Application of Data Envelopment Analysis by the Evaluation of the Quality and Operational Factors

Saba Ahmed

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Prof. Dr. Mustafa Tümer
Acting Director

I certify that this thesis satisfies the requirements as a thesis for the degree of Master of Science in Industrial Engineering.

Assoc. Prof. Dr. Gökhan İzbırak
Chair, Department of Industrial Engineering

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Master of Science in Industrial Engineering.

Asst. Prof. Dr. Sahand Daneshvar
Supervisor

Examining Committee

1. Prof. Dr. Bela Vizvari
2. Asst. Prof. Dr. Sahand Daneshvar
3. Asst. Prof. Dr. Hüseyin Güden

ABSTRACT

In the last decade, soft drink products among FMCG (Fast Moving Consumer Goods) industry have been facing serious problems due to the change in the consumer preferences. Health concerns towards these products had risen and companies keep making strategies to cope with this change. Since, the condition of the market shares getting narrower, maintaining efficient operations throughout the industry supply chain became an essential matter. The study focuses on the efficiency evaluation of soft drink company's production lines between 2010 and 2015 located in Köprülüköy Cyprus, since the production phase is one of the most essential part of the whole operation. Data Envelopment Analysis is a widely known technique used for the evaluation of technical efficiencies of decision making units where multiple inputs and multiple outputs were under concern. Here, production lines of the production facility have chosen as DMUs and among the models of DEA, standard CCR and standard BCC models were utilized. Since the study was being performed in FMCG sector, where perishable food products were under concern, quality factors were also taken into consideration besides operational factors in the operation. Especially for the food production process, efficiency of the whole operation is definitely affected by the efficiency of the quality operations. In this study a general procedure for the evaluation of the production line efficiencies for the perishable goods had built that could easily adapted to the whole industry. Findings of the models can help management in decision making process, budget planning purposes, categorize production lines, future plans, and help to build a corporate memory for the efficiency of the lines.

Keywords: Data Envelopment Analysis, FMCG, Quality Factors, Operational Factors, Efficiency, CCR Model, BCC Model, Food Production, Soft drink.

ÖZ

Son on yıl dikkate alındığı taktirde, hızlı tüketim malları sektöründe yer alan gazlı içecek endüstrisi, müşteri tercihlerinin değişimi konusunda ciddi sorunlarla karşılaşmaktadır. Bu ürünlerin insan sağlığına etkileri ile ilgili endişeler artmakta ve şirketler bu durumla başaçıkmak için stratejiler geliştirmektedirler. Endüstrideki pazar paylarının giderek daralması ile birlikte sektör genelinde verimli operasyonlar sağlamak önem arz eder olmuştur. Üretim prosesleri bu zincirin en önemli parçası olduğundan bu çalışma Köprüköy, KKTC'de bulunan bir gazlı içecek üreticisinin 2010 ve 2015 yılları arası üretim hatlarının verimliliği üzerine bir değerlendirme içermektedir. Veri Zarflama Analizi, verimlilik analizinde birden fazla girdi ve çıktı olması durumunda teknik verimliliklerin hesaplanmasında yaygın olarak kullanılan etkin bir yöntemdir. Bu çalışmada, üretim alanındaki her bir üretim hattı bir Karar Verme Birimi olarak seçilmiş ve Veri Zarflama Analizi modellerinden Standard CCR ve Standard BCC modelleri kullanılmıştır. Bu çalışma hızlı tüketim malları sektöründe yapıldığından kısa ömürlü gıda ürünlerinin üretimi incelenmiş ve operasyonel faktörlerin yanında kalite faktörlerinin de dikkate alınmasına karar verilmiştir. Özellikle gıda üretimide kalite operasyonlarının verimliliği, genel anlamda operasyonel verimliliği de etkilemektedir. Bu çalışma neticesinde tüm endüstriye uyarlanabilecek şekilde üretim hatları verimliliklerinin ölçümü için genel bir prosedür oluşturulmuştur. Modelden alınacak sonuçlar şirket yönetiminin karar verme mekanizmasına yardımcı olacak ve bütçe planlaması, üretim hatlarının kategorize edilmesi, gelecek planları ve üretim hatlarının verimliliği hususunda şirket hafızasının oluşturulmasını sağlayacaktır.

Anahtar Kelimeler: Veri Zarflama Analizi, HTM, Kalite Faktörleri, Operasyonel FaktörlerQuality, Verimlilik, CCR Model, BCC Model, Gıda Üretimi, Gazlı İçecek.

To My Family

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LIST OF ABBREVIATION

DEA	Data Envelopment Analysis
DMU	Decision Making Unit
FMCG	Fast Moving Consumer Goods
PPS	Production Possibility Set
MPM	Marketing Performance Measurements
RTS	Return to Scale
AHP	Analytic Hierarchy Process
CI	Consistency Index
RI	Random Index
SKU	Stock Keeping Unit
SoD	Set of Data
QA	Quality Assurance

Chapter 1

INTRODUCTION

1.1 Problem Description

FMCG's (Fast moving consumer goods) are the largest sectors of the business world. It is a huge market including the largest companies in the world. FMCG category consists of regularly purchased essential or non-essential products such as food, soft drinks, disposable goods or toiletries. These products have some common features like they sold quickly with relatively low prices. Carbonated beverages (soft drinks) are one of the main contributors of the FMCG market.

An article published in March 2014 by Daily Mail UK reveals that sales trends for the recent years showing the customer preferences towards carbonated beverages have been decreasing. Recent medical researches, increase in the number of health conscious customer and susceptibility to child obesity issues lead to a decrease in the carbonated beverage consumption. According to the article the carbonated soft drink sales in the USA market drop by 1% in 2011, 1.2% in 2012 and 3% in 2013. In Figure 1.1, a report published by Beverage Digest in 2014, the volumetric fall in the sales of the soft drink from 2004 to 2013 is illustrated. Heath concerns among people lead to much healthy and natural choices of food consumption. Major companies keep introducing calorie free (diet) products to satisfy consumers.

Government policies also have a major role in this decrease, for instance in 2010 Cypriot Ministry of Education issued a notice stating the banning of the sales of the carbonated beverages in school cafeterias. Moreover, since March 2016 only fresh foods, milk and water is allowed in the school cafeteria of Turkey. All these factors eventually have an effect on the sales of the carbonated beverages. While the situation in the FMCG market is getting rough, some precautions need to be taken in the factory floor to cope with the increasing competition resulting from shrinkage in the total FMCG market. In order to perform this objective, careful efficiency evaluation should be performed to determine and differentiate efficient and inefficient operations. Some improvements for inefficient operations need to be suggested to make them efficient. Furthermore, yearly budgets should be adjusted to maintain efficiency in the operations.

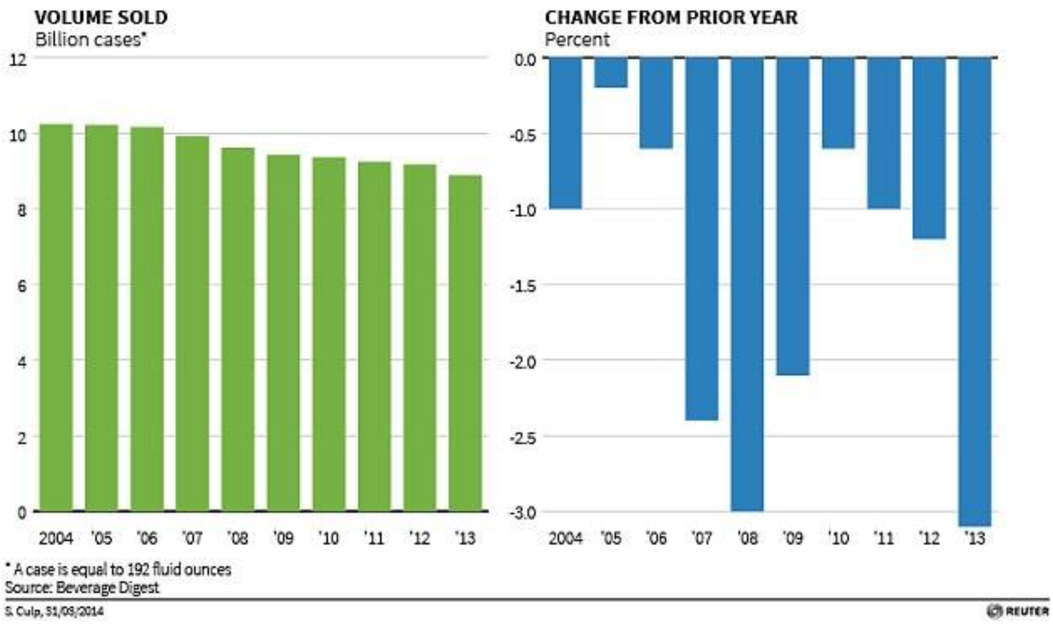

Figure 1.1: Sales Trends of the Carbonated Beverages Between 2004-2013.

Due to the decrease in the consumption of the carbonated beverages, efficient production lines should be used for producing products with the stated quality standards and hence, a reduction in the production costs must definitely be achieved. For the food industry, traditional efficiency approach may not be applicable since the quality standards of the product is a restriction in the process. In other words, factory cannot increase its outputs for the efficiency purposes while disregarding quality factors as stated in the traditional efficiency formula. Utilization of such conventional methods will still help to cope with the changes described in Figure 1.1. The following formula (1.1) is the simplest way and commonly used to evaluate general purpose efficiency values. In economical view of point when our Decision Making Unit (DMU) consumes one input, it produces one output.

$$Efficiency = \frac{Output}{Input} \qquad (1.1)$$

By this formula some problems and limitations might occur when attempting to evaluate efficiency with multiple outputs and multiple inputs case. In this study, Data Envelopment Analysis (DEA), a technique originally proposed by Charnes, Cooper and Rhodes (1978) for evaluating relative efficiency of decision making unit's (DMUs) is utilized. It is a non-parametric method based on linear programming to evaluate relative efficiency. Non-parametric method is a commonly used method in statistics where small sample sizes are used to analyze nominal data. It is often used when the analyzer does not know anything about the parameters of the sample chosen from the population. In other words it can be expressed as parameter-free or distribution-free method.

The main advantages of using DEA approach for efficiency evaluation is that it provides multiple dimensions for efficiency, it makes it possible to rank the operations, it helps the management to identify and seek solutions for the inefficient operations. Furthermore in more detail, the model makes it possible to identify sources and amounts of inefficiency in each input and output for each entity and it could identify the benchmark members of the efficient sets effecting these evaluations and identify these sources of inefficiency.

To sum up, due to rigorous competition and shrinkage of the soft drink market share in the FMCG industry some precautions need to be taken by the manufacturers to cope with this competition. Operation on the factory floor must definitely be efficient in order to assure good manufacturing practices. The nature of a FMCG food product like carbonated beverages is that a certain quality standards need to be assured before sending product to the market. In this study, while considering and maintaining the quality and operational efficiency aspects, the main contributors to the input values and output values of a carbonated beverage factory is listed. Each production line in the factory floor is assigned as a DMU. In order to form a corporate memory for the efficiency values, input/output data between the years of 2010-2015 is collected. Eventually efficiency values for each DMU are calculated to seek for any improvement in the inefficient operations. Weights of the input/output values are calculated to make suggestions on the types of enhancements. Furthermore, 6 different sets of data (SoD) are formed by subtracting one input variable at a time while denoting the original problem as SoD 1 and to identify which input value contributes the most to the number of efficient DMUs.

It is expected from this study to bring an insight to the manufacturing operations. As can be seen in the literature section numerous studies have been performed regarding the FMCG industry with the sole purpose of analyzing its efficiency. Studies in the literature mainly focused on marketing, financial or logistics point of view since due to the characteristic of the FMCG product, logistics operations are the main contributor to efficiency of the industry and marketing operations have a huge effect on customer preferences and purchasing choices which are again important for the industry. In this study focus is given to the factory operations mainly to the factory floor. Maintaining efficiency in the manufacturing operations is a critical factor for the soft drink industry due to the reasons mentioned above and this paper will help to identify inefficient operations and guides management accordingly.

1.1 Structure of the Thesis

After the Chapter 1 which is the introduction part, thesis will be shaped in the following structure. The literature review regarding the study will be summed up in Chapter 2 then Chapter 3 is continued by the presentation of the methodology. Definition of the data and their collection procedure will be given in Chapter 4 and in Chapter 5 there will be an explanation of the results and recommendations regarding the study. Finally in Chapter 6 the whole study will be concluded and suggestion for the future studies will be given. Figure 1.2 illustrated the main sections of the thesis.

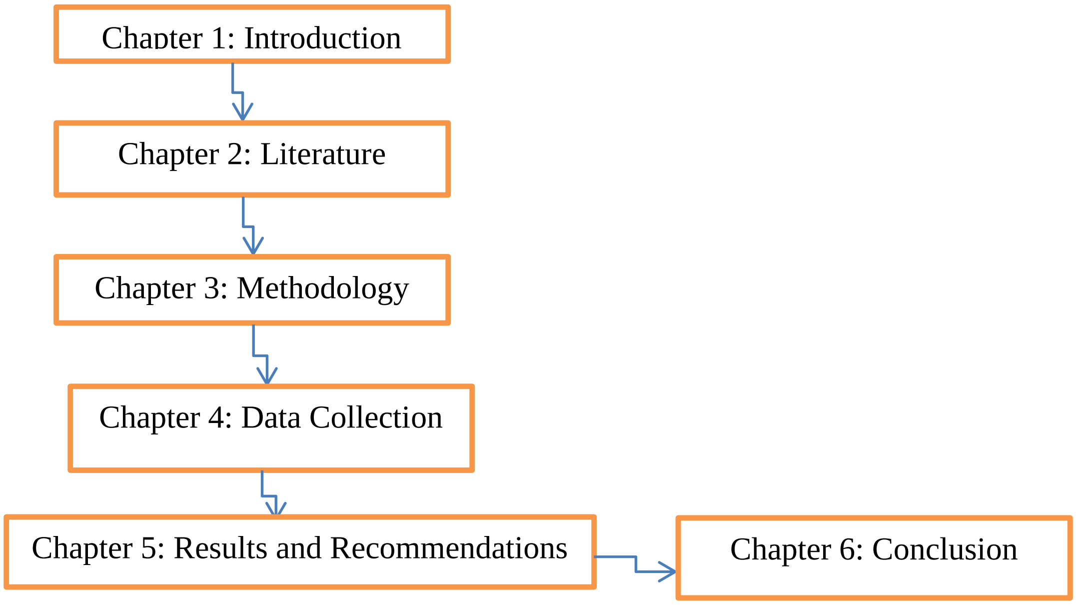

Figure 1.2: Structure of the thesis

Chapter 2

LITERATURE REVIEW

2.1 Literature Review on DEA, Standard CCR and BCC Models

Data Envelopment Analysis is a widely known technique for analyzing relative efficiencies of the DMU. The different models of DEA can be adapted to various area; health sector especially hospitals, transportation sector especially airports, energy generation plants especially electric generation plants, education sector especially schools. In the history of efficiency evaluation, the productive efficiency measurement for the economic policy makers goes back to 1957 where Farrell *et al.* combined inputs and outputs to obtain a satisfactory efficiency measurement for the industry. Until then, it was considered adequate to measure the average productivity of the labor for the measurement of the efficiency. However, neglecting the other variables does not seem reasonable, and this method guided economic decision makers in a wrong direction for a long time. Farrel *et al.* (1957) solved this problem by taking account all the inputs and yet avoiding index number problems. Charnes, Cooper and Rhodes (1978) proposed a nonlinear (non-convex) programming model providing a new definition of efficiency for the use in evaluating activities of not-for-profit entities participating in public programs. In this paper, the new approach to efficiency evaluation makes it possible to control managerial behavior while connecting the engineering and economic aspects of the efficiency itself. A scalar measurement of the efficiency for each of the participating units is provided along with methods for objectively determining weights by reference to the observational data for the multiple outputs and multiple inputs. Banker *et al.* (1984) brought a new insight and provide a separation into technical and scale efficiencies without altering the conditions for the data. Technical inefficiencies are identified with failures to achieve best possible output levels and/or usage of excessive amounts of inputs. The new approach includes a new separate variable which makes it possible to determine whether operations were conducted in regions of increasing, constant or decreasing returns to scale (in multiple input and multiple output situations). The former proposed efficiency evaluation model denoted as CCR model and the latter was denoted as BCC model. The detailed explanation of the both of the models will be defined in the following chapters of this study. Wide sorts of application of these models have been performing in the distinct range of the cases and distinct range of study area from applied engineering to social sciences. Golany *et al.* (1989) introduced their work providing a systematic application procedure of the DEA methodology in its various stages. The paper explained the selection of 'decision making units' (DMUs) to enter the analysis as well as the choice and screening of factors. Paper also gives certain demonstrations regarding different DEA models while providing relative efficiencies within the compared DMUs. Moreover, Boussofiane *et al.* (1991) introduced the model where multiple inputs and multiple outputs case and focused on some key issues that may arise regarding the application of the standard DEA models.

