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Cost Efficiency of Construction Firms in Libya Using the Data Envelopment Analysis Method

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ABSTRACT

Using a non-parametric technique for data from 1995 to 2005, we investigate the cost efficiency of 26 Libyan construction firms. The results indicate that overall these firms experienced a fairly low level of inefficiency of 38.33 percent. 42.31 percent of the firms operate above the average efficiency score, while 57.69 percent below it. Only 2 firms scored full efficiency (CE = 1.00). The results indicate that some of these firms did not optimize the use of their resources that could improve their efficiency levels. As this is also a longitudinal study to examine the implications of the UN sanctions (1992-1999) and the liberalized open door policy (2003 onwards) on cost efficiency scores, the results show that the period of 2003-2005 has high number of firms with full efficiency, while the period of 2000-2001 has low number of firms with full efficiency. Up to 2005, the lowest rate was in the period 1995-2001 of which cost efficiency scores declined from 0.652 to 0.411. In terms of scale of production, a majority of inefficient firms are operating at increasing returns to scale implying optimality problem in relation to resource usage. The results also show that larger firms are more efficient than smaller firms. From the results above, we could say that large firms did not gain from economies of scale, but from other factors that need to be investigated in future research with the exception of date of establishment as the variable age has no influence on cost efficiency scores.

Keywords: *Libya; Cost efficiency; Data envelopment analysis, Construction firms; Scale of production; Optimal.*

INTRODUCTION

The importance of the construction industry in contributing to Libyan economic growth is undeniable. The process of exploiting local resources to construct buildings contributes to an increase in GDP and provides employment opportunities. Libya is a rich country with abundant natural resources, for example iron quarries in Sabha; and clay, silicon, and sulfur in the Gharian mountains, Benghazi and Darnah respectively. These resources are used in manufacturing cement, brick and glass. Nevertheless, Libya relies primarily on oil and natural gas as its main source of income. Given this background, the motive of this study is to evaluate the performance of firms in the construction industry on the aspect of efficiency. This is timely as this action would not only increase production of its member firms and support GDP growth, but more importantly efficiency performance evaluations serve as a benchmark to make them sustainable and competitive.

The Libyan economic policy before 1978 was under the capitalist system. After that, it adopted the socialist system, when the leader of Libya, Colonel Muammar Qadhafi, published his green book. Unfortunately, during this transition, the United Nations (UN) imposed sanctions on Libya in 1992. However, when the UN lifted its sanctions in 1999, Libya introduced socioeconomic reforms to liberalize its socialist system so that an open market policy could be adopted.

Coincidently, the suspension of the UN sanctions occurred at a time when global demand for petroleum products was increasing and oil prices were improving. As a result, Libya's hydrocarbon-based revenues increased sharply between 1999-2003, contributing

about 50 percent to GDP, 97 percent to exports, and 75 percent to government revenue. This made Libya continue to rely heavily on oil and natural gas revenues.

Libyan construction industry, only contributes about 5 percent to GDP and employs only about 20 percent of its 1.6 million population that were employed in 2004. Construction firms, like other firms, are owned by the government, which may explain the reason behind the low productivity and efficiency due to low competition (Central Libyan Bank, 2004). The Libyan economy also faced mounting unemployment problems, compounded by high rate of population growth and a low rate of job creation and low efficiency (EIU, 2004). Despite the fact that in 2003, Libya shifted from public ownership to open market and invited foreign and local investors to invest in all active economic corners (John, 2008). Hence, the issue that is raised in this study is whether the government policy of open market has really increased the efficiency of the construction firms.

The low efficiency in the construction industry might be explained by several factors that typically affect performance. Inabilities of the firms to take advantage of scale economies, difficulties in getting some resources in terms of qualified human capital and skills, and the industry's dependency on government funding might possibly be some of the reasons for low efficiency. Also, it appears that almost all the firms, particularly the ones that have been long in the business, adopt weak technology, and the majority of workers have a low level of education and knowledge. An important cause might be the weak system of incentive and salary structure which Libya is still applying based on the old salary system,that has persisted unchanged since 1981.

