

Analyzing Manufacturing Company's Production Lines Efficiency using Data Envelopment Analysis (DEA) (Case Study: Tehran PAK Dairy Company)

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Abstract

Of the goals this study pursues are to study the efficiency of PAK dairy company production line status and propose some strategies to improve these lines' efficiency. For this, first all PAK company production lines are considered as decision making units and then after consulting with the company middle and senior managers, highly important indices have been identified as the input and output. Then the input and output related data have been gathered, classified and integrated. After that in order to determine all production lines, we've considered CCR model as input. Having solved efficiency model, all production lines have been determined. Finally the lines with efficiency as 1 have been introduced as the efficient units and those with efficiency less than 1 have been made efficient by proposing some solutions based on some input or output increase or decrease.

Keywords: CCR Model, Efficiency Analysis, Data Envelopment Analysis, Pak Dairy Company, Production Lines

1. Introduction

Generally speaking, production process is a process during which the manufacturing organization processes its desired resources in order to produce the desired output or the same final product. The process in which human resources, raw materials, machinery and overall, the organization's assets will be employed. In today competitive world, production isn't considered at any price in the organizations agenda and the top companies are the ones producing significant and optimal quantities of output using the input optimally. Among this, production units' efficiency is highly critical for converting input to output since an inefficient production unit results in wasting the resources and input. For this reason, the recent years Data Envelopment Analysis have been focused by world researchers and various applications of Data Envelopment Analysis (DEA) have been observed for the institutions performance evaluation and other common activities in diverse areas. The reason why DEA is more widespread

than other methods is that the possibility to address complicated and often unknown relations between several input and several output is usually non-measurable existing in these activities⁴.

The units' performance evaluation allows the organizations' senior decision makers and also the middle and operational managers to evaluate, control and if required, to modify the units being monitored. The highly used technique as DEA allows the managers that besides under-monitoring units' efficiency evaluation, to acquire accurate information on how to increase or decrease each unit's input or output to raise the units' efficiency.

Applying the same DEA technique, efforts have been made to study PAK Dairy Company production lines so that in addition to evaluating and defining the production lines' efficiency, to propose some strategies to increase the production lines' efficiency.

The decision making units' input and output proportionality, especially in production units is of the most

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important problems the decision makers, the middle and senior managers are dealing with.

Thus regarding this company's glorious past and the present status, it seems essential to revise the short- and long-term decision makings and adopt optimal decisions considering the organizations' conditions and using mathematical techniques such as DEA.

PAK Dairy Company, with three subordinate branches as Sari based PAKSAR, PAKPEY Shahrekord based and Sanadaj based PAKARA and holding very authentic brand, sophisticated personnel, being supported by Foundation for the Oppressed, accessing the mega market of Tehran and Karajand ..., is highly potential to take up the industrial leader position of the country dairy industry. To achieve its goals, PAK Company is required to select the best solutions and be extremely accurate to design its production lines.

In this research, it has been tried first to estimate PAK Dairy company production lines' efficiency and then to propose some strategies to raise inefficient lines' efficiency. To realize this goal, CCR model has been applied in the input oriented whose goal is to minimize the input subject to minimum expected output production. Guided by and consulting and interviewing with PAK Dairy Company senior and middle managers, the mentioned model's input and output have been obtained and the model data have been collected from accounting, financial and production units.

This study aims first to determine PAK Dairy Company production lines' efficiency. In the next step, it is going to recognize which input or output increase or decrease will result in the inefficient production lines' efficiency raise.

The study derived results can be handed in to PAK Company middle and operational managers and besides being aware of the production line efficiency, they can be informed about the inefficient production lines' input and output so that they could raise their efficiency.

2. Materials and Method

2.1. Data Envelopment Analysis and CCR Model

DEA is a mathematical programming for the decision making units' relative efficiency evaluation. Decision making unit refers to an organizational that process includes a system, i.e., a number of input is utilized to achieve some output. The

main objective of this model is to identify the most efficient organization's unit among a group of units in order to provide a similar output. This model defines the model units as the objective for inefficient units and also it proposes some strategies to raise other inefficient units' efficiency in the units' development area (Tavakoli Moghaddam, 2004).