2.2 Literature Review on Operational and Quality Efficiency in DEA

When we focus on the factory point of view, operational efficiency is an important notion that needs to be evaluated for the sake of the management. In the FMCG industry which is the case of soft drink industry in this study, besides operational factors, quality is also an important notion that should be maintained throughout the process. Product's quality need to be assured before sending to the market. This notion leads to defected products to be eliminated from the process, hence affecting the efficiency of the factory. Quality of a process can be expressed as either qualitatively or quantitatively. The concept of quality increasingly getting attention for the customers and it is not limited to food industry. Customer service outcomes and their quality scores are getting attention in corporate world. For example, Jimenez *et al.* (1996) set out a model of primary health care performance which is based on the premise that certain measurable quality indicators can act as proxies for outcome. They chose DEA for the study for its characteristic that it can handle multiple dimensions of performance more comfortably, and is less vulnerable to the misspecification bias that afflicts statistically based models. Similarly Adler *et al.* (2001) applied standard DEA models to the measurement of the relative efficiency and quality of the airports. The quality scores in this study were expressed as by the means of detailed questionnaire filled by the airlines' companies. Quality indicators for the airports in Adler's study helped the airlines' choice of hubs. Similarly, Nayar *et al.* (2008) utilized DEA approach to make a comparison on hospital efficiency and quality where quantitative hospital specific quality measures are taken as output variables. The study concluded that the technically efficient hospitals were performing well as far as quality measures were concerned. DEA methodology can be utilized by the quality management aspect which is an approach to the management made up of a set of mutually reinforcing principles, each of which is supported by a set of practices and techniques. Kuah *et al.* (2010) utilize DEA to assessed quality management efficiency where the steps for evaluating quality efficiency is described thoroughly, quality factors were introduced and improvement suggestions were given to the inefficient operations. On the other hand, relative efficiency of an operation can be measured with DEA also with the contribution of the operational performances of each DMU. Subrahmanya *et al.* (2006) for example, studied the role of labor efficiency in promoting energy efficiency and economic performance with reference to small scale brick enterprises' cluster in Malur, Karnataka State, India. In brick industry, labor efficiency negatively affects the energy cost since enterprises having higher labor productivities had lower energy intensities. Therefore, labor efficiency is here a major concern for these companies. Önüt *et al.* (2006) used DEA to analyze energy use and efficiency in manufacturing sector where small and medium sized enterprises are studied for energy efficiency. Relative efficiency of the systems was compared within the industry with multiple inputs and multiple outputs DMUs. Energy cost is usually a small portion of the total production cost but in this case Turkish industrial sector comprises about 35% of the total energy consumption. Efficiency in energy consumption again became a major concern for small and medium enterprises in this industry. Liu *et al.* (2009) used DEA to evaluate thermal power plant operational performances where the efficiency is handled operational point of view. Overall operational performances of the thermal power plants were investigated between the years of 2004 to 2006, hence the overall performances of the plants were evaluated and results were drawn in yearly basis. For the factory floor operations, DEA utilized by Lin *et al.* (2009) to select a subset of potential product variants that can simultaneously minimize product proliferation and maintain market coverage. Efficient production lines and product variety selected with the results of the standard DEA model. Here, the product variations were under concern rather than production lines itself and production lines are utilized or bypassed according to the product mix.

2.3 Literature Review on FMCG Industry

Various studies have been performed regarding the dynamics of the FMCG (Fast Moving Consumer Goods) Industry. The common attribute of these studies were they all focus on improving efficiency of the companies in the industry. Lakmal *et al.* (2011) for example worked on enhancing the effectiveness and efficiency of warehouse operations in FMCG sector in Sri Lanka. The study focused on eliminating the inefficiencies and ineffective logistics operations since warehouse operations are one of the main contributors to the supply chain of the industry. The relation between factors affecting warehouse efficiency/effectiveness and the overall performance of the warehouse operation has been investigated and the hypothesis was tested by the regression analysis. With the financial point of view Paswan (2013) analyzed the solvency of selected FMCG companies. The study concentrates on the various accounting ratios to analyse the financial performance in terms of solvency of the selected companies. Statistical analysis has been performed on the collected data from the annual financial reports of the FMCG companies. Hezekiah *et al.* (2016) studied the marketing operations and investigated the advertising media efficiency of the Indian FMCG firms. The urge for advertising is simply because of the need to sell and so it is necessary that the prospective buyers be informed. 17 companies were participated in the study and advertising spending efficiency of these companies were investigated with the utilization of Data Envelopment Analysis. Again for the marketing operations Testa *et al.* (2016) studied the marketing performance measurements of the FMCG companies. Marketing performance measurements (MPM) have been considered a priority in marketing research and managerial practices. The author also proposed a model for MPM and tested the model on the leading FMCG Company.

From the past literature, various versions of efficiency methodologies have been widely utilized for the variety of study areas, however, to the best our knowledge Data Envelopment Analysis has not been used to evaluate production line efficiency of FMCG manufacturing operations with the combination of operational and quality aspects of the process.

Chapter 3

METHODOLOGY

3.1 Standard DEA Models (CCR and BCC Models)

As mentioned before Data Envelopment Analysis (DEA) is a technique, originally proposed by Charnes, Cooper and Rhodes (1978), used for evaluating relative efficiency of decision making unit's (DMUs). Definition of DMU as done by Tone (2007) as generically a DMU is regarded as the entity responsible for converting inputs into outputs and whose performances are to be evaluated. There are two main DEA models that are commonly used by analyzers. Standard CCR model is the most basic DEA model and originally proposed by Charnes, Cooper and Rhodes (1978). Secondly, Standard BCC model is proposed by Banker, Charnes and Cooper (1984) which is a variation of CCR model. The former model is built on the assumption of constant returns to scale of activities which will be illustrated in next sections. On the other hand, the BCC model has its production frontiers spanned by the convex hull of the DMUs. This piecewise linear and concave characteristic of the frontiers, leads to variable return to scale of activities (Tone, 2007).

3.1.1 CCR Models in Economical View of Point

Regarding to the formulation (1.1) and following assumptions, efficiency can be calculated under the structure mentioned in Figure 3.1.

k= the DMU being evaluated in the set of $j= 1,2,\dots,n$ DMUs

θ_k= the measure of efficiency of DMU k, the DMU in the set of $j= 1,2\dots,n$ rated relative to the others

y_{rk}= the amount of output r produced by DMU k

x_{ik}= the amount of resource input i used by DMU k

y_{rj}= the amount of service output r produced by DMU j

x_{ij}= the amount of service input i used by DMU j

u_{rk}= the weight assigned to service output r computed in the solution of the DEA model

v_{ik}= the weight assigned to resource input i computed in the solution of the DEA model

m= number of inputs used by the DMUs

s= number of outputs produced by the DMUs

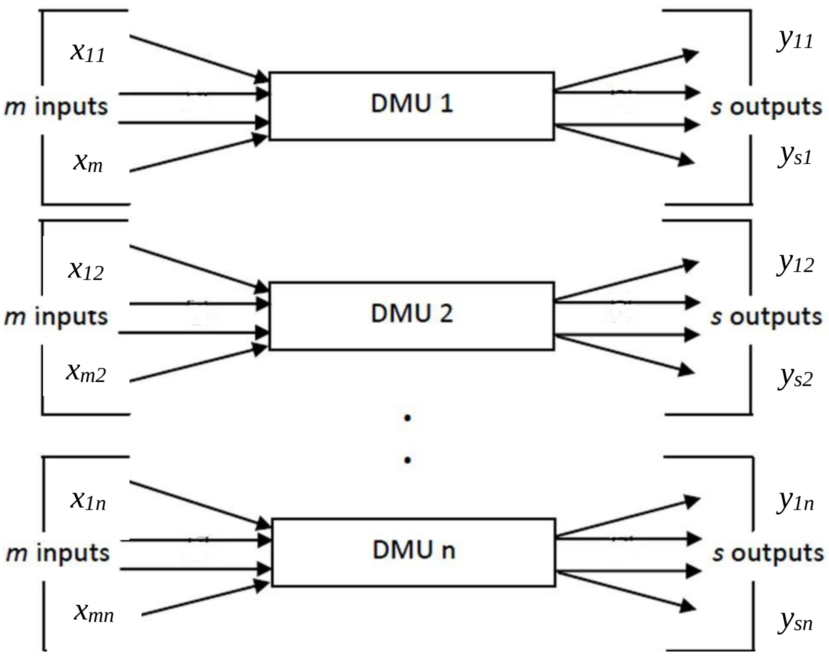

Figure 3.1: Efficiency evaluation structure regarding n homogenous DMUs

In equation 3.1, virtual input and output values are calculated for every single DMU by utilizing unknown weights v_i and υ_r. The weights are then determined by utilizing linear programming to maximize the ratio illustrated in equation 3.3. Hence, in DEA approach weights are not designated in advance and they are calculated directly from data itself. Each DMU has different weights for each input and output values. This enables researcher to analyze the degree of effect of each input and output values on specific DMU under concern. It can be interpreted that which values should be enhanced to obtain an increase in efficiency of the DMUs.

$$VirtualInput = v_1 x_{10} + ... + v_m x_{m0} \qquad (3.1)$$

$$VirtualOutput = u_1 y_{10} + ... + u_s y_{s0}$$

$$Efficiency = \frac{VirtualOutput}{VirtualInput} \qquad (3.2)$$

The fractional form of CCR model (Charnes, Cooper and Rhodes (1978)Önüt, Soner 2006):

$$Max \frac{\sum_{r=1}^{s} u_{rk} y_{rk}}{\sum_{i=1}^{m} v_{ik} x_{ik}} \tag{3.3}$$

Subject to:

$$\frac{\sum_{r=1}^{s} u_{rk} y_{rj}}{\sum_{i=1}^{m} v_{ik} x_{ij}} \leq 1; \qquad j = 1,2,...,n \tag{3.4}$$

$$u_{rk}, v_{ik} \geq 0; \qquad r = 1,2,...,s; \quad i = 1,2,...,m \tag{3.5}$$

Since it is rather difficult to solve the fractional objective function, the model should be converted to linear form. The denominator is forced to be equal to one, hence the fractional formula became linear and solving this linear programming model is much easier. The mathematical interpretation of the model will be discussed in the next chapter.

3.1.2 CCR and BCC Models in Mathematical Point of View

The main purpose of the technical efficiency is that evaluation of a DMU is important to test whether the DMU is on the surface; meaning the production frontier or not of the production possibility set. The production possibility set "PPS" has the following properties which make it easier to understand its importance in data envelopment analysis:

1- "PPS" is the set including observed activities (X_j,Y_j) where $j= 1,2,3,...,n$ and "*m*" inputs and "*s*" outputs case. Semi-positive "*n*" DMUs are under concern meaning all the data assumed to be non-negative but at least one component of every input and every output vector is positive.
2- If an activity (X, Y) belongs to PPS then the activity (tX, tY) also belongs to PPS for any positive scalar t. This property is called constant returns to scale assumption.
3- For any activity (X,Y) in PPS with input no less than x in any component and any activity with output no greater than y in any component is feasible.
4- Any semi positive linear combination of activities in PPS belongs to PPS.
5- "λ" a semi-positive linear vector in R^n is also defined as follow after arranging data sets in matrices:

$X = (x_j)$ and $Y = (y_j)$

$$PPS_C = \left\{ (X,Y) \middle| X \geq \sum_{j=1}^{n} \lambda_j X_j, Y \leq \sum_{j=1}^{n} \lambda_j Y_j, \lambda_j \geq 0, j = 1,2,...,n \right\} \quad (3.6)$$

$X_j \geq 0$, $X_j \neq 0$ $x \in R^m$, $j=1,2,\ldots,n$

$Y_j \geq 0$, $Y_j \neq 0$ $x \in R^s$, $j=1,2,...,n$

Now, for input orientation CCR Model we try to find θ_k in a manner that

$$Min\ \theta_k \tag{3.7}$$

$$s.t.\ (\theta_k X_k, Y_k) \in PPS_C.$$

$$PPS_C = \left\{ (X, Y) \middle| X \geq \sum_{j=1}^{n} \lambda_j X_j, Y \leq \sum_{j=1}^{n} \lambda_j Y_j, \lambda_j \geq 0, j = 1,2,...,n \right\} \tag{3.8}$$

The primal form of CCR model is the following (Charnes, Cooper and Rhodes (1978) Önüt, Soner 2006):

$$Min \quad \theta_k \tag{3.9}$$

Subject to:

$$\sum_{j=1}^{n} x_{ij}\lambda_j \leq \theta_k x_{ik} \qquad i = 1,2,...,m \tag{3.10}$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j \geq y_{rk} \qquad r = 1,2,...,s; \tag{3.11}$$

$$\lambda_j \geq 0 \ , \forall i,j,r \tag{3.12}$$

θ_k= Measure of the efficiency of the DMU_k in the set of j=1,2,…,n

λ_j= Weight assigned to the *DMUs*

The dual form of CCR model becomes the following (Charnes, Cooper and Rhodes (1978) Önüt, Soner 2006):

$$Max \sum_{r=1}^{s} u_{rk} y_{rk} \tag{3.13}$$

Subject to:

$$\sum_{i=1}^{m} v_{ik} x_{ik} = 1 \tag{3.14}$$

$$\sum_{r=1}^{s} u_{rk} y_{rj} - \sum_{i=1}^{m} v_{ik} x_{ij} \leq 0 \, ; \qquad j = 1,2,...,n \qquad (3.15)$$

$$u_{rk}, v_{ik} \geq 0 \qquad r = 1,2,...s; \quad i = 1,2,...,m \qquad (3.16)$$

When some of the ν_{ik} and υ_{rk} are zero, it seems that the related inputs and outputs have not any effect on efficiency of the DMU under evaluation. Therefore infinitesimal positive number ε is introduced, which constraints the input and output coefficients to be positive, hence eliminating the possibility that they will be given a zero relative value in DEA results. So, the constraint (3.16) will be in the following form.

$$u_{rk}, v_{ik} \geq \varepsilon \qquad r = 1,2,...,s; \quad i = 1,2,...,m \qquad (3.17)$$

From the economic interpretation of the model, the BCC model assumed production possibility sets as convex combination of the observed DMUs. Hence, BCC score is named as local pure technical efficiency. On the contrary the constant returns to scale assumption (without convexity condition) where, $\sum_{j=1}^{n} \lambda j \ = 1$ meaning expansion and reduction of all observed DMUs and their non-negative combinations are possible. CCR score is named as global technical efficiency. If the comparison between CCR and BCC efficiencies were performed, a much more detailed analysis regarding the sources of inefficiencies can be obtained (Luptacik, 2000). In Figure3 production frontiers drawn by production possibility sets with CCR and BCC models having economic interpretation point of view. In the above graph where CCR model is the case, production frontier forms a linear line passing from the origin and efficient frontier. On the contrary in the below graph where BCC model is the case, the frontiers have piecewise and concave characteristics. This characterization consists of increasing returns to scale in the initial parts, decreasing returns to scale in the middle parts and finally constant returns to scale in the end of the graph. Production possibility set for BCC model is defined by

$$PPS_B = \left\{ (X,Y) \middle| X \geq \sum_{j=1}^{n} \lambda_j X_j, Y \leq \sum_{j=1}^{n} \lambda_j Y_j, e\lambda = 1, \lambda_j \geq 0, j = 1,2,...,n \right\} \quad (3.18)$$

Where "*e*" is a row vector with all elements unity and "λ" is a column vector with all the elements non-negative. $e\lambda = 1$ condition given to differentiate BCC model from former with the interpretation of the convexity condition $\sum_{j=1}^{n} \lambda j = 1$, where $\lambda_j \geq 0$ for all j.