The objectives of this study are thus to evaluate the cost efficiency of Libyan construction firms and to examine the impact of the open market system on the efficiency of these firms. Improved cost efficiency is important as it sustains competition, supports GDP growth and contributes to diversification of income, as well as reduces the dependence on oil and natural gas for Libya.

This paper is organized into five sections. The next section discusses the relevant literature followed by the methodology in use, empirical results, and conclusion and suggestions for future research.

LITERATURE REVIEW

There is an abundance of literature on firm-level frontier efficiency studies. However, the bulk of studies go to analyze firms in developed countries and financial institutions, particularly banks. Only few studies investigate the other types of industries such as manufacturing, construction and agricultural; and the public sectors such as schools and hospitals. In addition, for most of these studies, technical efficiency has been evaluated to a greater extent than cost and profit efficiency.

Studies of technical efficiency (TE) in the long run are usually aimed to look at its contribution to total factor productivity (TFP) as TFP can be decomposed into technical efficiency and technical progress (Nishimizu & Page, 1982). Moreover, measuring TE for the individual firm is more meaningful because of micro data and further analysis of factors that influence TE can be investigated. Hence, many studies of TE are conducted at firm level (Danlin *et al*., 2001; Mahadevan, 2000; Tay, 1992; Wu, 2003; Yao & Zhang, 2001). Additionally, a study by Wu (2000) on all APEC countries using the stochastic frontier parametric technique found that

technical progress was a dominant contribution to total factor productivity growth, while technical efficiency also contributed, but on a small scale.

There are also studies evaluating farm efficiency using the non-parametric technique (Byrnes *et al*., 1987; Weersink *et al*., 1990). (Byrnes *et al*., 1987) found that the major source of technical inefficiency in the Illinois grain farm was scale inefficiency, while (Weersink *et al*., 1990) found that the source of efficiency in the Ontario dairy farms was pure technical efficiency. Whereas in other studies, efficiency was related to farm size, financial structure and degree of specialization (Chavas & Aliber, 1993; Featherstone *et al*., 1997; Kalaitzandonakes *et al*., 1992). A study by (Wu, 2003) found that efficient firms were in the transport machinery and sugar processing sectors, while the inefficient ones were in consumer electronics, telecommunication, and equipment repair sectors.

In Malaysia, Mohd Noor and Ismail (2004) studied technical efficiency and its determinants for 138 manufacturing firms. They found that only 6.3 percent of firms were fully efficient using CRS estimates, and 92.6 percent of firms were not efficient with less than 0.5 percent efficiency scores. Further, this study found that level of mechanization and firm size significantly and positively determine the level of technical efficiency. Ismail and Sulaiman (2007) evaluated technical efficiency of 264 Malay manufacturing firms over the 2001 to 2002 period. The results show that majority of Malay firms are operating inefficiently and more efficient firms are found in the metal and fabricated metal products sectors. The findings also demonstrated determinants of efficiency to be R&D expenditure, training expenditure and level of technology.

On another strand of efficiency studies, a majority of studies evaluating financial institutions, particularly banks, concentrate on cost efficiency. However, as to the technique employed, various studies have examined cost efficiency using parametric techniques

(Berger & DeYoung, 2001, 2006; Berger & Mester, 1997, 2003; Clark & Siems, 2002; Rogers, 1998). Hence, our study is distinct as it investigates the construction industry, of which this sector has limited efficiency studies, and employs the non-parametric frontier technique of Data Envelopment Analysis (DEA).

METHODS

During the past few decades, firms around the world experienced profound regulatory and technological changes. Advanced applications in computer and communications technology have significantly modified the technology of firm's production and efficiency. This subsequently altered the way economists look at the functions performed by those firms by measuring their efficiency levels. One of the popular techniques used in the literature to evaluate efficiency of firms is Data Envelopment Analysis (DEA) as this technique is able to evaluate the components of Total Factor Productivity (or TFP). Non-parametric linear programming method of measuring (in) efficiency is fundamentally based on the work of Farrell (1957) which was further extended by Charnes *et al*. (1978) and Banker *et al*. (1984). This technique (see (Fare & Grosskopf, 1985) has been widely used in empirical efficiency (or productivity) analysis of firms because of its ability to evaluate firms that use multiple inputs to produce multiple outputs, and to overcome problems in defining weights and/or specifying functional forms to be employed in analysis as faced by the parametric techniques.