Using weighted efficiency measurement method, Charnes, Cooper and Rhodes⁴ presented a novel model called CCR measuring and comparing the organizational units' relative efficiency including schools, hospitals, bank branches and etc. having several identical input and output⁴.

Two basic features of DEA model are as the following:

- Return to scale of the desired pattern is highly important. CCR model considers the units return to scale as constant. In this research, regarding the goods production occurring based on the B.O.M, return to scale is constant.
- The mode of the applied model is very important. If in the evaluation process, we try to minimize the input by keeping the output level constant, the applied model is output oriented.

But if we keep the input level constant in the evaluation process and try to increase the output, the applied model is output oriented⁶.

Assuming the data available, we have to solve (n) optimizing problems, every time the efficiency of a Decision Making Unit (DMU) is estimated. CCR envelopment model is as the following in input oriented:

$$\begin{aligned} (LP_o) \max & uy_o \\ s.t. & vx_o = 1 \\ & -vX + uY \leq 0 \\ & v \geq 0, u \geq 0 \end{aligned} \quad (1)$$

The above dual problem with real variable (θ) and non-negative vector from the variables is $\lambda = (\lambda_1, \lambda_2, \dots, \lambda_n)^T$:

$$\begin{aligned} (DLP_o) \min & \theta \\ s.t. & \theta x_o - X\lambda \geq 0 \\ & Y\lambda \leq y_o \\ & \lambda \geq 0 \end{aligned} \quad (2)$$

It is worth mentioning that the problem (DLP_o) has a feasible solution as the following:

$$\begin{aligned} \theta &= 1 \\ \lambda_0 &= 1, \lambda_j = 0 \\ (2 \text{ } (j \neq 0)) \end{aligned} \quad (1)$$

Thus (θ) displayed as (θ^*) isn't more than 1. However, (DLP_o) will be applied in the computations for three reasons:

- Computer assisted computation to solve LP proportionate with a power of the constraints number increases. Usually in DEA, (n) , DMU number is significantly bigger than $(m+s)$, input and output number. Thus the time to solve (LP_o) with (n) constraints is longer than (DLP_o) with $(m+s)$ constraint. In addition, the required memory for reserve base or its reverse equals the constraints square, then solution is more suitable regarding the required memory.
- By solving (LP_o) we can't find get the solution with higher slack value appropriately.
- Interpretation is easier since the solution is expressed in the form of input and output corresponding the initial data while (LP_o) induced solution shows observation evaluation. Though these values are important, they are usually used for post (DLP_o) solution interpretations.

CCR model in input oriented is the model whose goal is to minimize the input subject to producing the minimum expected output. It's also worth mentioning that CCR model in output oriented tries to maximize output while it uses none of its input more than the observed value⁴.

CCR model is considered as a basis for other models formation in DEA. This model has constant return to scale and by selecting optimal weights for study input and output variables, it tries to increase this unit's efficiency drop so that the other units' efficiency doesn't exceed more than one. This model has been outlined in two input oriented and output oriented and in three forms of fraction, multiplier and envelopment. Regarding the envelopment form specifications, envelopment form CCR model in input oriented has been chosen for this research. The input oriented envelopment form solution directly depicts the study units' relative efficiency and if they obtained (θ^*) for each unit equals 1, it means that the study unit is efficient and if it is smaller than 1, it is inefficient. The significant issue in CCR model is that if compared with input and output number, the study units number doesn't differ much, after solving the problem we will see that most units as efficient. This has been followed well in the current study.

In final CCR model solution in input oriented, if equals 1, it means that the study unit is efficient and otherwise, it won't be efficient¹.

4. Constant Return to Scale

Production technology has constant return to scale, i.e., if input (X) produces output (Y) , then it will produce (λX) and (λY) . Put in other words, any input change will equally create changes in output. In other words, input increase will neither cause saving nor costs raise. Of course, the above definition requires that no constant cost exist in production. That is, (0) input produces (0) outputs.