Now, for input orientation BCC Model we try to find θ_k in a manner that

$$Min\ \theta_k \quad (3.19)$$

$$s.t.\ (\theta_k X,Y) \epsilon\ PPS_B.$$

$$PPS_B = \left\{ (X,Y) \middle| X \geq \sum_{j=1}^{n} \lambda_j X_j, Y \leq \sum_{j=1}^{n} \lambda_j Y_j, \sum_{j=1}^{n} \lambda_j = 1, \lambda_j \geq 0, j = 1,2,...,n \right\} \quad (3.20)$$

The BCC equation is the same as the one used for CCR model but a convexity constraint is added. Hence, primal form of BCC model (Banker (1984),Liu, Lin, Lewis 2009):

$$\text{Min} \quad \theta_k \quad (3.9)$$

Subject to:

$$\sum_{j=1}^{n} x_{ij} \lambda_j \leq \theta_k x_{ik} \qquad i = 1,2,...,m \quad (3.10)$$

$$\sum_{j=1}^{n} y_{rj} \lambda_j \geq y_{rk} \qquad r = 1,2,...,s; \quad (3.11)$$

$$\sum_{j=1}^{n}\lambda_j = 1 \qquad \text{* (convexity constraint)} \tag{3.21}$$

$$\lambda_j \geq 0 \ , \forall i,j,r \tag{3.12}$$

The dual form of BCC model becomes the following (Charnes, Cooper and Rhodes (1978) Önüt, Soner 2006):

$$Max \sum_{r=1}^{s} u_{rk} y_{rk} + u_0 \tag{3.22}$$

Subject to:

$$\sum_{i=1}^{m} v_{ik} x_{ik} = 1 \tag{3.23}$$

$$\sum_{r=1}^{s} u_{rk} y_{rj} - \sum_{i=1}^{m} v_{ik} x_{ij} + u_o \leq 0 \ ; \quad j = 1,2,...,n \tag{3.24}$$

$$u_{rk}, v_{ik} \geq 0 \ , \ u_0 \ \mathit{free}, \quad r = 1,2,...s; \quad i = 1,2,...,m \tag{3.25}$$

In Table 3.1, the difference between the two model's both with envelopment side and multiplier side can be seen. As mentioned before, in BCC model $e \lambda = 1$ constraint and u_0 variable was introduced.

Table 3.1 Primal and Dual Correspondences (Tone 2007)

Model	Multiplier form constraints	Envelopment form variables	Envelopment form constraints	Multiplier form variables
CCR	$vx_0 = 1$ $-vX + uY \leq 0$	θ $\lambda \geq 0$	$\theta x_0 - X\lambda \geq 0$ $Y\lambda \geq y_o$	$v \geq 0$ $u \geq 0$
BCC	$vx_0 = 1$ $-vX + uY - u_0 e \leq 0$	θ $\lambda \geq 0$	$\theta x_0 - X\lambda \geq 0$ $Y\lambda \geq y_o$ $e\lambda = 1$	$v \geq 0$ $u \geq 0$ u_0

The scale efficiency values are then calculated after obtaining BCC and CCR efficiencies. The scale efficiency is calculated by the following formula (3.26).

$$SE = \frac{\theta_{CCR}}{\theta_{BCC}} \qquad (3.26)$$

When scale efficiency is one, it is the best situation where is the most productive scale size occurs. Here, a DMU is BCC efficient in a constant return to scale environment θ_{CCR} is defined as technical (global) efficiency since it takes no account of scale. . In other words, if *(X, Y)* is a feasible point then *(tX, tY)* for any positive t is also feasible. On the other hand θ_{BCC} is defined as pure (local) technical efficiency since it works under variable return to scale (RTS) environment. Variable return to scale environment can be identified in standard BCC model by the following theorem proposed by Banker and Thrall (1992).

Theorem: When (X_0, Y_0) are the coordinates of the point on the efficiency frontier then,

(i) Increasing RTS at (X_0, Y_0), IFF $u_0^* < 0$

(ii) Decreasing RTS at (X_0, Y_0), IFF $u_0^* > 0$

(iii) Constant RTS at (X_0, Y_0), IFF $u_0^* = 0$

All of the behavior of the variable and constant return to scale behavior can be seen in Figure 3.2.

Scale efficiency formula helps us to investigate the sources of inefficiencies.

$$\theta_{CCR} = \theta_{BCC} * SE \qquad (3.27)$$

The inefficiency of a DMU might be stemmed from inefficient operation or it might be stemmed from its failure to achieve scale efficiency or both cases.

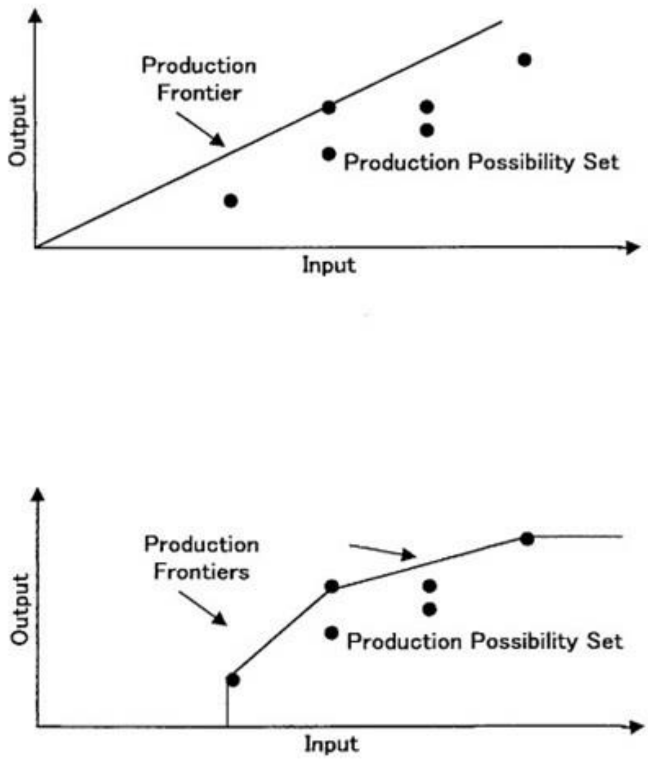

Figure 3.2: Production Frontiers of the CCR (above) and BCC (below) models. (Tone,2007) in two dimensional *m = 1* and *s = 1* (single input and single output) case

DEA models can either be input oriented or output oriented. Input oriented DEA model was chosen for this study. In this model the objective is to minimize inputs while producing at least the given output values. In FMCG industry, demand is in the market. Serious marketing activities have been performed by companies to increase the market share of their products. Companies cannot increase their production rates and sales with a sole purpose of increasing operational efficiency, when there is not enough demand in the market. That is why input oriented model is utilized where focus is given to decreasing inputs to acquire a certain level of output. Keep increasing the output for efficiency purposes is not logical in FMCG industry since it creates surplus and food products certainly have shelf life which makes them perishable goods.

3.2. AHP (Analytic Hierarchy Process) Analysis

3.2.1 AHP (Analytic Hierarchy Process) Analysis Methodology

In order to interpret the effect of indirect labor wages (laboratory technicians, maintenance workers, syrup making workers, management and seasonal workers) to the calculation of the total annual labor wages, AHP (Analytic Hierarchy Process) was utilized. AHP is a very useful decision making methodology where pairwise comparison taken place by enabling judgments of the experts. It helps decision makers to choose between alternatives or decide on which one is prior to other. Firstly, the alternatives selected that are desired to be compared with AHP. Then, objectives were defined that would guide while comparing these alternatives, here indirect labor force is under concern. In this study the objective of comparison was chosen as maintenance hours, working hours and produced quantity, since these three aspects are the most important for the management (decision makers). Now step by step the methodology of AHP analysis will be described.

<u>Step 1:</u> The alternatives of comparison are chosen. Here, production lines (Pet-6, Pet-2, Can, Glass Bottle and Premix) will be weighted in terms of indirect labor force contribution.

<u>Step 2:</u> The objective of comparison will be chosen which will guide the decision making process. In this study the objectives were chosen as maintenance hours, working hours and produced quantity while these aspects are the most important factors affected by indirect labors. Hence, indirect labor cost in the production lines will be compared while considering these certain objectives.

<u>Step 3:</u> First of all weight of the objectives should be assigned as in formula 3.28 in order to determine the order of importance and make the AHP analysis accordingly. The comparison performed by the use of Table 3.2 as the scale and eventually how much one sample dominates the other one is scored. In this study the scores were given after a brain storming activity where the factory manager and the engineers were attended.

$$\sum_{i=1}^{n} w_i = 1 \quad \text{(the alternative } j\text{'s score on objective } i\text{)} \qquad (3.28)$$

As in formula 3.28 "*j*" many alternatives will be compared while considering "*i*" many objectives with the guidance of the Table 3.2 having a scale of 1-9.

Table 3.2 AHP (Analysis Hierarchy Process) Comparison Scale

SCALE	VERBAL EXPRESSION	EXPLANATION
1	Equal importance	Two activities contribute equal to the objective
3	Moderate importance	Experience and judgement slightly favour one activity over another
5	Strong importance	Experience and judgement strongly favour one activity over another
7	Very strong importance	An activity is favoured very strongly over another
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Values 2, 4, 6 and 8 are compromises between the previous definitions.		

Step 4: A pairwise comparison matrix "*A*" (*nxn* matrix) will be formed after obtaining weight for objectives. The matrix will be in the following form:

$$A = \begin{pmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots\cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots\cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots\cdots & \frac{w_n}{w_n} \end{pmatrix}$$

Step 5: After forming an *nxn* matrix for the objectives, all the alternatives were pairwisely compared while considering 3 objectives separately. Eventually, three separate *nxn* matrix were formed for production lines in sequence for maintenance hours, production hours and production quantity (Appendix A).

Step 6: In order be precise on the decimal values, the eigenvectors and eigenvalues must be computed. Before explaining eigenvalues, eigenvectors should be defined. Almost all vectors change direction when they are multiplied with *A*. Certain exceptional vectors "*x*" are in the same direction as "*Ax*" which is called eigenvectors. Multiply an eigenvector by *A*, and the vector *Ax* is a number of λ times the original *x*.

The basic equation $Ax = \lambda x$ = The number λ is an eigenvalue of *A*.

The eigenvalue λ tells whether the special vector *x* stretched or shrunk or reversed or left unchanged when it is multiplied by *A*.

Step 7: Matrix multiplication is performed to the *nxn* matrices, hence for example objectives weight pairwise comparison matrix was multiplied by itself several times until the average of the summed rows have the same decimal values and the results can be seen in Table 3.3.

Table 3.3: Objectives' Pairwise Comparison Matrix

	Maintenance Hours	Working Hours	Produced Quantity
Maintenance Hours	1	0.25	0.33
Working Hours	4	1	1.33
Produced Quantity	3	0.75	1

			Summed Rows	
2.99	0.7475	0.9925	4.73	0.124686965
11.99	2.9975	3.98	18.9675	0.5
9	2.25	2.9875	14.2375	0.375313035
		Total:	37.935	1

			Summed Rows	
26.835125	6.70878125	8.90771875	42.451625	0.124686803
107.610125	26.90253125	35.720375	170.2330313	0.5
80.775	20.19375	26.81265625	127.7814063	0.375313197
		Total:	340.4660625	1

			Summed Rows	
2161.577705	540.3944262	717.519529	3419.49166	0.124686803
8668.029197	2167.007299	2877.287369	13712.32386	0.5
6506.451492	1626.612873	2159.76784	10292.83221	0.375313197
		Total:	27424.64773	1

			Summed Rows	
14025078.85	3506269.712	4655519.876	22186868.44	0.124686803
56241231.89	14060307.97	18668855.68	88970395.54	0.5
42216153.04	10554038.26	14013335.81	66783527.11	0.375313197
		Total:	177940791.1	1

Step 8: The same methodology applied to the all *nxn* matrices again until the decimal values resulted the same for the last two matrix multiplications.

Table 3.4 Pairwise Comparison Matrix for Production Lines for Maintenance Hours

	PET-6	PET-2	CAN	GLASS BOTTLE	PREMIX
PET-6	1	5	3	7	6
PET-2	0.2	1	0.33	3	5
CAN	0.33	3	1	5	7
GLASS BOTTLE	0.14	0.33	0.2	1	0.5
PREMIX	0.17	0.2	0.14	2	1

					Summed Rows	
4.99	22.51	9.89	56	61.5	154.89	0.491609721
1.7789	4.98	2.56	19.05	15.01	43.3789	0.137681509
3.15	10.7	4.96	35.31	33.48	87.6	0.2780361
0.497	2.06	0.9989	4.97	4.89	13.4159	0.042581102
0.7062	2.33	1.256	6.49	5	15.7822	0.050091568
				Total:	315.067	1

					Summed Rows	
167.359939	588.9027	289.2135	1734.9264	1557.2173	4337.619839	0.49186524
45.867545	166.451739	80.921326	476.9744	438.06545	1208.28046	0.137013196
91.569376	328.0115	160.469139	948.1485	860.4587	2388.657215	0.270862247
15.214507	53.7664	26.249847	158.783159	143.682572	397.696485	0.04509687
18.381705	65.958562	31.941739	192.98836	177.19158	486.461946	0.055162446
				Total:	8818.715945	1

					Summed Rows	
136524.3289	487440.513	237749.1635	1421467.942	1292654.472	3575836.419	0.491871166
38030.35771	135800.1916	66233.46146	395972.5017	360126.3673	996162.8797	0.137026346
75306.49632	268892.4104	131149.8701	784076.3171	713059.4402	1972484.534	0.271323448
12473.05198	44533.92139	21720.88439	129871.1548	118106.1196	326705.1322	0.044939649

15219.90955	54344.80195	26505.07702	158476.1766	144128.9433	398674.9085	0.054839391
				Total:	7269863.874	1

					Summed Rows	
92484613638	3.30224E+11	1.61062E+11	9.62954E+11	8.75741E+11	2.42247E+12	0.49187153
25764485182	91994108571	44868762388	2.68261E+11	2.43965E+11	6.74854E+11	0.137026217
51016205479	1.82157E+11	88844546454	5.31183E+11	4.83075E+11	1.33628E+12	0.271325338
8449693835	30170292349	14715112743	87978605950	80010555779	2.21324E+11	0.044938976
10310955750	36816073555	17956493973	1.07358E+11	97634934210	2.70077E+11	0.054837939
				Total:	4.925E+12	1

					Summed Rows	
4.24446E+22	1.51552E+23	7.39171E+22	4.41935E+23	4.0191E+23	1.11176E+24	0.49187153
1.18243E+22	4.22195E+22	2.05919E+22	1.23115E+23	1.11965E+23	3.09715E+23	0.137026217
2.34132E+22	8.35987E+22	4.0774E+22	2.43779E+23	2.21701E+23	6.13266E+23	0.271325338
3.87788E+21	1.38463E+22	6.75331E+21	4.03766E+22	3.67198E+22	1.01574E+23	0.044938976
4.73208E+21	1.68963E+22	8.2409E+21	4.92706E+22	4.48083E+22	1.23948E+23	0.054837939
				Total:	2.26026E+24	1

For the indirect labors (laboratory technicians, maintenance workers, syrup making workers, management and seasonal workers), 3 factors were selected as the means of comparison, namely, maintenance hours, working hours and produced quantity. Then, these 3 factors were scored using AHP method and the order of importance hence, their weights were decided. Then according to the each factor, the production lines were scored again using the AHP scale. For example, can line is compared by the management with the glass bottle production line in terms of their requirement of the maintenance hours or they can be compared for the hours they work respectively. The comparison scores obtained in Step 5 are multiplied by the weights given for the factors themselves in Step 4 where important factor included in the calculation more than the other. The AHP analysis comparison tables are shown in detail in the appendix A section along with their eigenvalues and eigenvectors.