Cost efficiency is used to measure optimum inputs or outputs according to input unit costs of each company. The following linear programming model is used for this optimization which has been introduced by Farrell (1957).

$$
\begin{aligned}
&[\cos t] \qquad cx^{*} = \min\ cx \\
&\textit{Subject to} \qquad x \geq X\lambda \\
&\qquad\qquad\ \ y_0 \leq Y\lambda \\
&\qquad\qquad\ \ \lambda \geq 0
\end{aligned}
\qquad (1)
$$

where c =(c_1,…., c_m) is the common unit input price or unit-cost vector.

$X\ \lambda$ and $Y\lambda$ are the input and output vectors of the analyzed production unit. X and Y describe virtual inputs and outputs.

Cost efficiency ≤ 1 represents the ratio between the minimum costs (c *) which is associated with the use of the input vector (x^{*}) that minimizes costs and the observed costs (c) for a firm.

$$0 \leq \frac{cx^{*}}{cx_0} \leq 1 \qquad (2)$$

where x^{*} is the optimal or target input and x_0 is the observed or current input for a firm.

DATA

Data for this study were obtained from secondary sources relating to 26 Libyan construction firms for the period 1995-2005. They are located in all of the different states and operate at different sizes - small and large. The sample consists of 6 types of enterprises, namely, iron and steel; cement; bricks; glass; paint; and pipes. The variables used to analyze cost efficiency are three inputs (labor, physical capital and financial capital) and two outputs (revenue and profits). We used wages and benefits as proxy for labor expense.

The physical capital expense consists of building and equipment depreciation. The financial capital is total equity. The price of labor is calculated by dividing total personnel expenses on wages and fringe benefits by total number of employees. The price of physical capital input is computed by dividing total capital expenses by total assets as also done in (Tsu-Tan *et al*., 2008). The price of financial capital input is computed by dividing total equity by total tax expense. All the companies are state-owned and hence do not have shareholders. Therefore, in consideration for the capital funds that they received from the state government, the firms pay income taxes.

RESULTS AND DISCUSSION

This section focuses on the results of cost efficiency. For the computation of the cost efficiency scores, the DEA-Solver developed by Zhu (2003) is used. This new software has been adapted from the former form (Coelli T J, 1996) which employed input orientation. The DEA technique will produce results at constant returns to scale (or CRS).

The best performers will be determined by their ability to produce outputs with minimal use of resources (inputs). The score of cost efficiency means that optimal inputs should be used in order to produce certain level of output. This study applies the DEA model to firms in the Libyan construction industry with full efficiency indicated by 1.00 and that which is less than 1.00 is considered to be inefficient. Table 1 refers to the cost efficiency scores of the sampled firms with average efficiency score of 67.62 percent. Full efficiency was achieved by only 4 firms. 12 firms have efficiency scores more than average (46.15 percent) and 14 firms have less than average or 53.85 percent. The low efficiency scores might be due to the constraints brought about by the international sanctions imposed on Libya then. Table 2 shows the current total cost against optimal cost of producers. Table 3 illustrates the level of current cost that should be reduced to get optimal cost. Table 4 and Figure 1 refer to efficiency scores across years and average efficiency. The average efficiency score in Figure 1 shows a score of less than 0.70. As shown in Table 4, there are only two firms with full efficiency, representing 7.69 percent. In 1997, the average efficiency score was less than 0.41 and this might be due to many reasons such as termination of some production lines, especially in the cement factories and iron, and absence of renewing production lines for many years, as well as obsolescence of some factories such as Marble plant, Tiles plant, Janzoor plant and Swany baked brick plant.

