely Sony Ericsson and Motorola. Efficiency scores of these two inefficient companies are 0.972 and 0.906, respectively. In Table 3, the value in parenthesis that is associated with each member of the efficiency reference set, represents the relative weight assigned to that efficient unit in calculated the efficiency rating for inefficient firm. These relative weights are the shadow prices that are associated with the respective efficient unit constraints in the linear programming solution.

Of the seven, five companies were found to be efficient, as shown in Table 3. The results of the traditional DEA technique, however, do not provide the most efficient firms and their respective rankings. Therefore, one needs to run the super-efficiency analysis to determine the most efficient mobile phone companies and rank them with respect to CS efficiency. The results of the proposed super-efficiency model are presented in Table 4. The input oriented super-efficiency scores for the Nokia and LG are 1.251 and 1.159, respectively. The results show that the Nokia Mobile Phone Company have to produce at least 79 per cent (1/1.251) of its current output proportionally to remain efficient, while LG Mobile Phone Company by producing 86 per cent (1/1.159) of its output can still remain efficient. Therefore, Nokia ranks the first, while LG features as the second in terms of CS efficiency.

**Reasons for Inefficiency**

In addition to the identification of inefficient companies and their efficiency reference set, DEA provides additional insights about the magnitude of inefficiency for the inefficient companies. The magnitude of inefficiency is determined by the magnitude of excess resources (inputs) and/or deficient outputs produced by inefficient companies. Excess inputs or deficient outputs are calculated by subtracting the actual input/output values of a given company from the ideal values of the composite (best practice) company. The results of averaging the input excesses for each input variable are summarized in Tables 5 and 6.

Table 4 Super Efficiency Results

| DMU No. | DMU Name | Super Efficiency Score | Benchmarks |
|---|---|---|---|
| 1 | Motorola | 0.906 | Nokia (0.509), Samsung (0.069), LG (0.112) |
| 2 | Nokia | 1.251 | 1.000 |
| 3 | Panasonic | 1.024 | 1.000 |
| 4 | Samsung | 1.015 | 1.000 |
| 5 | BenQ | 1.031 | 1.000 |
| 6 | Sony Ericsson | 0.972 | Nokia (0.282), Panasonic (0.230), BenQ (0.442) |
| 7 | LG | 1.159 | 1.000 |

Table 5 The Input Excesses for Inefficient Firms

| MOTOROLA | | | | |
|---|---|---|---|---|
| **Inputs** | **Actual Input Values** | **Target Input Value** | **Difference** | **Average Improvement Potential %** |
| *Image* | 4.882 | 4.882 | 0 | 0.00 |
| *Expectations* | 5.582 | 5.463 | -0.119 | -2.13 |
| *Perceived quality* | 5.364 | 5.364 | 0 | 0.00 |
| *Perceived value* | 4.508 | 4.508 | 0 | 0.00 |
| **SONY ERICCSON** | | | | |
| **Inputs** | **Actual Input Values** | **Target Input Value** | **Difference** | **Average Improvement Potential %** |
| *Image* | 6.227 | 6.209 | -1.77E-02 | -0.28 |
| *Expectations* | 6.821 | 6.821 | 0 | 0.00 |
| *Perceived quality* | 6.744 | 6.744 | 0 | 0.00 |
| *Perceived value* | 6.103 | 6.103 | 0 | 0.00 |

Table 6 The Output Deficits for Inefficient Firms

| MOTOROLA | | | | |
|---|---|---|---|---|
| **Outputs** | **Actual Output values** | **Target Output Value** | **Difference** | **Average Improvement Potential %** |
| *Customer satisfaction* | 4.370 | 4.821 | 0.450 | 10.31 |
| *Customer loyalty* | 3.208 | 4.884 | 1.675 | 52.22 |
| **SONY ERICCSON** | | | | |
| **Outputs** | **Actual Output values** | **Target Output Value** | **Difference** | **Average Improvement Potential %** |
| *Customer satisfaction* | 6.078 | 6.249 | 0.170 | 2.80 |
| *Customer loyalty* | 5.784 | 6.185 | 0.401 | 6.94 |

It is clear from Table 5 that *expectation* ranks first in the input excesses for Motorola Company. It shows that Motorola Company utilizes more resources than required to meet the customers' expectations. The other inefficient company, Sonny Ericsson overuses required resources to improve their *image*. On the other hand, Table 6 indicates that both inefficient mobile phone companies have problems to reach their target value in both output items of *customer satisfaction* and *customer loyalty*.

## IV. Conclusion

The evidence obtained from the analysis of relative CS efficiency reveals that from a total of seven mobile phone companies Nokia and LG features as the most efficient companies, while Sonny Ericsson and Motorola rank as the two least efficient companies.

While this study provides useful insights into the use of super-efficiency DEA as a modeling tool to assist managerial decision making in measuring CS efficiency, its limitations should also be acknowledged. First, the input and output measures of the study were determined using subjective measures related to CSI model. In a future study, some subjective and objective inputs and outputs may be added in investigating the CS efficiency of the companies. In the future study, two stages approach, which combines super efficiency and multiple regression analysis, can be employed to obtain further insights using some control variables such as age, region, and price level. Extending CS efficiency model to company samples in other sectors would be particularly useful. To avoid infeasibility problem associated with super-efficiency models, some other alternative techniques such as slack-based DEA approach can be used to determine the efficiency of the DMUs. Finally, given the relative paucity of marketing research in emerging country contexts, there is an obvious need for comparison studies. Particularly interesting would be those that have some commonalities with Turkey, such as India, Brazil, China and Russia.

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## Background of Authors

**Ekrem Tatoglu** received the B.Sci. degree from the Middle East Technical University University, Turkey, the MBA from University of Nottingham, UK and the Ph.D from University of Leeds, UK. He currently serves as the Chair of International Trade and Business at Bahcesehir University, Istanbul, Turkey. His research interests include global management strategies, FDI in emerging markets, international entry mode strategies and supply chain management. He has published over 50 articles in leading scholarly business and management journals.

**Erkan Bayraktar** received the B.Sci. and MSc. degrees from Dokuz Eylul University, Turkey, and the PhD from the University of Iowa in Industrial Engineering. He currently serves as an associate professor of Industrial Engineering at Bahcesehir University, Istanbul, Turkey. His principal research areas include supply chain management, lean production, and process improvement. He has published in several academic journals including International Journal of Production Economics, International Journal of Production Research, Industrial Management and Data Systems among others, EMAIL: erkanb@bahcesehir.edu.tr.

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**Ali Turkyilmaz** received the B.Sci. degree from Yildiz East Technical University University, Turkey, the M.Sc. from Fatih University, Turkey and the Ph.D from Istanbul Technical University, UK. He currently serves as an assistant professor of Industrial Engineering at Fatih University, Istanbul, Turkey. His research interests include quality management, customer satisfaction models, lean manufacturing and system design, EMAIL: aturkyilmaz@fatih.edu.tr.