3.2.2. AHP (Analytic Hierarchy Process) Consistency Analysis

Decision maker's comparison should be checked in terms of its consistency for the accuracy of the judgment. Following are the steps for checking consistency of the AHP. Our first comparison matrix is the following:

Table 3.5: Weights of the Production Lines with Respect to Comparison Factors

	Maintenance Hours	Working Hours	Produced Quantity
Pet-6	0.49187153	0.43298666	0.498763319
Pet-2	0.137026217	0.049727945	0.100505063
Can	0.271325338	0.283874177	0.319015177
Glass	0.044938976	0.029387005	0.033455443
Premix	0.054837939	0.204024212	0.048260999

Our second comparison matrix is the following:

Table 3.6: Weights of the Comparison Factors

	Weights
Maintenance Hours	0.124686803
Working Hours	0.500000000
Produced Quantitiy	0.375313197

Step 1: Aw^T is the product of these matrices where "w" denotes the estimate of the decision maker's weights.

$$\begin{pmatrix} 1 & 0,25 & 0,33 \\ 4 & 1 & 1,33 \\ 3 & 0,75 & 1 \end{pmatrix} \begin{pmatrix} 0,124686803 \\ 0,500000000 \\ 0,375313197 \end{pmatrix} = \begin{pmatrix} 0,37354015801 \\ 1,49791376401 \\ 1,124373606 \end{pmatrix}$$

Step 2: Then the following formula is computed for the calculation of the consistency index CI.

$$\frac{1}{n}\sum_{i=1}^{n}\frac{Aw_i^T}{w_i^T} \qquad (3.29)$$

$$= \frac{1}{3}\left\{\frac{0,37354015801}{0,124686803}+\frac{1,49791376401}{0,500000000}+\frac{1,124373606}{0,375313197}\right\} = 2,9958$$

Step 3: Consistency index *(CI)* then calculated:

$$CI = \frac{2,9958-n}{1-n} = \frac{2,9958-3}{1-3} = 0,0021$$

Step 4: In the next step CI is compared to random index *(RI)* derived from Table 3.7. In this study we have n=3 and therefore RI becomes 0,58

Table 3.7: Random Index Reference: (Wayne L. Winston ,1994)

n	RI
2	0
3	0,58
4	0,90
5	1,12
6	1,24
7	1,32
8	1,41
9	1,45
10	1,51

If *CI* is sufficiently small, the decision maker's comparisons are probably consistent enough to derive useful estimates of the weights for the objective function under concern.

If $\frac{CI}{RI} \leq 0{,}10$ then it can be concluded that the degree of consistency is satisfactory.

If $\frac{CI}{RI} \geq 0{,}10$ then it can be concluded that serious inconsistencies might exists and AHP may not yield meaningful results. (Wayne L. Winston ,1994)

In our study, $\frac{CI}{RI} = \frac{0{,}0021}{0{,}58} = 0{,}0036$ meaning the degree of consistency is satisfactory, in other words AHP will definitely yield meaningful results.

Chapter 4

DATA COLLECTION

4.1 Defining the Input/ Output Variables and Factors

Ektam Kıbrıs Ltd. founded in 1981 and a soft drink manufacturer located in Cyprus was investigated for efficiency utilizing Data Envelopment Analysis. The factory has 5 production lines: Pet-6, Pet-2, Can, Glass Bottle and Premix lines. Data regarding the production lines was collected from 2010 to 2015 and every yearly data for a production line is designated as a DMU obtaining 30 different DMUs. Hence, inefficient and efficient production lines are determined thorough the history of the factory. By this way management can see and identify the precautions and measures that made a production line efficient or inefficient. The yearly trend of the efficiency values also calculated for each production line, this helps management to decide on the future operational and budget planning of the production lines.

For the DEA study, 5 input and 2 output variables are used in the model and their definition is can be seen in Table 6.

Input Variables:

1- Electricity consumption (Operational Factor),
2- Fuel consumption (Operational Factor),
3- Direct and indirect labor wages (Quality + Operational Factor). The management, quality, laboratory and maintenance workers were also taken

into consideration indirectly along with direct labors working in each production line.

4- Number of labors directly involved in the production line (Operational Factor),

5- Number of defected materials separated by the quality assurance (QA) personnel in the production lines (Quality Factor)

Output Variables:

1- Production SKU (Stock Keeping Unit) (Quality), number of the products produced with the approval of the quality assurance department (Quality + Operational Factor).

2- Income contribution of the each production line (Operational Factor)

In the further parts of this chapter data collection procedure will be explained. Raw data for Input 1, 2, 4 and 5 was directly used for the study. However, for the Input 3 further analysis need to be performed in order to combine direct and indirect labor costs. For the Output values, Output 1 is directly used in the efficiency analysis however Output 2 was calculated by multiplication of the sold quantity and price of the products and the resulting value is then used as Output 2.

4.2 Incorporating AHP Results with the Labor Costs

Wages of the labors directly involved in the production lines are added as direct labor cost. However, laboratory technicians, maintenance workers, syrup making workers, seasonal workers and white collar managers are designated as indirect labor cost since they are not directly linked to a specific production line and their cost should be distributed to the all production lines. Analytic Hierarchy Process (AHP) was utilized to decide on the weight of these indirect labor cost to the production lines respectively. AHP is a multi-criteria decision making method originally developed by Thomas L. Saaty in the 1970s. The advantage of this method for decision maker is that it not only uses quantified data but also allows user to make decisions by subjective opinions. In other words it is a method based on both mathematics and psychology. Maintenance hours of the production lines, working hours of the production lines and produced quantities are the major factors effecting the weight of the indirect labor cost (laboratory technicians, maintenance workers, syrup making workers, seasonal workers and white collar managers) in the Ektam Kıbrıs Ltd. soft drink factory. The production lines are compared according to these three aspects and the ratio scales are derived from the principal eigen vectors and the consistency index is derived from the principal eigen value. The comparison is performed using a 1-9 scale described in Table 3.2.

Table 3.5 interprets the comparison matrix of production lines and comparison objectives namely maintenance hours, working hours and produced quantities. Then, in Table 3.6 the importance of these comparison aspects are again weighted utilizing AHP methodology. Finally, in Table 4.1 with the matrix multiplication of the both, weights for the each production lines' acquired for the calculation of the indirect labor cost.

Table 3.5: Weights of the Production Lines with Respect to Comparison Factors

	Maintenance Hours	**Working Hours**	**Produced Quantity**
Pet-6	0.49187153	0.43298666	0.498763319
Pet-2	0.137026217	0.049727945	0.100505063
Can	0.271325338	0.283874177	0.319015177
Glass Bottle	0.044938976	0.029387005	0.033455443
Premix	0.054837939	0.204024212	0.048260999

Table 3.6: Weights of the Comparison Factors

	Weights
Maintenance Hours	0.124686803
Working Hours	0.500000000
Produced Quantitiy	0.375313197

$$\begin{pmatrix} 049187153 & 0{,}43298666 & 0{,}498763319 \\ 0{,}137026217 & 0{,}49727945 & 0{,}100505063 \\ 0271325338 & 0{,}283874177 & 0{,}319015177 \\ 0{,}044938976 & 0{,}029387005 & 0{,}033455443 \\ 0{,}054837939 & 0{,}20424212 & 0{,}048260999 \end{pmatrix} \begin{pmatrix} 0{,}124686803 \\ 0{,}500000000 \\ 0{,}375313197 \end{pmatrix} = \begin{pmatrix} 0{,}465015674 \\ 0{,}07967021 \\ 0{,}295498383 \\ 0{,}032853069 \\ 0{,}126962663 \end{pmatrix}$$

Above, pairwise comparison scores of the DMUs were multiplied by the weight of the factors, and then Table 4.1 is obtained.

Table 4.1: Weight for each Production of the Lines for Indirect Labor Cost Calculation

Production Line	Score
Pet-6	0.465015674
Pet-2	0.07967021
Can	0.295498383
Glass Bottle	0.032853069
Premix	0.126962663

Therefore, for calculation of total the labor wages, direct labor cost is added directly and indirect labor costs are multiplied with weight calculated in Table 4.1 and then added to the direct labor cost. The detailed comparisons for AHP analysis can be seen in the Appendix A section.

4.3 Data Collection Procedure

Input and output data collection was performed with a certain procedure and identify the sourced of inefficiencies in order to prevent any future deficiencies. Firstly, input 1 and input 2 were recorded by examining yearly energy (electricity and fuel) consumption reports of the factory production lines separately under the supervision of the production engineer. Secondly, records regarding the labor wages for different worker types were inquired from the Human Resource Specialist of the company. Then, factory workers were categorized as direct workers whom are directly involved in the production lines and indirect workers whom are general purpose workers whose wages' distribution need to be further studied. Then, with the utilization of the AHP following formulation is used for the total labor cost calculation:

$TLC_{ik} = DLW_{ik} + (IDLW_{ik} * W_i)$ (4.1)

Where,

TLC_i = Total labor cost of the production line i at year k.

DLW_{ik} = Direct labor's wages working on production line i at year k.

$IDLW_{ik}$ = Indirect Labor's Wages working on production line i at year k.

W_i = Weight of Production line i

i=Pet-6, Pet-2, Can, Glass Bottle, Premix k=2010, 2011, 2012, 2013, 2015

Hence, Input 3 column was filled after repeating this calculation for every production line and yearly data on labor wages. The detailed information regarding the labor wages calculation for Ektam Kıbrıs Ltd. Company can be seen in Appendix C. In addition Input 4 was easily filled after the counting the total number of labor directly involved in the previous calculation. For the number of defected materials information (Input 5) the Quality Assurance Department's annual reports were examined and summation of the all the defected raw material and defected finished good were taken into consideration. For the data of the Output 1, again the records from Quality Assurance Department were investigated and eventually summation of the all the products that had confirmation from the QA were recorded. Finally for the Output 2, Sales Department of the company assisted while providing yearly sales data and yearly price changes. In order to fill the column for the output 2, the yearly prices of the each SKU is multiplied by its quantity of sales and the result is recoded. Repeating this calculation for every SKU is added and the final value is recorded in the column of the Output 2. . The detailed information regarding the income contribution of the each SKU calculation for Ektam Kıbrıs Ltd. Company can be seen in Appendix D.

Table 4.2: Definition of input/output variables

Variable	Unit	Define
<u>Inputs:</u>		
1- Electricity Consumption	KWh	Electricity consumption of the equipments in each production line
2- Fuel Consumption	Liter	Fuel consumption of the equipments in each production line
3- Labor Wages	Turkish Lira	Direct and indirect labor wages for each production line
4- Number of Labors Directly Involved	Numeral	Number of labors working directly in the production line
5-Number of Defected Materials	Numeral	Total number of defected materials that are collected in each production line
<u>Outputs:</u>		
1- Production	SKU	Total produced SKU of each production line
2-Income Contribution	Turkish Lira	Total income coming from the sales of the products produced in each production line

4.4 Correlation between Input and Output Data

Statistical correlation is a notion that tells us if the two variables are related or not. It is interpreted by the calculation of correlation coefficient (*r*) which describes the strength of the relationship between the variables. Correlation coefficient ranges from *+1.0* to *-1.0*. If the correlation coefficient is close to *+1.0*, then there is a strong positive linear relationship between *x* and *y*. In other words, if *x* increases, *y* also increases. On the other hand if the correlation coefficient is close to *-1.0*, then there is a strong negative linear relationship between *x* and *y*. In other words, if *x* increases, *y* will decrease. Less of a linear relationship between *x* and *y* exists when the correlation coefficient gets closer to zero. The effect of the changes in the correlation coefficient value is described in the Table 4.3.

Table 4.3: Correlation Relationship

Value of r	Strength of Relationship
1.0 – 0.5	Strong
0.5 – 0.3	Moderate
0.3 – 0.1	Weak
0.1 – 0.1	None or very weak

The correlation between the input and output values are also important for efficiency to make sense. Hence, correlation coefficient between each variable is calculated by formula (4.5).

$$S_{xx} = \sum x^2 - \frac{\left(\sum x\right)^2}{n} \qquad (4.2)$$

$$S_{yy} = \sum y^2 - \frac{\left(\sum y\right)^2}{n} \quad (4.3)$$

$$S_{xy} = \sum xy - \frac{\left(\sum x\right)\left(\sum y\right)}{n} \quad (4.4)$$

$$r = \frac{S_{xy}}{\sqrt{S_{xx} S_{yy}}} \quad (4.5)$$

As seen in the Figure 4.1 there is a trend between the DMUs and input/output values. Meaning that when one input starts to increases, the others also follow a similar behavior and similarly when the value of an output falls the other variables also seem to be fell. So, the data chosen for input and output values are consistent.

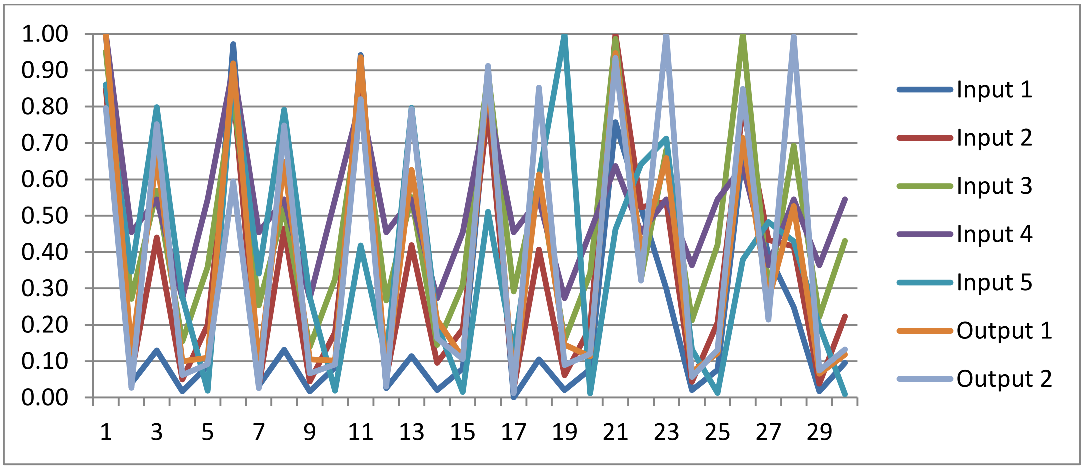

Figure 4.1 DMUs vs Input/Output Values

The correlation coefficient results between input and output variables are shown in Table 4.4 and most of the values are higher than the 0.5 meaning there is a strong positive correlation between the input and output variables. Only input 5 (number of defected materials) showed a moderate correlation with other input variables, but again it is strongly correlated with both of the output variables.