Table 5 displays the level of reduction in inputs, namely assets; equity; and employees across years to reach optimal efficiency.

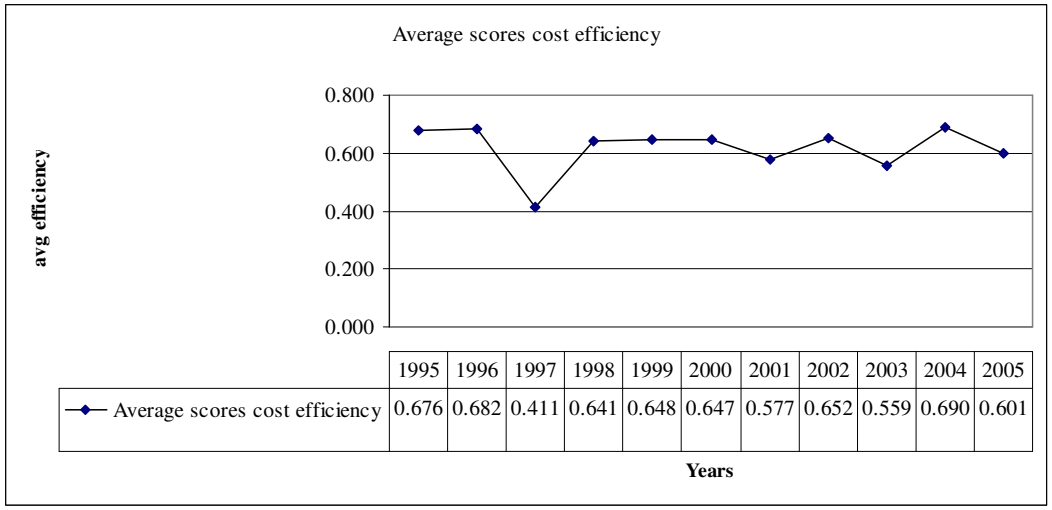
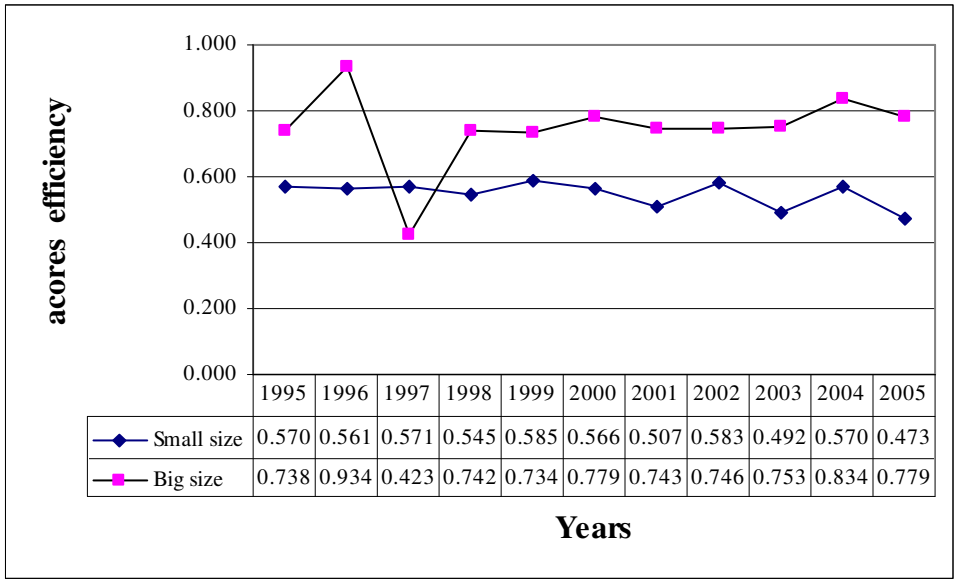


Figure 1: Cost efficiency scores across years

Figure 2 shows the efficiency scores of firms for the period 1995-2005 based on firm size. There are several ways of classifying firms by size in the literature. Employment, sales and total assets are the most commonly used (Karl & George, 2000). For the purpose of this study, we used total assets. We divided the sample into two groups based on the value of total assets. 15 million Libyan dollar or more is categorized as large-sized firms and small-sized firms have total assets less than that amount. By looking at the trend of efficiency scores across years, the larger firms seem to be more efficient than the smaller firms.