Generally speaking, constant return to scale means any input multiplier produces the same output multiplier. CCR model in input oriented assumes the units' return to scale as constant².

5. Efficiency

Efficiency is a very broad and comprehensive concept discussed more in engineering, management and economics fields. Efficiency indicates this concept as to how well an organization has employed its resources for production to the best performance within a period of time^{13,14}.

In other words, efficiency is the performance criterion of an organizational system established based on the resources level or the input and the consumed resources for production shows a certain amount of product.

DEA technique is of non-parametric and multi-criteria methods for the units' decision making and efficiency measurement.

In DEA, the efficiency of a decision making unit is determined to other decision making units' efficiency regarding their input and output values.

Efficiency is a concept with long history in diverse disciplines and efficiency measurement and analysis suggests how the units can use their resources to achieve the best performance and increase production within a period of time¹².

In terms of the applied goals, several definitions have been presented for efficiency. Overall, efficiency refers to output to input ratio compared with a certain standard.

Efficiency measurement and its computations have stimulated most economists in late 20th century. Measurement methods are generally production efficiency frontier and getting frontier curve or frontier production function via two parametric and non-parametric methods. DEA was proposed by⁴. Using linear programming, in this method, various units' efficiency frontier is determined as performance standard and the units' efficiency is measured compared with that and defined as a degree of efficiency. Coeli displayed that out of diverse methods for performance evaluation, DEA has two major advantages for efficiency measurement:

- First off, it doesn't require specifying a form of function among the input and output, that is, the researcher can avoid the limiting conditions for choosing production function form or cost function influencing efficiency analysis results^{4,6,7}.
- It doesn't need statistical distributions assumption for efficiency elements. On the other hand, using DEA, we can propose an efficient unit or units as the reference one for each of the inefficient units and show the optimal input and output structure as linear combination for each of the inefficient units. In fact, besides computing various kinds of efficiency, this model presents a proposed program for inefficient units, based on which each input optimum level and its ideal level get accessible for output, presentation and efficiency gets maximum.

6. Efficiency Types

6.1 Technical Efficiency

Most studies done before 1950s are based on this type of efficiency, that is, maximum possible production level obtained by certain amount of production factors and technical efficiency that only emphasizes using all resources capacity and considers the unit efficient subject to not wasting resources and using all of them.

6.2 Specialized Efficiency

It indicates the existing factors optimal assignment dimensions, so that it accompanies minimum cost for the unit and in simpler words, it can be stated that specialized efficiency results from using appropriate input ratio that minimizes production cost.

6.3 Economic Efficiency

This kind of efficiency is the technical efficiency multiplied by the specialized efficiency. As the definition states, the economic efficiency is the capability of the unit to gain the maximum potential profit regarding the price and input levels and in fact, economic efficiency is realized if in addition to resources loss, they are used in the best way. To gain this order usually requires selecting a combination of the input, which incurs the least costs.

7. Using DEA Method

DEA is a non-parametric and linear programming based model coined by Charnes & Cooper et al. in 1987 to evaluate the relative efficiency of decision making units taking up similar tasks⁴. It is worth mentioning that since 1987, a lot of advancement and development has occurred in this area. The DEA models potential to meet the applied demands resulted in performing broad studies in the scientific fields as mathematics, management, economics and engineering. It can be claimed that due to DEA successful uses and applied specifications and also the published case studies in the past years, this technique has developed increasingly.

Data storage efficiency assessment¹¹, bank branches performance assessment^{3,8}, analysis of the financial condition of the organization⁵, higher education institutions' efficiency measurement¹⁰, facility layout design⁹, organizations IT based investment efficiency evaluation¹³ and information system projects prioritization¹⁴ are some applications of this technique.

DEA models are proper tools to measure the identical decision making units' efficiency but in contrast, it is possible to correctly extract input and output parameters and their related information as much as possible in order to design a model very close to reality and the result can bring about the process and operation progress and improvement.

DEA uses mathematical programming able to apply lots of variables and relations (constraints) and it is free from the existing input and output number limitation like other methods. It provides the simplicity of computation, evaluation and limitation free factors selection, the possibility to deal with more complex existing problems in management and policy making. In addition, the robust mathematical programming theory makes analysis and interpretation easier. This technique provides

some opportunities for analysts and decision makers collaborating including cooperation in selecting input and output used in the model.