Table 4.4: Correlation Matrix of Inputs and Outputs

	Input 1	Input 2	Input 3	Input 4	Input 5	Output 1	Output 2
Input 1	1	0.923422	0.832631	0.832666	0.448815	0.845838	0.641324
Input 2		1	0.933665	0.812780	0.532602	0.947772	0.839578
Input 3			1	0.867604	0.435619	0.916049	0.876384
Input 4				1	0.348341	0.797874	0.645821
Input 5					1	0.678919	0.61896
Output 1						1	0.919563
Output 2							1

4.5 Collected Data

The input and output data summarized in Table 4.5 were collected from the year of 2010 to the 2015. Totally 30 different values were recorded for each of the input/ output value showing the situation of the data in the designated year and each and every one of it denoted as a DMU. The collected input and output data were in different scales as can be seen in Table 4.5 that might be difficult to take into evaluation. Normalization is performed to bring the data to the same scale in order to interpret data and calculate efficiency values more easily. It was performed by selecting the highest value for each column (input and output values) and the remaining values in the column were divided to this value. Hence all the values became in between 0.0 and 1.0 Moreover, increased decimal values are eliminated and rescaled for the ease of calculation. Normalized data is shown in Table 4.6.

Table 4.5: Input/Output Data

Year	Prodution Line	DMUs	Input 1	Input 2	Input 3	Input 4	Input 5	Output 1	Output 2
2010	Pet-6 Line	DMU1	836191	48323	729,215.22	11	115235	779486	13,846,881.29
	PEt-2 Line	DMU2	33182	3665	208,132.51	5	46330	93896	471,150.00
	Can Line	DMU3	108773	25102	436,009.43	6	106928	518787	13,073,962.88
	Glass Bottle Line	DMU4	14422	2846	118,049.16	3	37039	77643	1,072,267.25
	Premix Line	DMU5	72280	11420	275,413.67	6	2513	85574	1,600,515.80
2011	Pet-6 Line	DMU6	812782	48378	637,309.70	10	118233	716385	10,337,609.31
	PEt-2 Line	DMU7	27507	1709	194,255.38	5	45598	66071	450,192.95
	Can Line	DMU8	109864	26535	398,676.46	6	105982	505381	13,013,013.82
	Glass Bottle Line	DMU9	13999	2538	106,691.63	3	37040	81866	1,156,515.12
	Premix Line	DMU10	69551	10224	249,610.83	6	2549	79419	1,588,380.00
2012	Pet-6 Line	DMU11	787492	47542	626,690.89	9	55986	729653	14,271,344.31
	PEt-2 Line	DMU12	21749	3080	204,686.23	5	14209	47865	526,322.40
	Can Line	DMU13	95105	23907	422,429.78	6	106595	487924	13,789,411.85
	Glass Bottle Line	DMU14	17266	5453	111,016.33	3	26925	166373	2,839,733.87
	Premix Line	DMU15	66760	10760	237,368.76	5	2082	85310	1,838,951.40
2013	Pet-6 Line	DMU16	713322	45382	687,102.15	9	68319	692072	15,859,469.03
	PEt-2 Line	DMU17	466	1325	223,696.97	5	16589	26421	205,064.00
	Can Line	DMU18	88014	23184	459,321.28	6	81282	478374	14,813,417.93
	Glass Bottle Line	DMU19	17529	3495	120,731.37	3	133836	113214	1,557,216.34
	Premix Line	DMU20	64905	11022	261,676.24	5	1584	88118	2,089,638.40
2014	Pet-6 Line	DMU21	633045	57025	756,110.18	7	61829	738233	16,244,660.11
	PEt-2 Line	DMU22	436378	29839	249,654.64	5	85903	311934	5,592,703.20
	Can Line	DMU23	249452	30737	522,519.00	6	95332	513083	17,390,305.56
	Glass Bottle Line	DMU24	17031	2455	163,061.18	4	17664	55085	981,231.78
	Premix Line	DMU25	63670	11770	322,098.22	6	1697	94787	2,289,852.40
2015	Pet-6 Line	DMU26	560201	45518	766,440.21	7	50855	556809	14,758,001.10
	PEt-2 Line	DMU27	329300	24694	221,205.43	4	64644	208534	3,719,996.08
	Can Line	DMU28	207499	23704	530,946.61	6	57565	410623	17,272,191.48
	Glass Bottle Line	DMU29	14585	2195	170,453.07	4	26407	50700	1,291,422.38
	Premix Line	DMU30	80034	12696	329,798.57	6	1179	91991	2,306,254.85

Table 4.6: Normalized Input/Output Data

Year	Prodution Line	DMUs	Input 1	Input 2	Input 3	Input 4	Input 5	Output 1	Output 2
2010	Pet-6 Line	DMU1	1.00000	0.84740	0.95143	1.00000	0.86102	1.00000	0.79624
	PEt-2 Line	DMU2	0.03968	0.06427	0.27156	0.45455	0.34617	0.12046	0.02709
	Can Line	DMU3	0.13008	0.44019	0.56888	0.54545	0.79895	0.66555	0.75180
	Glass Bottle Line	DMU4	0.01725	0.04991	0.15402	0.27273	0.27675	0.09961	0.06166
	Premix Line	DMU5	0.08644	0.20026	0.35934	0.54545	0.01878	0.10978	0.09203
2011	Pet-6 Line	DMU6	0.97201	0.84836	0.83152	0.90909	0.88342	0.91905	0.59445
	PEt-2 Line	DMU7	0.03290	0.02997	0.25345	0.45455	0.34070	0.08476	0.02589
	Can Line	DMU8	0.13139	0.46532	0.52017	0.54545	0.79188	0.64835	0.74829
	Glass Bottle Line	DMU9	0.01674	0.04451	0.13920	0.27273	0.27676	0.10503	0.06650
	Premix Line	DMU10	0.08318	0.17929	0.32568	0.54545	0.01905	0.10189	0.09134
2012	Pet-6 Line	DMU11	0.94176	0.83370	0.81766	0.81818	0.41832	0.93607	0.82065
	PEt-2 Line	DMU12	0.02601	0.05401	0.26706	0.45455	0.10617	0.06141	0.03027
	Can Line	DMU13	0.11374	0.41924	0.55116	0.54545	0.79646	0.62596	0.79294
	Glass Bottle Line	DMU14	0.02065	0.09562	0.14485	0.27273	0.20118	0.21344	0.16329
	Premix Line	DMU15	0.07984	0.18869	0.30970	0.45455	0.01556	0.10944	0.10575
2013	Pet-6 Line	DMU16	0.85306	0.79583	0.89649	0.81818	0.51047	0.88786	0.91197
	PEt-2 Line	DMU17	0.00056	0.02324	0.29186	0.45455	0.12395	0.03390	0.01179
	Can Line	DMU18	0.10526	0.40656	0.59929	0.54545	0.60733	0.61370	0.85182
	Glass Bottle Line	DMU19	0.02096	0.06129	0.15752	0.27273	1.00000	0.14524	0.08955
	Premix Line	DMU20	0.07762	0.19328	0.34142	0.45455	0.01184	0.11305	0.12016
2014	Pet-6 Line	DMU21	0.75706	1.00000	0.98652	0.63636	0.46198	0.94708	0.93412
	PEt-2 Line	DMU22	0.52186	0.52326	0.32573	0.45455	0.64185	0.40018	0.32160
	Can Line	DMU23	0.29832	0.53901	0.68175	0.54545	0.71230	0.65823	1.00000
	Glass Bottle Line	DMU24	0.02037	0.04305	0.21275	0.36364	0.13198	0.07067	0.05642
	Premix Line	DMU25	0.07614	0.20640	0.42025	0.54545	0.01268	0.12160	0.13167
2015	Pet-6 Line	DMU26	0.66994	0.79821	1.00000	0.63636	0.37998	0.71433	0.84863
	PEt-2 Line	DMU27	0.39381	0.43304	0.28861	0.36364	0.48301	0.26753	0.21391
	Can Line	DMU28	0.24815	0.41568	0.69274	0.54545	0.43012	0.52679	0.99321
	Glass Bottle Line	DMU29	0.01744	0.03849	0.22240	0.36364	0.19731	0.06504	0.07426
	Premix Line	DMU30	0.09571	0.22264	0.43030	0.54545	0.00881	0.11801	0.13262

Chapter 5

RESULTS AND RECOMMENDATIONS

5.1 DMUs Efficiency Results

All the gathered data initially normalized to bring to the same scale. The normalization was performed by identifying the biggest value for each column (input and output values) and the remaining values in the column were divided to this value. Then with the utilization of the PIMDEA software and using the standard CCR and standard BBC modeling options, the efficiency values, weights, lambda values are calculated. When in Table 5.1 the efficiency values of the production lines from 2010 to 2015 are investigated, it can be seen that the can production line is the only line which is efficient both CCR and BCC throughout the study. Hence, from the management point of view, can production in the factory should be taken into consideration while budget planning. Serious attention should be given for maintaining and planning operation for this production line. The marketing activities for the can products should be encouraged and new product development studies need to be performed to increase the capacity utilization of the production line.

Glass bottle line is come out as BCC efficient and CCR inefficient for year 2010, 2014, and 2015. In other words when we commend on sources of inefficiencies it can be said that glass bottle production line is pure technically efficient (efficient operation) under variable return to scale environment and it is CCR inefficient due to failure to achieve scale efficiency.

Pet-6 and Premix production lines seemed to be inefficient in the previous years, and became efficient in the later years. These lines seem to be working at the efficiency frontier and some precautions taken by the management in the previous years seem to be worked that brought both of these lines to the efficient level. From now on management could rely on both of these production lines and consider investment to maintain its efficient performance.

Finally when the results regarding Pet-2 line is considered it came out as inefficient operation most of the study. Although the output variables are at the highest level in 2010, 2014 and 2015 the efficiency values are the lowest. It can be concluded that this production line is the inefficient one among the others and it maintain its inefficiency despite the constant increase in the output variables. Management should cease the production in this line and look for alternative solutions for these product portfolios. Economy of scale could not be achieved for this production line and the option of the contract manufacturing can seriously be considered by the management.

Table 5.1. CCR and BCC Efficiencies of the Production Lines

Production Line	Year	DMUs	CCR Efficiency	BCC Efficiency	Scale Efficiency ($\theta CCR/\theta BCC$)
Pet-6	2010	DMU1	0.90	1.00	0.90
	2011	DMU6	0.91	0.96	0.94
	2012	DMU11	1.00	1.00	1.00
	2013	DMU16	0.96	1.00	0.96
	2014	DMU21	1.00	1.00	1.00
	2015	DMU26	1.00	1.00	1.00
Pet-2	2010	DMU2	0.77	0.79	0.98
	2011	DMU7	1.00	1.00	1.00
	2012	DMU12	0.53	1.00	0.53
	2013	DMU17	1.00	1.00	1.00
	2014	DMU22	0.92	0.94	0.98
	2015	DMU27	0.71	0.82	0.86
Can	2010	DMU3	1.00	1.00	1.00
	2011	DMU8	1.00	1.00	1.00
	2012	DMU13	1.00	1.00	1.00
	2013	DMU18	1.00	1.00	1.00
	2014	DMU23	1.00	1.00	1.00
	2015	DMU28	1.00	1.00	1.00
Glass Bottle	2010	DMU4	0.85	1.00	0.85
	2011	DMU9	1.00	1.00	1.00
	2012	DMU14	1.00	1.00	1.00
	2013	DMU19	1.00	1.00	1.00
	2014	DMU24	0.75	1.00	0.75
	2015	DMU29	0.95	1.00	0.95
Premix	2010	DMU5	0.88	0.93	0.95
	2011	DMU10	0.89	1.00	0.89
	2012	DMU15	0.99	1.00	0.99
	2013	DMU20	1.00	1.00	1.00
	2014	DMU25	1.00	1.00	1.00
	2015	DMU30	1.00	1.00	1.00

5.2 DMUs Weight Calculation

In DEA weights of the input and output values are calculated to maximize efficiency. When we analyze the average weights in Table 5.2, Input 1 (Electricity Consumption), Input 2 (Fuel Consumption) and Input 5 (Number of Defected Materials Separated from Production Lines) scored the highest meaning these aspects effect the most the efficiency score. For the further enhancement of all the production lines, some precautions need to be taken to minimize electricity/ fuel consumption and number of defected materials. This result also shows the effect of energy and quality factors to the efficiency score. Minimizing number of defective materials achieved due to the increased quality in production processes. Furthermore, minimizing the energy consumption is achieved by practicing some changes in the production lines especially detecting the most energy consuming machines and deciding on energy reducing policies. For the output variables, Output 1 (Production SKU) scored more than the Output 2 (Income Contribution of DMUs) meaning an increase in the production has more influence on the efficiency score. The number of approved end products by the quality department is an important output parameter. Increase in quality practices will lead to decrease the number of the annihilated products hence increasing number of production SKUs. Marketing activities should also be encouraged to increase the demand of the products, hence having a bigger market share than the rival company leading to an increase in the production.

Table 5.2. Weights of Inputs and Outputs Using CCR Model

DMUs	Input 1	Input 2	Input 3	Input 4	Input 5	Output 1	Output 2
DMU 1	0	0.48	0.09	0.36	0.17	0.9	0
DMU 2	0	13.37	0	0.29	0.03	6.38	0
DMU 3	0	1.54	0	0.59	0	1.32	0.16
DMU 4	4.36	17.91	0	0.08	0.04	8.58	0
DMU 5	2.29	2.66	0.4	0	6.73	8.03	0
DMU 6	0	0	0.8	0.28	0.09	0.99	0
DMU 7	0	24.71	0	0.53	0.05	11.8	0
DMU 8	0	0.69	0.76	0.37	0.1	1.11	0.38
DMU 9	3.95	19.92	0.27	0	0.04	9.52	0
DMU 10	0	4.19	0.13	0	10.84	8.69	0
DMU 11	0	0.83	0	0	0.74	1.07	0
DMU 12	0	6.72	0	0	6	8.67	0
DMU 13	0	1.22	0.43	0.47	0	1.18	0.33
DMU 14	0.45	1.5	0.96	1.78	1.1	4.69	0
DMU 15	0	0	2.46	0	15.4	9.03	0
DMU 16	0	0.56	0	0.45	0.36	0.92	0.15
DMU 17	118.85	40.19	0	0	0	29.5	0
DMU 18	0.44	2.35	0	0	0	0.44	0.86
DMU 19	0	13.68	0	0.59	0	6.89	0
DMU 20	2.46	2.9	0.49	0	7.03	7.58	1.19
DMU 21	0	0.55	0	0.44	0.36	0.91	0.15
DMU 22	0	0	2.2	0.62	0	2.29	0
DMU 23	0	0.82	0	1.02	0	0.74	0.51
DMU 24	0	23.23	0	0	0	5	7.07
DMU 25	1.76	3.8	0	0	6.39	7.11	1.03
DMU 26	0.01	0.23	0	0.18	1.84	0.6	0.67
DMU 27	0	0	2.55	0.72	0	2.66	0
DMU 28	0	2.41	0	0	0	0.52	0.73
DMU 29	0	25.98	0	0	0	5.59	7.91
DMU 30	0	3.15	0.42	0	13.18	0.6	7
Average Weights	**4.4857**	**7.1863**	**0.3987**	**0.2923**	**2.3497**	**5.1103**	**0.9380**

5.3 Discussion on Inefficient DMUs

From the efficiency calculations in Table 5.1, it can be clearly seen that Pet-6 and Premix lines were come out as inefficiently operated in the former years as the latter years. To better understand the inefficiency at these lines, the lambda (λ_j) values derived from the PIMDEA software calculations were carefully examined. When the standard CCR model is investigated it can be noted that since slack variables (S_{ik}^{-}, S_{rk}^{+}) are non-negative, θ_k cannot exceed *1*. The composite unit has input levels that do not exceed those of the unit j_0 and having the output values at least as high. When unit j_0 is efficient, the slack variables become *0* and θk results *1*. Meaning it has proved impossible to find a composite unit outperforming unit j_0. On the contrary, when j_0 is not efficient (inefficient) θ_k will be less than *1* and some slack variables may be positive. Meaning it has proved that there is a more efficient composite unit exists. The λj's form an efficient composite unit providing targets for j_0 and θ_k representing the proportion of the input levels of j_0 that the efficient composite unit would require to produce at least of the output levels of j_0. Since θ_k is the measurement of the efficiency of the DMUs, the composite unit therefore provides a set of targets for an inefficient unit.