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Small size	0.570	0.561	0.571	0.545	0.585	0.566	0.507	0.583	0.492	0.570	0.473
Big size	0.738	0.934	0.423	0.742	0.734	0.779	0.743	0.746	0.753	0.834	0.779

Figure 2: Efficiency scores according to size

In the small size category, there is only 1 firm with full efficiency. The average efficiency score is 49.8 percent. Only 8 firms have more than the average score and this represents 61.54 percent. 5 firms have efficiency scores below the average (representing 38.46 percent). Meanwhile, in the large size category, the average cost efficiency is 67.8 percent with 1 firm scoring full efficiency; this represents 7.69 percent. Finally, only 4 firms have more than the average score, which represent 30.77 percent and only 8 firms have scores below the average (representing 61.54 percent).

Figure 2 illustrates the efficiency scores of firms based on age. Again, we divided the sample into two groups, old and new. The old firms were established before 1980 and the new ones were established after that. From the trend of the scores, we find that

generally the efficiency scores of firms are not a consequence of age. This indicates that date of establishment is not important in influencing efficiency of the firm.

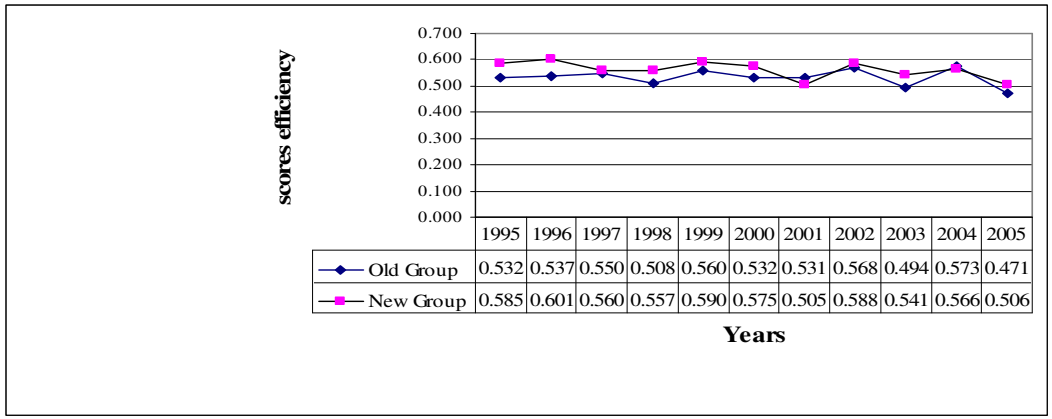


Figure 2: Efficiency scores according to firms' age

Table 4 shows that firms scoring full efficiency across the period of study are mainly in the 2003-2005 period. The period 2000-2001 has the lowest number of efficient firms, and firms experiencing average efficiency are mainly in the 2003-2005 period. Up to 2005, the lowest rate was in the period 1995-2001 of which the efficiency scores declined from 0.652 to 0.411. This might have been due to the impact from the international sanctions which were imposed on Libya for more than 11 years.

This study suggests that Libyan firms should reduce their inputs in order to produce the same level of output or they must increase their output with the same level of inputs as suggested in Table 5 for the input variables of asset, equity and employee. Meanwhile, to

attain optimal cost, firms should operate well enough to reach the target as suggested in Table 5. Table 5 indicates the specified capacities that firms need to produce.

CONCLUSION AND POLICY IMPLICATION

The main findings of the study are summarized as follows. Overall, Libyan construction industry is characterized by a fairly low level of inefficiency, to the extent that companies' costs are only about 38.33 percent above the estimated cost frontier. As shown in Table 4, 2 firms namely, Souk Alkames cement plant and Samaka painting company, were operating with full efficiency; this represents 7.69 percent of the sample, while 57.69 percent were operating below the average efficiency score.