8. PAK Dairy Company History

Tehran based PAK Pasteurized Dairy Company (Joint Stock Co.) was formed as one of the first dairy products producing companies in Iran dated 12 March 1960, holding the trade name “PAK Pasteurized Dairy Joint Stock Company” and established on 15 March 1960 under No. 7205 at Tehran Companies Registration Office and Industrial Ownership with Permit 321/20/4801 of the Ministry of Industries and Mines under U.S.A. Foremost Company License and started working receiving 24 tons of raw milk daily. Referring to the Exceptional Agenda of the General Assembly dated 24 November 1971, its name and kind tuned to “PAK Pasteurized Dairy Company” (Joint Stock Co.)” and at the General Assembly dated 18 November 1975, its trade name and kind changed to “PAK Pasteurized Dairy Company” (Joint Stock Co.) due to the newspaper notice No.9015 dated 14 December 1975.

This company bought the ice-cream producing facility “Canada Frost” and two years later, in 1972, it added “Eldorado” ice-cream producing facility in Canada to its assets list. In 1974, it invested in “Sepahan dairy farm”. This company was listed in Tehran Stock Market in 1976. After Iran Islamic Revolution in 1978, following the existing government’s policies, PAK Company cut its relationships with American and Canadian companies. Then in 1997, it purchased 3 domestic and foreign companies called “PAKPEY” in Shahrekord, “PAKARA” in Sanadaj and “PAK SAMAN” in Tajikistan, became the possession of Pak Company in 1997. Buying “Mazandaran based Milk and Meat Complex” company in Sari happened in 1998, later changed to “PAKSAR”.

9. Statistical Population

In the current research, 23 PAK Dairy Company production lines have been analyzed and evaluated in terms of their efficiency. These lines are:

Milk 0.6%, milk 2%, chocolate milk 3%, fortified milk 0.5%, low-lactose milk 1.5%, caramel dessert 3.2%, chocolate cream dessert 3.2%, strawberry dessert 3%, probiotic yogurt 1.4%, yogurt 3.1%, stirred yogurt 5%, shallot yogurt 5%, breakfast cream 30%, chocolate cream 15%, date cream 30%, honey cream 30%, confectionery

cream 35%, sweet confectionery cream 28%, mint and penny royal dough 1.5%, processed cheese 20% and butter 82% fat.

The above lines data have been processed by DEA-Solver software.

10. Data Collection and Analysis

The model used in the study is an input-oriented CCR model analyzing 23 PAK Dairy Company production lines in terms of efficiency level. This model has 5 parameters as input and 4 parameters as output. Part of the model’s available data including the raw material cost, human force cost, sales distribution cost, administrative and financial costs and profit percent have been obtained through cooperating with the accounting and financial department of PAK Dairy Company. Other information like product processing time, product life-time, products production tonnage have been extracted regarding the personal presence and experience and the researcher accessing the products production document. It is pointed out that all information have been integrated in terms of time and Rials.

11. Results

After being collected and analyzed, the aforementioned data have been processed using DEA-Solver and finally, each production line’s efficiency has been estimated. In addition, the input and output variations have been determined in order to increase the inefficient lines’ efficiency).

It has to be stated that all collected data in this research belong to Winter 2015.

Table 1 includes input oriented CCR envelopment model input data.

12. DEA Model Solution

After solving CCR-I model with DEA-Solver, it has been determined that the efficiency of 8 production lines as numbers 1-2-3-7-19-20-21-23 equals one. That indicates they are efficient. Also production line No. 17 with efficiency 0.2552 has been introduced as the poorest one.

The following table fully displays the production lines’ efficiency.