When we go back and investigate the λ_j table in the Appendix B, there can a few suggestions be made after the investigation of the inefficient Pet-6 lines and Premix lines between 2010 and 2015. Since these lines were became efficient after a period of inefficiency, some conclusion regarding the λ_j values can be gained to interpret target units for inefficient ones. Initially, λ_j values for inefficient operations of the Pet-6 line were examined; which are DMU1, DMU6, DMU16, the common largest positive λ value among these is DMUs is λ_{11} which is calculated as 0.5, 0.41 and 0.72

respectively. In other words these 3 inefficient DMUs should work similar with DMU11 in order to become efficient. The input values of these inefficient ones should become as close as the one of the DMU11 in order to perform efficiently. On the other hand, when the inefficient operations of the Premix line are examined, DMU5, DMU10 and DMU15, the common largest positive λ value among these DMUs is λ_{25} which is calculated as 0.62, 0.34 and 0.87 respectively. Similarly it can be concluded that words these 3 inefficient DMUs should work similar with DMU25 in order to become efficient. The input values of these inefficient ones should become as close as the one of the DMU25 in order to perform efficiently.

5.4 Consistency of the Derived Results

In order to verify the importance of input values and support the arguments mentioned above by weight evaluation, CCR efficiency is calculated by deleting one input variable at a time, hence obtaining 6 different set of data where SoD 0 is the original one. Number of efficient DMUs in the original model is the highest score 17. However, when Input 5 (number of defected materials separated from production line) is deleted from input variables and then the CCR model was run, the number of efficient DMUs drastically dropped to 11. In other words, number of defected materials which is a quality factor has the biggest effect on efficiency scores of the DMUs. Similarly, in SoD 2 where input variable fuel consumption is subtracted from the calculation, the number of efficient DMUs also decreased to a certain point. These results also support the previous argument derived by the weight calculation of the standard CCR model.

Apart from the change in the number of efficient DMUs, the average efficiency values of the all DMUs were evaluated to commend on the consistency of the model.

Here we can say again that input 2 and input 5 have the biggest effect on the efficiency evaluation. Furthermore, number of efficient DMUs of SoD 1, 3 and 4 were calculated as same as 15. However, changes in the average efficiency values show that SoD 3 where labor wages were subtracted has more effect on the efficiency scores than the others.

Table 5.3 Sensitivity Analysis on CCR Efficiency

DMU	SoD 0	SoD 1	SoD 2	SoD 3	SoD 4	SoD 5
DMU 1	0.90	0.90	0.88	0.89	0.81	0.84
DMU 2	0.77	0.77	0.33	0.77	0.77	0.76
DMU 3	1.00	1.00	1.00	1.00	0.96	1.00
DMU 4	0.85	0.84	0.55	0.85	0.85	0.84
DMU 5	0.88	0.88	0.87	0.87	0.88	0.26
DMU 6	0.91	0.91	0.91	0.85	0.82	0.88
DMU 7	1.00	1.00	0.25	1.00	1.00	1.00
DMU 8	1.00	1.00	1.00	0.98	1.00	1.00
DMU 9	1.00	0.99	0.60	1.00	1.00	1.00
DMU 10	0.89	0.89	0.86	0.88	0.89	0.28
DMU 11	1.00	1.00	1.00	1.00	1.00	0.94
DMU 12	0.53	0.53	0.46	0.53	0.53	0.46
DMU 13	1.00	1.00	1.00	0.99	1.00	1.00
DMU 14	1.00	1.00	1.00	1.00	1.00	1.00
DMU 15	0.99	0.99	0.99	0.95	0.99	0.30
DMU 16	0.96	0.96	0.93	0.96	0.94	0.86
DMU 17	1.00	0.60	1.00	1.00	1.00	1.00
DMU 18	1.00	1.00	1.00	1.00	1.00	1.00
DMU 19	1.00	1.00	0.68	1.00	1.00	1.00
DMU 20	1.00	1.00	1.00	1.00	1.00	0.32
DMU 21	1.00	1.00	1.00	1.00	1.00	1.00
DMU 22	0.92	0.92	0.92	0.66	0.85	0.92
DMU 23	1.00	1.00	1.00	1.00	1.00	1.00
DMU 24	0.75	0.75	0.47	0.75	0.75	0.75
DMU 25	1.00	1.00	1.00	1.00	1.00	0.32
DMU 26	1.00	1.00	1.00	1.00	0.94	0.83
DMU 27	0.71	0.71	0.71	0.54	0.64	0.71
DMU 28	1.00	1.00	1.00	1.00	1.00	1.00
DMU 29	0.95	0.95	0.52	0.95	0.95	0.95
DMU 30	1.00	1.00	1.00	1.00	1.00	0.30

No. of Efficient DMUs	17	15	14	15	15	11
Average Efficiency	0.93	0.92	0.83	0.91	0.92	0.78

When we analyze production lines one by one with sensitivity point of view the same results can be interpreted as in the Table 5.4. Here the most shocking finding is about the sensitivity of Premix line to the Input 5. When the input 5 is eliminated from the data list and then the efficiency is calculated it can be clearly seen that the efficiency score drastically fell. In other words the number of defected products plays a huge role to bring Premix line to the efficiency frontier. On the contrary sensitivity of can production line comes out as very low since the efficiency score is not affected abruptly by the change in the set of data.

Table 5.4: Sensitivity Analysis on CCR Efficiency Scores in terms of Production Lines

Production Line	Year	DMUs	SoD 1	SoD 2	SoD 3	SoD 4	SoD 5	SoD 6
Pet-6	2010	DMU1	0.90	0.90	0.88	0.89	0.81	0.84
	2011	DMU6	0.91	0.91	0.91	0.85	0.82	0.88
	2012	DMU11	1.00	1.00	1.00	1.00	1.00	0.94
	2013	DMU16	0.96	0.96	0.93	0.96	0.94	0.86
	2014	DMU21	1.00	1.00	1.00	1.00	1.00	1.00
	2015	DMU26	1.00	1.00	1.00	1.00	0.94	0.83
Pet-2	2010	DMU2	0.77	0.77	0.33	0.77	0.77	0.76
	2011	DMU7	1.00	1.00	0.25	1.00	1.00	1.00
	2012	DMU12	0.53	0.53	0.46	0.53	0.53	0.46
	2013	DMU17	1.00	0.60	1.00	1.00	1.00	1.00
	2014	DMU22	0.92	0.92	0.92	0.66	0.85	0.92
	2015	DMU27	0.71	0.71	0.71	0.54	0.64	0.71
Can	2010	DMU3	1.00	1.00	1.00	1.00	0.96	1.00
	2011	DMU8	1.00	1.00	1.00	0.98	1.00	1.00
	2012	DMU13	1.00	1.00	1.00	0.99	1.00	1.00
	2013	DMU18	1.00	1.00	1.00	1.00	1.00	1.00
	2014	DMU23	1.00	1.00	1.00	1.00	1.00	1.00
	2015	DMU28	1.00	1.00	1.00	1.00	1.00	1.00
Glass Bottle	2010	DMU4	0.85	0.84	0.55	0.85	0.85	0.84
	2011	DMU9	1.00	0.99	0.60	1.00	1.00	1.00
	2012	DMU14	1.00	1.00	1.00	1.00	1.00	1.00
	2013	DMU19	1.00	1.00	0.68	1.00	1.00	1.00
	2014	DMU24	0.75	0.75	0.47	0.75	0.75	0.75
	2015	DMU29	0.95	0.95	0.52	0.95	0.95	0.95
Premix	2010	DMU5	0.88	0.88	0.87	0.87	0.88	0.26
	2011	DMU10	0.89	0.89	0.86	0.88	0.89	0.28
	2012	DMU15	0.99	0.99	0.99	0.95	0.99	0.30
	2013	DMU20	1.00	1.00	1.00	1.00	1.00	0.32
	2014	DMU25	1.00	1.00	1.00	1.00	1.00	0.32
	2015	DMU30	1.00	1.00	1.00	1.00	1.00	0.30

5.5 Summary of the Results

To sum up, in this derived model for the calculation of efficiency values for the perishable food products in the FMCG industry, the input variables have the sequence of importance as follows:

1- Number of defected materials eliminated in the production,

2- Energy (Fuel, Electricity) usage,

3- Labor Wages,

4- Number of labors directly involved in the production lines.

Weight calculations, together with the consistency analysis of the results brought insight regarding the data sets and hence, an order of importance among input variables was established. In this study we are dealing with the input oriented situation, which is why it is utmost important to analyze input variables and discuss corrective actions to enhance them.

Chapter 6

CONCLUSION

6.1 Conclusion

This study helped decision makers, management of the Ektam Kıbrıs Ltd. Company to commend on the certain aspects of the production lines of the production facility. Every year a certain amount of budget is set by the company managers and fraction of this budget used for the production lines need to be decided. This decision should carefully be made in order not to waste capital to an inefficient operation. Data Envelopment Analysis with the utilization of the PIMDEA software made it possible to distinguish efficient and inefficient operations. This study also revealed the sources of inefficiencies and forms a pathway to efficient operations for the managers of the factory. By this study a general model for the efficiency evaluation of the FMCG manufacturing facility is formed and it can easily be utilized by similar operations. In this model both operational and quality factors are considered since, both have a major effect on FMCG food products. Weight calculations revealed that energy consumption (electricity and fuel) and number of defected materials have the highest influence on efficiency scores. Some actions need to be taken by the management regarding these areas to enhance efficiency of the production lines. Verification of the model also revealed that number of the efficient DMUs changed abruptly while subtracting the 5th input namely, number of defected materials separated from the production. This shows drastic effect of this input to the efficiency calculation. Good working production lines move to the efficiency frontier as soon as the defected material input is introduced.

6.2 Future Studies

In this study the factory production lines' efficiency values were calculated for ease of the management decision making process. A future study on this topic is recommended to perform a ranking method on these production lines. This also gives direction to the management of the factory to a certain point for the ease of the decision making regarding production lines. Ranking will help to make a distinction between the efficient DMUs. Moreover, this developed model can be adapted to other perishable goods of the FMCG industry; mainly food products or clothing industry in which seasonal fashion concept gives perishability to these kinds of goods. Also the return to scale of efficient production lines can be estimated. The RTS value for each efficient production line can help the management to have investment plans on efficient production lines. Obviously an efficient DMU with increasing RTS might be a good opportunity for investment.

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APPENDICES

Appendix A: AHP Analysis

A.1 AHP for Comparison Factors

	Maintenance Hours	Working Hours	Produced Quantitiy
Maintenance Hours	1	0.25	0.33
Working Hours	4	1	1.33
Produced Quantitiy	3	0.75	1

			Summed Rows	
2.99	0.7475	0.9925	4.73	0.124686965
11.99	2.9975	3.98	18.9675	0.5
9	2.25	2.9875	14.2375	0.375313035
		Total:	37.935	1

			Summed Rows	
26.835125	6.70878125	8.90771875	42.451625	0.124686803
107.610125	26.90253125	35.720375	170.2330313	0.5
80.775	20.19375	26.81265625	127.7814063	0.375313197
		Total:	340.4660625	1

			Summed Rows	
2161.577705	540.3944262	717.519529	3419.49166	0.124686803
8668.029197	2167.007299	2877.287369	13712.32386	0.5
6506.451492	1626.612873	2159.76784	10292.83221	0.375313197
		Total:	27424.64773	1

			Summed Rows	
14025078.85	3506269.712	4655519.876	22186868.44	0.124686803
56241231.89	14060307.97	18668855.68	88970395.54	0.5
42216153.04	10554038.26	14013335.81	66783527.11	0.375313197
		Total:	177940791.1	1

A.2 AHP for Production Lines for Maintenance Hours

	PET-6	PET-2	CAN	GLASS BOTTLE	PREMIX
PET-6	1	5	3	7	6
PET-2	0.2	1	0.33	3	5
CAN	0.33	3	1	5	7
GLASS BOTTLE	0.14	0.33	0.2	1	0.5
PREMIX	0.17	0.2	0.14	2	1

					Summed Rows	
4.99	22.51	9.89	56	61.5	154.89	0.491609721
1.7789	4.98	2.56	19.05	15.01	43.3789	0.137681509
3.15	10.7	4.96	35.31	33.48	87.6	0.2780361
0.497	2.06	0.9989	4.97	4.89	13.4159	0.042581102
0.7062	2.33	1.256	6.49	5	15.7822	0.050091568
				Total:	315.067	1

					Summed Rows	
167.359939	588.9027	289.2135	1734.9264	1557.2173	4337.619839	0.49186524
45.867545	166.451739	80.921326	476.9744	438.06545	1208.28046	0.137013196
91.569376	328.0115	160.469139	948.1485	860.4587	2388.657215	0.270862247
15.214507	53.7664	26.249847	158.783159	143.682572	397.696485	0.04509687
18.381705	65.958562	31.941739	192.98836	177.19158	486.461946	0.055162446
				Total:	8818.715945	1

					Summed Rows	
136524.3289	487440.513	237749.1635	1421467.942	1292654.472	3575836.419	0.491871166
38030.35771	135800.1916	66233.46146	395972.5017	360126.3673	996162.8797	0.137026346
75306.49632	268892.4104	131149.8701	784076.3171	713059.4402	1972484.534	0.271323448
12473.05198	44533.92139	21720.88439	129871.1548	118106.1196	326705.1322	0.044939649
15219.90955	54344.80195	26505.07702	158476.1766	144128.9433	398674.9085	0.054839391
				Total:	7269863.874	1

					Summed Rows	
92484613638	3.30224E+11	1.61062E+11	9.62954E+11	8.75741E+11	2.42247E+12	0.49187153
25764485182	91994108571	44868762388	2.68261E+11	2.43965E+11	6.74854E+11	0.137026217
51016205479	1.82157E+11	88844546454	5.31183E+11	4.83075E+11	1.33628E+12	0.271325338
8449693835	30170292349	14715112743	87978605950	80010555779	2.21324E+11	0.044938976
10310955750	36816073555	17956493973	1.07358E+11	97634934210	2.70077E+11	0.054837939
				Total:	4.925E+12	1