The results also show that larger firms were more efficient than smaller firms. However, interestingly, efficiency scores are not a consequence of age. This might indicate that in Libya, being old might be related more with bureaucracy and clumsy formal organizational forms rather than with learning by doing. Interestingly, change in government policy has a strong effect on cost efficiency in that after the open door policy, efficiency scores gradually increased in value.

Cost efficiency is crucial for companies to compete head-on, especially in this era of globalization and liberalization. However, this study shows that majority of firms in the construction industry are operating inefficiently and some of them do not optimize the use of their resources that could contribute significantly to their efficiency level. Hence, the analyses suggest that the firms should reduce their inputs in order to produce the same level of output or vis-à-vis they must increase their output with the same level of inputs as indicated in Table 5 for the inputs: assets, equity and number of employees.

Meanwhile, in order to increase the level of technology in the construction industry, firms must operate on a larger scale. Besides easier adoption of advanced technology by large-sized firms, the advantage of operating at a larger scale could also be viewed from the economies of scale perspective. That is, when firms operate on a large scale, they would gain by economies of scale that could reduce average cost of production; hence they will have comparative advantage in terms of pricing by lowering price per unit output. The results indicate that majority of inefficient firms are operating at increasing returns to scale (IRS). Only 3 firms with full efficiency are operating in constant returns to scale (CRS) and 7 firms are operating in decreasing returns to scale (DRS). Those firms which perform on the IRS should increase using their resources to get to CRS, and the firms that operate on DRS should decrease their input use to reach CRS, which is full efficiency. Additionally, in terms of size, the larger firms are more efficient than smaller firms, and generally, cost efficiency scores of firms are not a consequence of date of establishment or specifically age of the firm.

The other issues we looked into were the implications from the change of government policy (2003 onwards) and the international sanctions imposed on Libya by the UN (1992-1999) on cost efficiency scores. The results show that the period 2003-2005 has high number of firms with full efficiency, while the period 2000-2001 has low number of firms with full efficiency, and firms experiencing average efficiency are mainly in the 2003-2005 period. Up to 2005, the lowest rate was in the period 1995-2001 of which the efficiency scores declined from 0.652 to 0.411.

Based on the reported findings, a number of policy implications have been suggested. First, as most companies are owned and controlled by the State, it would be beneficial if this is continually pursued to sustain growth and prosperity, and to meet future challenges. Hence, it would be more appropriate for the government to take the necessary measures such as giving high priority to

improve efficiency. Especially after the government liberalized the economic system from public ownership and state control of all factories and projects' to open market in 2003, which resulted in increased competition in the domestic market. Hence, it would be beneficial to introduce strategies to face the new environment.

Additionally, the government also needs to lift the barriers to entry of private and foreign companies, allowing market forces to dictate economic condition instead; therefore improving the efficiency of firms. Furthermore, the government needs to continue with the policy subsides as support for the firms to face competition, and also impose tax on the important goods in order to protect domestic products from foreign competition.

Finally, the study provides a guide for the industry to evaluate cost efficiency and hence chart their milestones in achieving the desired level of efficiency over a designated period of time. The information from the evaluation can be used to improve managerial performance, identify the strength and weaknesses of firms and, introduce strategies to improve their competitive positioning. In this regard, the results of this study are useful for managerial and state management to help them make informed decisions. Moreover, this study has applied the flexible nonparametric technique which is the DEA. Future research can be extended to formulate and implement a dynamic measure of efficiency study by using the parametric approach.