Besides, the production lines’ efficiency level can be observed in the following graph:

Table 1. Input oriented CCR envelopment model input data

Prod. Line No.	Raw Material cost(Rls.)	Human force cost(Rls.)	Sales distribution cost (Rls.)	Financial & admin. Costs(Rls.)	Product processing time(day)	Profit %	Product lifetime (day)	Customers satisfaction length	Production tonnage(Kg)
1	10639.6	1160.8	744.77	904.37	0.292	0.12	5	0.2	140000
2	15218	1660	1065.26	1293.53	0.033	0.13	5	0.4	12000
3	17040	1858	1192.8	1448.4	0.042	0.12	5	0.85	40000
4	21333	2327	1493.31	1813.31	0.167	0.12	5	0.35	30000
5	14825	1617	1037.75	1260.13	0.083	0.12	5	0.15	1000
6	18132	1978	1269.24	1541.22	0.083	0.12	5	0.2	2000
7	18108	1975	1267.56	1539.18	0.01	0.12	5	0.15	5000
8	37120	4050	2598.4	3155.2	0.125	0.12	20	0.05	1000
9	37080	4040	2595.6	3151.8	0.125	0.12	20	0.15	1000
10	33200	3620	2324	2822	0.125	0.13	20	0.1	1000
11	25140	2740	1759.8	2136.9	1	0.12	20	0.2	40000
12	20747.6	2263.2	1452.33	1736.55	1	0.12	20	0.5	40000
13	39312	4288	2751.84	3341.52	1	0.13	30	0.2	5500
14	35680	3890	2497.6	3032.8	1	0.12	25	0.3	5000
15	50770	5540	3553.9	4315.45	0.167	0.12	7	1	18000
16	62160	6780	4351.2	5283.6	0.167	0.12	10	0.95	8000
17	64240	7010	4496.8	5460.4	0.167	0.12	10	0.5	2000
18	64240	7010	4496.8	5460.4	0.167	0.13	10	0.95	6000
19	48694.6	5312.2	3408.62	4139.04	0.125	0.12	240	1	15000
20	46606.8	5084.4	3262.48	3961.58	0.125	0.12	240	1	3000
21	10839.23	1182.31	758.75	921.33	1	0.12	60	0.1	50000
22	140070	15280	9804.9	11905.95	0.042	0.12	45	0.3	500
23	163790	17870	11465.3	13922.15	0.017	0.12	365	1	15000

13. Input Mode CCR Model

13.1 (PAK Dairy Company) Graph 1

Having determined the production lines efficiency level, it has been set that 8 production lines have been efficient with efficiency 1. In order to raise other production lines' efficiency, some changes have to be applied on their input and output. These variations result in efficiency increase of other production lines so that efficiency reaches 1.

14. Discussion

In the current study, efforts have been made to analyze all PAK Dairy Company production lines regarding their input and output in order to ultimately define which production line is efficient and which ones require some changes and modification in their input and output to reach efficiency. After performing input oriented CCR envelopment model related computations, it has been established that 8 PAK Dairy Company production lines' efficiency equals 1, indicating that they are efficient and consequently, other production lines determined as inefficient. In the continuation, some solutions are proposed

to change the inefficient production lines' input and output in order to raise their efficiency reaching 1.

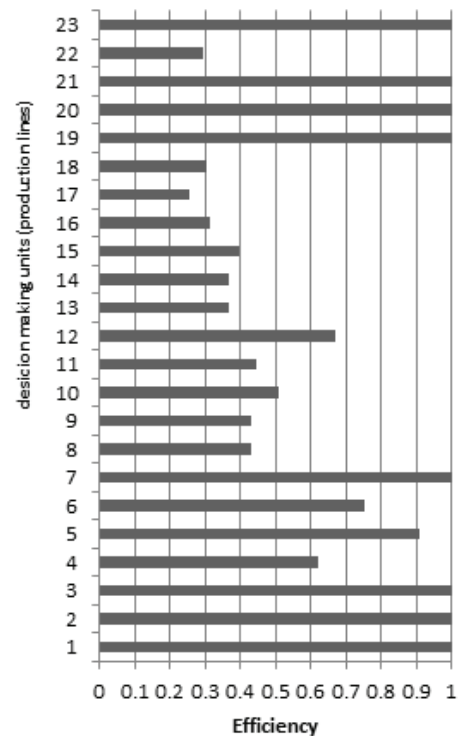
It deserves noticing that this research has been done in a certain time range and the gained results are exclusively related to that time period, so the results can't be viewed absolute to adopt these results as a permanent heading for production project. Rather DEA model can be solved again in future by collecting more up-to-date data and define production lines' efficiency.