					Summed Rows	
4.24446E+22	1.51552E+23	7.39171E+22	4.41935E+23	4.0191E+23	1.11176E+24	0.49187153
1.18243E+22	4.22195E+22	2.05919E+22	1.23115E+23	1.11965E+23	3.09715E+23	0.137026217
2.34132E+22	8.35987E+22	4.0774E+22	2.43779E+23	2.21701E+23	6.13266E+23	0.271325338
3.87788E+21	1.38463E+22	6.75331E+21	4.03766E+22	3.67198E+22	1.01574E+23	0.044938976
4.73208E+21	1.68963E+22	8.2409E+21	4.92706E+22	4.48083E+22	1.23948E+23	0.054837939
				Total:	2.26026E+24	1

A.3 AHP for Production Lines for Working Hours

	PET-6	PET-2	CAN	GLASS BOTTLE	PREMIX
PET-6	1	8	2	9	3
PET-2	0.125	1	0.142	3	0.142
CAN	0.5	7	1	8	2
GLASS BOTTLE	0.11	0.33	0.125	1	0.125
PREMIX	0.33	7	0.5	8	1

					Summed Rows	
4.98	53.97	7.761	82	12.261	160.972	0.429797254
0.69786	4.978	0.98	9.397	1.318	17.37086	0.046380414
3.415	34.64	4.994	57.5	7.494	108.043	0.288476162

0.365	3.29	0.57936	4.98	0.87686	10.09122	0.026943684
2.665	22.78	3.654	43.97	4.984	78.053	0.208402487
				Total:	374.53008	1

					Summed Rows	
151.5732842	1355.35988	222.608028	2309.24976	323.364518	4362.15547	0.433177023
17.23836488	157.3313582	25.44886938	265.102306	37.27035088	502.3912493	0.049889177
99.1940904	889.62595	146.087327	1508.55826	212.721417	2856.187044	0.283629185
10.2467057	92.5047712	15.03954808	157.5152642	21.89024188	297.1965311	0.029512636
70.9787708	642.00027	104.9415362	1080.81574	153.4784712	2052.214788	0.203791978
				Total:	10070.14508	1

					Summed Rows	
115034.2682	1037931.566	169418.4603	1758386.326	247061.1831	3327831.804	0.43298726
13211.21739	119208.1225	19457.28765	201947.7396	28374.94011	382199.3072	0.049728304
75418.32753	680488.8704	111074.2293	1152820.673	161979.2868	2181781.387	0.283873585
7807.347143	70445.90202	11498.38217	119343.8418	16768.0684	225863.5415	0.029387313
54203.61457	489081.0992	79830.50055	828540.807	116417.8627	1568073.884	0.204023537
				Total:	7685749.923	1

					Summed Rows	
66842420941	6.03119E+11	98443902437	1.02174E+12	1.43561E+11	1.93371E+12	0.43298666
7676763663	69267421298	11306152029	1.17346E+11	16487803305	2.22084E+11	0.049727945
43823145137	3.95416E+11	64541669254	6.69875E+11	94121354886	1.26778E+12	0.283874177
4536626062	40933966765	6681433245	69346277287	9743558802	1.31242E+11	0.029387005
31496287358	2.84191E+11	46386970975	4.81448E+11	67646291271	9.11169E+11	0.204024212
				Total:	4.46598E+12	1

					Summed Rows	
2.25689E+22	2.0364E+23	3.3239E+22	3.44986E+23	4.84726E+22	6.52906E+23	0.43298666
2.59201E+21	2.33877E+22	3.81746E+21	3.96212E+22	5.56701E+21	7.49854E+22	0.049727945
1.47966E+22	1.3351E+23	2.17921E+22	2.26179E+23	3.17795E+22	4.28057E+23	0.283874177
1.53176E+	1.38211E+	2.25595E+	2.34144E+22	3.28985E+	4.4313E+22	0.0293870

21	22	21		21		05
1.06345E+22	9.59554E+22	1.56623E+22	1.62558E+23	2.28404E+22	3.07651E+23	0.204024212
				Total:	1.50791E+24	1

A.4 AHP for Produced Lines for Production Quantity

	PET-6	PET-2	CAN	GLASS BOTTLE	PREMIX
PET-6	1	5	3	9	8
PET-2	0.2	1	0.17	4	3
CAN	0.33	6	1	8	7
GLASS BOTTLE	0.11	0.25	0.125	1	0.5
PREMIX	0.125	0.33	0.142	2	1

					Summed Rows	
4.98	32.89	9.111	78	56.5	181.481	0.493095519
1.2711	5.01	1.866	17.16	10.79	36.0971	0.098078136
3.615	17.96	5.004	56.97	38.64	122.189	0.331995351
0.37375	1.965	0.6935	4.99	3.505	11.52725	0.031320278
0.58286	2.637	0.9651	7.581	4.984	16.74996	0.045510716
				Toplam=	368.04431	1

					Summed Rows	
161.627234	794.46516	260.958114	2289.43257	1543.28814	5049.771218	0.499134875
32.1464884	162.592569	52.5810051	458.85081	311.90045	1018.071323	0.100629292
102.7353639	512.58852	168.2898	1452.45162	983.65207	3219.717374	0.31824674
10.7739258	53.6405825	17.38544075	153.8521	104.074935	339.7269841	0.033579657
15.48174299	77.7543044	25.12792176	221.308641	150.087945	489.7605552	0.048409435
				Toplam=	10117.04745	1

Summed

					Rows	
127031.2216	634149.2636	206450.7215	1807381.681	1223824.915	3998837.802	0.498764763
25596.84401	127792.6554	41601.74819	364195.741	246612.77	805799.7586	0.100505333
81249.32198	405619.7046	132052.147	1155993.573	782763.5946	2557678.341	0.319012647
8520.668276	42537.63658	13847.78484	121233.864	82091.55894	268231.5127	0.033455827
12291.31119	61363.36993	19976.20526	174883.6812	118420.5988	386935.1663	0.048261429
				Toplam=	8017482.581	1

					Summed Rows	
79585644816	3.97317E+11	1.29345E+11	1.13235E+12	7.66752E+11	2.50535E+12	0.498763319
16037186262	80062688075	26064176529	2.28178E+11	1.54507E+11	5.04849E+11	0.100505063
50903961042	2.54129E+11	82730835998	7.24263E+11	4.90424E+11	1.60245E+12	0.319015177
5338349714	26650724189	8676066174	75954199914	51431280812	1.68051E+11	0.033455443
7700812283	38444881889	12515620099	1.09567E+11	74191961985	2.42421E+11	0.048260999
				Toplam=	5.02312E+12	1

					Summed Rows	
3.12394E+22	1.55957E+23	5.07713E+22	4.44475E+23	3.0097E+23	9.83412E+23	0.498763319
6.295E+21	3.14266E+22	1.02308E+22	8.95655E+22	6.0648E+22	1.98166E+23	0.100505063
1.99811E+22	9.97519E+22	3.24739E+22	2.84292E+23	1.92504E+23	6.29002E+23	0.319015177
2.09544E+21	1.04611E+22	3.40558E+21	2.98139E+22	2.01881E+22	6.59641E+22	0.033455443
3.02276E+21	1.50906E+22	4.9127E+21	4.3008E+22	2.91222E+22	9.51563E+22	0.048260999
				Toplam=	1.9717E+24	1

Appendix B: Standard CCR Model λ_j Results

Name	DMU 3	DMU 7	DMU 8	DMU 9	DMU 11	DMU 13	DMU 14	DMU 17	DMU 18	DMU 19	DMU 20	DMU 21	DMU 23	DMU 25	DMU 26	DMU 28	DMU 30
DMU 1	0.5	0	0	0	0.56	0	0.46	0	0.08	0	0	0	0	0	0	0	0
DMU 2	0	0.56	0	0	0	0	0.34	0	0	0.01	0	0	0	0	0	0	0
DMU 3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 4	0	0.01	0	0.74	0	0	0.09	0	0	0.01	0	0	0	0	0	0	0
DMU 5	0	0	0	0	0.01	0	0.01	0	0	0	0.62	0	0	0.23	0	0	0
DMU 6	0	0	0.69	0	0.41	0	0.41	0	0	0	0	0	0	0	0	0	0
DMU 7	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 8	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 9	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 10	0	0	0	0	0.02	0	0	0	0	0	0.34	0	0	0.37	0	0	0
DMU 11	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
DMU 12	0	0	0	0	0	0	0.27	0	0	0	0	0	0	0	0	0	0
DMU 13	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
DMU 14	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
DMU 15	0	0	0	0	0.01	0	0	0	0	0	0.87	0	0	0	0	0	0
DMU 16	0	0	0	0	0.72	0	0	0	0.2	0	0	0.03	0	0	0	0.13	0
DMU 17	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
DMU 18	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
DMU 19	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
DMU 20	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
DMU 21	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
DMU 22	0	0	0.34	0	0	0	0.86	0	0	0	0	0	0	0	0	0	0
DMU 23	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
DMU 24	0	0	0	0	0	0	0.32	0	0	0	0	0	0	0	0	0	0
DMU 25	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
DMU 26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
DMU 27	0	0	0.29	0	0	0	0.36	0	0	0	0	0	0	0	0	0	0
DMU 28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
DMU 29	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0.04	0
DMU 30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Appendix C: Distribution Table for Labor Cost

YEAR	SECTION	PERSONEL	MONTHLY COST	ANNUAL TOTAL COST	COST DISTRIBUTION WITH AHP
2010	LABORATUVAR	4	13,920.00	167,040.00	
	SYRUP MAKING	4	9,512.00	114,144.00	
	MAINTENANCE	8	32,944.00	395,328.00	
	MANAGEMENT	5	14,772.00	177,264.00	
	SEASONAL WORKER	0	0.00	0.00	
	PET-6	11	27,683.00	332,196.00	729,215.22
	PET-2	5	11,676.00	140,112.00	208,132.51
	CAN	6	15,310.00	183,720.00	436,009.43
	GLASS BOTTLE	3	7,500.00	90,000.00	118,049.16
	PREMIX	6	13,918.00	167,016.00	275,413.67
2011	LABORATUVAR	4	12,528.00	150,336.00	
	SYRUP MAKING	4	8,630.00	103,560.00	
	MAINTENANCE	8	30,299.00	363,588.00	
	MANAGEMENT	5	13,711.00	164,532.00	
	SEASONAL WORKER	0	0.00	0.00	
	PET-6	10	22,805.00	273,660.00	637,309.70
	PET-2	5	10,996.00	131,952.00	194,255.38
	CAN	6	13,966.00	167,592.00	398,676.46
	GLASS BOTTLE	3	6,750.00	81,000.00	106,691.63
	PREMIX	6	12,527.00	150,324.00	249,610.83
2012	LABORATUVAR	4	13,224.00	158,688.00	
	SYRUP MAKING	4	8,966.80	107,601.60	
	MAINTENANCE	8	32,364.00	388,368.00	
	MANAGEMENT	5	15,544.00	186,528.00	
	SEASONAL WORKER	0	0.00	0.00	
	PET-6	9	19,627.20	235,526.40	626,690.89
	PET-2	5	11,472.40	137,668.80	204,686.23
	CAN	6	14,488.40	173,860.80	422,429.78
	GLASS BOTTLE	3	6,948.40	83,380.80	111,016.33
	PREMIX	5	10,880.80	130,569.60	237,368.76
2013	LABORATUVAR	4	14,326.00	171,912.00	
	SYRUP MAKING	4	9,802.00	117,624.00	
	MAINTENANCE	8	34,626.00	415,512.00	
	MANAGEMENT	5	17,980.00	215,760.00	
	SEASONAL WORKER	0	0.00	0.00	
	PET-6	9	21,576.00	258,912.00	687,102.15

	PET-2	5	12,528.00	150,336.00	223,696.97
	CAN	6	15,602.00	187,224.00	459,321.28
	GLASS BOTTLE	3	7,540.00	90,480.00	120,731.37
	PREMIX	5	12,064.00	144,768.00	261,676.24
2014	LABORATUVAR	4	15,361.50	184,338.00	
	SYRUP MAKING	4	10,683.75	128,205.00	
	MAINTENANCE	8	33,100.00	397,200.00	
	MANAGEMENT	6	22,060.50	264,726.00	
	SEASONAL WORKER	9	19,339.07	116,034.42	
	PET-6	7	20,750.75	249,009.00	756,110.18
	PET-2	5	13,564.50	162,774.00	249,654.64
	CAN	6	16,689.75	200,277.00	522,519.00
	GLASS BOTTLE	4	10,602.90	127,234.80	163,061.18
	PREMIX	6	15,303.75	183,645.00	322,098.22
2015	LABORATUVAR	4	16,195.44	194,345.28	
	SYRUP MAKING	3	8,422.70	101,072.40	
	MAINTENANCE	7	31,150.88	373,810.56	
	MANAGEMENT	6	23,471.42	281,657.04	
	SEASONAL WORKER	11	23,065.16	138,390.96	
	PET-6	7	21,659.14	259,909.68	766,440.21
	PET-2	4	11,201.88	134,422.56	221,205.43
	CAN	6	17,422.27	209,067.24	530,946.61
	GLASS BOTTLE	4	11,222.25	134,667.00	170,453.07
	PREMIX	6	15,958.43	191,501.16	329,798.57

Appendix D: Income Contribution Data Tables

YEAR 2010																			
Pet-6				Pet-2				Can				Glass Bottle				Premix			
SKU	SALES	UNIT PRIC	INCOME	SKU	SALES	UNIT PRICE	INCOME	SKU	SALES	UNIT PRIC	INCOME	SKU	SALES	UNIT PRIC	INCOME	SKU	SALES	UNIT PRICE	INCOME
PC 45	118258	15.85	1874389	FANA 33	8827	5	44135	PCK 25	11273	25	281825	PC 25	12953	15.85	205305	PC 18	48771	18.85	919333
DPC 45	7506	15.85	118970	FMNG 33	13883	5	69415	DPCK 25	4227	25	105675	7UP 25	4569	15.85	72418.7	DPC 18	4641	18.85	87482.9
7UP 45	15385	15.85	243852	FMUZ 33	4120	5	20600	7UPK 25	4345	25	108625	YM 25	4013	15.85	63606.1	7UP 18	11440	18.85	215644
D7UP 45	1922	15.85	30463.7	FCLK 33	25145	5	125725	YMK25	4570	25	114250	PC 20	28729	12.5	359113	YM 18	8624	18.85	162562
YM 45	30959	15.85	490700	FLIM 33	18712	5	93560	PC 33	309752	25.45	7883188	DPC 20	3784	12.5	47300	FRS 18	11432	18.85	215493
PC 1	119189	21.59	2573291	FMIX 33	23543	5	117715	DPC 33	31702	25.45	806816	7UP 20	12456	12.5	155700				
DPC 1	29559	21.59	638179					PTW 33	0	0	0	YM 20	13506	12.5	168825				
PMAX 1	0	0	0					PCMAX 33	0	0	0	FRG 20	0	0	0				
7UP 1	26873	21.59	580188					7UP 33	52591	25.45	1338441								
D7UP 1	5261	21.59	113585					D7UP 33	6030	25.45	153464								
YM 1	35744	21.59	771713					YM 33	69440	25.45	1767248								
FRT 1	8669	15.91	137924					FRT 33	2201	25.45	56015.5								
FRS 1	8324	15.91	132435					FRS 33	951	25.45	24203								
PC 1,5	25941	12.88	334120					CHR 33	19621	22.13	434213								
DPC 1,5	1595	12.88	20543.6																
7UP 1,5	7533	12.88	97025																
YM 1,5	9311	12.88	119926																
PC 2	8479	13.63	115569																
YM 2	3265	13.63	44502																
PC 2,5	238204	17.55	4180480																
YM 2,5	70030	17.55	1229027																
TOTAL			1.4E+07				471150				1.3E+07				1072267				1600516

YEAR 2011

Pet-6				Pet-2				Can				Glass Bottle				Premix			
SKU	SALES	UNIT PRIC	INCOME	SKU	SALES	UNIT PRIC	INCOME	SKU	SALES	UNIT PRIC	INCOME	SKU	SALES	UNIT PRIC	INCOME	SKU	SALES	UNIT PRIC	INCOME
PC 45	93597	16.68	1561198	FANA 33	6291	6.45	40577	PCK 25	9096	26.32	239407	PC 25	8686	16.68	144882	PC 18	45204	20	904080
DPC 45	6389	16.68	106569	FMNG 33	8771	6.45	56573	DPCK 25	3739	26.32	98410.5	7UP 25	3477	16.68	57996.4	DPC 18	4685	20	93700
7UP 45	13574	16.68	226414	FMUZ 33	0	0	0	7UPK 25	4360	26.32	114755	YM 25	2833	16.68	47254.4	7UP 18	11074	20	221480
D7UP 45	0	0	0	FCLK 33	18089	6.45	116674	YMK25	4366	26.32	114913	PC 20	32729	13.16	430714	YM 18	7164	20	143280
YM 45	23905	16.68	398735	FLIM 33	11984	6.45	77296.8	PC 33	293932	26.78	7871499	DPC 20	3967	13.16	52205.7	FRS 18	11292	20	225840
PC 1	139946	22.73	3180973	FMIX 33	15666	6.45	101046	DPC 33	32765	26.78	877447	7UP 20	15792	13.16	207823				
DPC 1	28311	22.73	643509	FLIM 1	1859	20.65	38388.4	PTW 33	0	0	0	YM 20	16386	13.16	215640				
PMAX 1	0	22.73	0	FMIX 1	951	20.65	19638.2	PCMAX 33	0	0	0	FRG 20	0	0	0				
7UP 1	27169	22.73	617551					7UP 33	52980	26.78	1418804								
D7UP 1	7439	22.73	169088					D7UP 33	6189	26.78	165741								
YM 1	38007	22.73	863899					YM 33	60740	26.78	1626617								
FRT 1	8237	16.5	135911					FRT 33	2021	26.78	54122.4								
FRS 1	7887	16.75	132107					FRS 33	938	26.78	25119.6								
PC 1,5	27526	13.56	373253					CHR 33	17440	23.29	406178								
DPC 1,5	0	13.56	0																
7UP 1,5	8668	13.56	117538																
YM 1,5	10206	13.56	138393																
PC 2	0	14.35	0																
YM 2	0	14.35	0																
PC 2,5	210195	6.16	1294801																
YM 2,5	61310	6.16	377670																
TOTAL			1E+07				450193				1.3E+07				1156515				1588380

YEAR 2012

Pet-6				Pet-2				Can				Glass Bottle				Premix			
SKU	SALES	UNIT PRIC	INCOME	SKU	SALES	UNIT PRIC	INCOME	SKU	SALES	UNIT PRIC	INCOME	SKU	SALES	UNIT PRIC	INCOME	SKU	SALES	UNIT PRICE	INCOME
PC 45	59992	17.56	1053460	FANA 33	2884	7.8	22495.2	PCK 25	8138	27.7	225423	PC 25	20649	17.56	362596	PC 18	47185	21.45	1012118
DPC 45	4633	17.56	81355.5	FMNG 33	3174	7.8	24757.2	DPCK 25	1051	27.7	29112.7	7UP 25	7735	17.56	135827	DPC 18	4970	21.45	106607
7UP 45	11699	17.56	205434	FMUZ 33	0	7.8	0	7UPK 25	3898	27.7	107975	YM 25	7679	17.56	134843	7UP 18	12240	21.45	262548
D7UP 45	0	0	0	FCLK 33	13546	7.8	105659	YMK25	3765	27.7	104291	PC 20	98977	13.85	1370831	YM 18	8217	21.45	176255
YM 45	15974	17.56	280503	FLIM 33	8548	7.8	66674.4	PC 33	291348	28.19	8213100	DPC 20	4199	13.85	58156.2	FRS 18	13120	21.45	281424
PC 1	151940	23.92	3634405	FMIX 33	11790	7.8	91962	DPC 33	38008	28.19	1071446	7UP 20	34428	13.85	476828				
DPC 1	28091	23.92	671937	FLIM 1	4619	21.36	98661.8	PTW 33	8490	28.19	239333	YM 20	20089	13.85	278233				
PMAX 1	0	23.92	0	FMIX 1	5436	21.36	116113	PCMAX 33	0	0	0	FRG 20	2211	10.14	22419.5				
7UP 1	26597	23.92	636200					7UP 33	50317	28.19	1418436								
D7UP 1	8378	23.92	200402					D7UP 33	7240	28.19	204096								
YM 1	40041	23.92	957781					YM 33	53154	28.19	1498411								
FRT 1	9949	17.63	175401					FRT 33	1886	28.19	53166.3								
FRS 1	8631	17.63	152165					FRS 33	2352	28.19	66302.9								
PC 1,5	58211	14.27	830671					CHR 33	22770	24.52	558320								
DPC 1,5	0	14.27	0																
7UP 1,5	15114	14.27	215677																
YM 1,5	18737	14.27	267377																
PC 2	0	0	0																
YM 2	0	0	0																
PC 2,5	195275	19.45	3798099																
YM 2,5	57094	19.45	1110478																
TOTAL			1.4E+07				526322				1.4E+07				2839734				1838951

YEAR 2013

Pet-6				Pet-2				Can				Glass Bottle				Premix			
SKU	SALES	UNIT PRIC	INCOME	SKU	SALES	UNIT PRIC	INCOME	SKU	SALES	UNIT PRIC	INCOME	SKU	SALES	UNIT PRIC	INCOME	SKU	SALES	UNIT PRICE	INCOME
PC 45	42954	19.51	838033	FANA 33			0	PCK 25	6194	30.78	190651	PC 25	4262	19.51	83151.6	PC 18	46512	23.6	1097683
DPC 45	4308	19.51	84049.1	FMNG 33			0	DPCK 25	42	30.78	1292.76	7UP 25	2532	19.51	49399.3	DPC 18	4730	23.6	111628
7UP 45	9029	19.51	176156	FMUZ 33			0	7UPK 25	3218	30.78	99050	YM 25	2972	19.51	57983.7	7UP 18	12991	23.6	306588
D7UP 45	0	0	0	FCLK 33	9886	8	79088	YMK25	2813	30.78	86584.1	PC 20	58369	15.39	898299	YM 18	10137	23.6	239233
YM 45	12052	19.51	235135	FLIM 33	6119	8	48952	PC 33	289648	31.33	9074672	DPC 20	2678	15.39	41214.4	FRS 18	14174	23.6	334506
PC 1	171755	26.58	4565248	FMIX 33	9628	8	77024	DPC 33	33362	31.33	1045231	7UP 20	8174	15.39	125798				
DPC 1	25970	26.58	690283	FLIM 1			0	PTW 33	7525	31.33	235758	YM 20	9408	15.39	144789				
PMAX 1		0	0	FMIX 1			0	PCMAX 33			0	YP 20	6422	15.39	98834.6				
7UP 1	25027	26.58	665218					7UP 33	48007	31.33	1504059	YKPN 20	822	15.39	12650.6				
D7UP 1	8440	26.58	224335					D7UP 33	7089	31.33	222098	YE 20	696	15.39	10711.4				
YM 1	32694	26.58	869007					YM 33	45863	31.33	1436888	FRG 20	3051	11.27	34384.8				
YP 1		26.58	0					FRT 33	2286	31.33	71620.4								
YKPN 1	9689	26.58	257534					FRS 33	775	31.33	24280.8								
YE 1	4720	26.58	125458					CHR 33	30148	27.24	821232								
FRT 1	11085	19.59	217155																
FRS 1	9832	19.59	192609																
PC 1,5	71902	15.86	1140366																
DPC 1,5		0	0																
7UP 1,5	13104	15.86	207829																
YM 1,5	17010	15.86	269779																
PC 2		0	0																
YM 2		0	0																
PC 2,5	186894	21.61	4038779																
YM 2,5	49167	21.61	1062499																
TOTAL			1.6E+07				205064				1.5E+07				1557216				2089638

YEAR 2014

Pet-6				Pet-2				Can				Glass Bottle				Premix			
SKU	SALES	UNIT PRICE	INCOME	SKU	SALES	UNIT PRICE	INCOME	SKU	SALES	UNIT PRICE	INCOME	SKU	SALES	UNIT PRICE	INCOME	SKU	SALES	UNIT PRICE	INCOME
PC 45	42195	21.68	914788	FANA 33	0		0	PCK 25	5696	34.2	194803	PC 25	11333	21.68	245699	PC 18	49569	24.2	1E+06
DPC 45	4117	21.68	89249	FMNG 33	0		0	DPCK 25	0	0	0	DPC 25	1204	21.68	26103	DPC 18	2505	24.2	60621
7UP 45	8550	21.68	185355	FMUZ 33	0		0	7UPK 25	3100	34.2	106020	7UP 25	3732	21.68	80910	7UP 18	14334	24.2	346883
D7UP 45	0	0	0	FCLK 33	0		0	YMK25	2870	34.2	98154	YM 25	4673	21.68	101311	YM 18	11803	24.2	285633
YM 45	11863	21.68	257190	FLIM 33	0		0	PC 33	276680	34.81	1E+07	PC 20	7173	17.1	122658	FRS 18	16230	24.2	392766
PC 1	128522	29.54	4E+06	FMIX 33	0		0	DPC 33	32110	34.81	1E+06	DPC 20	549	17.1	9387.9	PTW 18	181	24.2	4380.2
DPC 1	25616	29.54	756697	FLIM 1	0		0	PTW 33	12594	34.81	438397	7UP 20	3757	17.1	64245				
PMAX 1	0	0	0	FMIX 1	0		0	PCMAX 3	5456	34.81	189923	YM 20	3178	17.1	54344				
7UP 1	27158	29.54	802247	TLIMK 1	2E+05	19.1	3E+06	7UP 33	53770	34.81	2E+06	FRG 20	1105	12.52	13835				
D7UP 1	8861	29.54	261754	TLIMN 1	28632	19.1	546871	D7UP 33	7213	34.81	251085	TTM NR 25	7098	21.68	153885				
YM 1	34496	29.54	1E+06	TLIMP 1	17224	19.1	328978	YM 33	49345	34.81	2E+06	TTKPN NF	4007	21.68	86872				
FRT 1	11159	21.76	242820	TLIMYE 1	16446	19.1	314119	FRT 33	2388	34.81	83126	TTE NR 25	0	0	0				
FRS 1	10858	21.76	236270	TLIMK 25	0	0	0	FRS 33	655	34.81	22801	TTG NR 25	1014	21.68	21984				
PC 1,5	66869	17.62	1E+06	TICES 1	42651	18.2	776248	CHR 33	48287	30.27	1E+06								
DPC 1,5	0	0	0	TICEL 1	23169	18.2	421676	TTG 33	5916	34.81	205936								
7UP 1,5	13080	17.62	230470	TICEOM 1	12029	18.2	218928												
YM 1,5	18692	17.62	329353	TICESF 1	5561	18.2	101210												
PC 2	6419	18.65	119714	TTICES45	2494		0												
YM 2	0	0	0	TTICEL45	698		0												
PC 2,5	187264	24.01	4E+06	TTICEOM	328		0												
YM 2,5	55342	24.01	1E+06	TTM45	1094		0												
				TTP45	1006		0												
				TTKPN45	0		0												
				TTG45	4762		0												
				TTM1	1539		0												
				TTP1	1416		0												
				TTKPN1	493		0												
				TTG1	1362		0												
TOTAL			2E+07				6E+06				2E+07				981232				2E+06

YEAR 2015

Pet-6				Pet-2				Can				Glass Bottle				Premix			
SKU	SALES	UNIT PRICE	INCOME	SKU	SALES	UNIT PRICE	INCOME	SKU	SALES	UNIT PRICE	INCOME	SKU	SALES	UNIT PRICE	INCOME	SKU	SALES	UNIT PRICE	INCOME
PC 45	25327	22.82	577962	FANA 33	0		0	PCK 25	7010	36	252360	PC 25	16553	22.82	377739	PC 18	43899	26.45	1E+06
DPC 45	3071	22.82	70080	FMNG 33	0		0	DPCK 25	0	0	0	DPC 25	2331	22.82	53193	DPC 18	2247	26.45	59433
7UP 45	7687	22.82	175417	FMUZ 33	0		0	7UPK 25	3022	36	108792	7UP 25	5805	22.82	132470	7UP 18	13033	26.45	344723
D7UP 45	0	0	0	FCLK 33	0		0	YMK25	2414	36	86904	YM 25	7586	22.82	173113	YM 18	10571	26.45	279603
YM 45	9749	22.82	222472	FLIM 33	0		0	PC 33	265355	36.64	1E+07	FRG 25	79	22.82	1802.8	FRS 18	16385	26.45	433383
PC 1	122419	31.09	4E+06	FMIX 33	0		0	DPC 33	29801	36.64	1E+06	PC 20	534	18	9612	PCMAX	1058	26.45	27984
DPC 1	19583	31.09	608835	FLIM 1	0		0	PTW 33	120	36.64	4396.8	DPC 20	193	18	3474				
PMAX 1	1017	31.09	31619	FMIX 1	0		0	PCMAX 3	9869	36.64	361600	7UP 20	288	18	5184				
7UP 1	25711	31.09	799355	TLIMK 1	60863	21.27	1E+06	7UP 33	54462	36.64	2E+06	YM 20	290	18	5220				
D7UP 1	7105	31.09	220894	TLIMN 1	9827	21.27	209020	D7UP 33	6524	36.64	239039	FRG 20	0	0	0				
YM 1	32424	31.09	1E+06	TLIMP 1	0	0	0	YM 33	48962	36.64	2E+06	PCMAX 20	131	18	2358				
FRT 1	9798	22.91	224472	TLIMYE 1	6744	21.27	143445	FRT 33	2179	36.64	79839	TTK NR 25	7887	22.82	179981				
FRS 1	11115	22.91	254645	TLIMK 25	1E+05	14.36	2E+06	FRS 33	604	36.64	22131	TTM NR 2	4312	22.82	98400				
PC 1,5	56768	18.55	1E+06	TICES 1	7929	22.2	176024	CHR 33	47494	31.86	2E+06	TTP 25	2826	22.82	64489				
DPC 1,5	0	0	0	TICEL 1	6560	22.2	145632					TTG NR 2	8080	22.82	184386				
7UP 1,5	15241	18.55	282721	TICEOM 1	0	0	0												
YM 1,5	18765	18.55	348091	TICESF 1	5546	21.27	117963												
PC 2	10888	19.63	213731	TTICES45	2618	16.82	44035												
YM 2	3368	19.63	66114	TTICEL45	687	16.82	11555												
PC 2,5	159520	25.27	4E+06	TTICEOM	0	0	0												
YM 2,5	30210	25.27	763407	TTM45	170	22.82	3879.4												
				TTP45	777	22.82	17731												
				TTKPN45	0	22.82	0												
				TTG45	467	22.82	10657												
				TTM1	95	31.09	2953.6												
				TTP1	562	31.09	17473												
				TTKPN1	0	0	0												
				TTG1	441	31.09	13711												
TOTAL			1E+07				4E+06				2E+07				1E+06				2E+06