15. Conclusion

Considering the results obtained by solving input oriented CCR envelopment model, it has been determined that the efficiency of 8 production lines equals 1 and other ones are inefficient and the 8 above mentioned units have been identified as the reference ones in this study. This study extracted results can be handed to PAK Dairy Company decision makers and middle and operations managers so that they could decide about the company production lines and apply some variations in the production lines' input and output, if necessary. Moreover, they could increase efficient production lines' tonnage since these production lines produce some products accompanying efficiency and their input and output ratio is fairly ideal.

Table 2. Production lines' efficiency

Production line No.	Efficiency level
1	1
2	1
3	1
4	0.6237
5	0.9110
6	0.7543
7	1
8	0.4298
9	0.4307
10	0.5113
11	0.4460
12	0.6708
13	0.3692
14	0.3685
15	0.3974
16	0.3144
17	0.2552
18	0.3043
19	1
20	1
21	1
22	0.2933
23	1



By imposing some changes on the production line's input and output and solving DEA models before executing their decisions and operationalizing production projects, the decision makers could determine the line's

efficiency and in case of observing a production line with poor efficiency, they could revise that line and redo the computations.

Table 3.

Pro. line No.	Raw material cost(Rls.)	Human force cost(Rls.)	Sales distribution cost(Rls.)	Financial & administrative cost(Rls.)	Product processing time(Day)	Production tonnage(kg)	Customers satisfaction %	Product lifetime (Day)	Profit %
4	-8028.0865	-875.663	-561.9661	-682.3873	-0.0627	18505.5755	-	-	-
5	-1321.5827	-143.9907	-92.5108	-112.3345	-0.0074	32310.7763	0.1909	-	-
6	-4455.2899	-486.0986	-311.8703	-378.6996	-0.0205	24854.8947	0.1494	-	-
8	-21167.4313	-2309.8277	-1481.7202	-1799.2317	-0.0713	17852.3198	0.3495	-	-
9	-21128.986	-2299.9972	1479.029	-1795.9638	-0.0712	17910.2411	0.2494	-	-
10	-16233.2756	-1769.1965	-1136.3293	-1379.8284	-0.0611	22635.3885	0.3242	-	-
11	-13937.6144	-1517.8907	-975.633	-1184.6972	-0.554	75802.2533	-	-	-
12	-6830.9762	-745.4965	-478.1683	-580.633	-0.641	25104.8951	-	-	-
13	-24800.4097	-2704.8247	-1736.0287	-2108.0348	-0.6308	126356.2815	0.0732	-	-
14	-22539.3063	-2456.5255	-1577.7514	-1915.841	-0.6315	101866.3243	-	-	-
15	-30596.1484	-3340.2805	-2141.7304	-2600.6726	-0.1173	28848.4925	-	-	0.0211
16	-42614.7965	-4648.7915	-2983.0358	-3622.2577	-0.1187	35875.6281	-	-	0.0137
17	-47847.7805	-5222.0404	-3349.3446	-4067.0613	-0.1241	17816.6478	-	-	-
18	-44694.7965	-4878.7915	-3128.6358	-3799.0577	-0.1187	37875.6281	-	-	0.0037
22	-98991.1523	-10798.778	-6929.3807	-8414.2479	-0.0294	6870.1954	-	16.8225	-

Also ahead of launching the new production line, the decision makers could collect data and determine its input and output and carry out DEA models computation in order to figure out that production line's efficiency. This way they could decide to apply the necessary revision in that line's input and output if their production line doesn't have optimal efficiency.

It's worth to point out that in the existing study, DEA model's input and output have a sort of variety and different parameters like the product processing time, some production costs and satisfaction level, so if possible this research be done with cost, quality and human resources based approach in the future studies. However, conducting this research with fuzzy approach could give a highly applied and novel solution in this area.

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