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APPENDIXES

Table 1: Cost efficiency and Benchmark – DEA (CRS)

DMU No.	DMU Name	Cost Efficiency	Min Cost	$\sum\lambda$	RTS		Benchmarks		
1	Al-Marghab cement plant	0.77125	24308991.421	0.888	Increasing	0.070	Souk Alkames cement plant	0.818	Samaka painting Company
2	Libda cement plant	0.91292	93166247.006	1.236	Decreasing	0.699	Souk Alkames cement plant	0.537	Samaka painting Company
3	Zlitan cement plant	0.71526	100098434.093	1.613	Decreasing	0.532	Souk Alkames cement plant	1.081	Samaka painting Company
4	Souk Alkames cement plant	1.00000	94974908.304	1.000	Constant	1.000	Souk Alkames cement plant		
5	Banghazi cement plant	0.62751	57562025.445	1.215	Decreasing	0.546	Souk Alkames cement plant	0.669	Anapip Rawi Bangazi Plant
6	El-Fataiah cement plant	0.67104	55241143.257	1.673	Decreasing	1.362	Souk Alkames cement plant	0.311	Anapip Rawi Bangazi Plant
7	Al-Hawari cement plant	0.56303	56771236.069	2.125	Decreasing	2.125	Anapip Rawi Bangazi Plant		
8	Al_kyaas of cement plant	0.20103	2836270.068	0.339	Increasing	0.173	Souk Alkames cement plant	0.166	Samaka painting Company
9	Anapip Bangazi Plant	0.74007	20706084.090	0.503	Increasing	0.238	Souk Alkames cement plant	0.265	Anapip Rawi Bangazi Plant
10	Anapip Halazoon Bangazi Plant	0.76680	18609437.972	0.439	Increasing	0.253	Souk Alkames cement plant	0.186	Anapip Rawi Bangazi Plant
11	Anapip Rawi Bangazi Plant	1.00000	26971146.631	1.000	Constant	1.000	Anapip Rawi Bangazi Plant		
12	Swany Baked brick Plant	0.46418	5112362.420	0.396	Increasing	0.039	Reinforced Concrete Plant	0.357	Samaka painting Company
13	Reinforced Concrete Plant	1.00000	4536174.879	1.000	Constant	1.000	Reinforced Concrete Plant		
14	Marble Plant	0.53647	2058519.922	0.285	Increasing	0.226	Reinforced Concrete Plant	0.059	Samaka painting Company
15	Tiles Plant	0.56739	1519874.726	0.223	Increasing	0.188	Reinforced Concrete Plant	0.036	Samaka painting Company
16	Janzoor Baked brick Plant	0.11356	1457568.631	0.399	Increasing	0.378	Reinforced Concrete Plant	0.021	Samaka painting Company
17	Samaka painting Company	1.00000	8283598.189	1.000	Constant	1.000	Samaka painting Company		
18	plant of Aziziyah flat glass	0.73784	18826470.329	0.378	Increasing	0.378	Anapip Rawi Bangazi Plant		
19	plant of Aziziyah hollow glass	0.80763	11349980.132	0.194	Increasing	0.194	Anapip Rawi Bangazi Plant		
20	Direct reduction plant (steel)	0.55996	231301341.082	1.375	Decreasing	1.103	Souk Alkames cement plant	0.272	Anapip Rawi Bangazi Plant
21	steel melt shop No.1	0.62821	262234882.983	1.486	Decreasing	1.343	Souk Alkames cement plant	0.143	Anapip Rawi Bangazi Plant
22	Steel Melt Shop No. 2.	0.60893	226184667.329	1.223	Decreasing	1.223	Souk Alkames cement plant		
23	Bar and Rod Mills. (steel)	0.63753	200880018.638	1.172	Decreasing	1.042	Souk Alkames cement plant	0.130	Anapip Rawi Bangazi Plant
24	Lught and medium section Mill	0.62530	286256612.432	1.540	Decreasing	1.540	Souk Alkames cement plant		
25	Hot Strip Mill. (steel)	0.69448	252495990.459	1.603	Decreasing	1.116	Souk Alkames cement plant	0.488	Anapip Rawi Bangazi Plant
26	Cold Rolling Mill (steel)	0.63182	198958938.824	1.755	Decreasing	0.974	Souk Alkames cement plant	0.780	Anapip Rawi Bangazi Plant

Table 2: Current (Observed) cost and Optimal cost

DMU	Scores Efficiency	Current Asset	Current Equity	Current Employees	Total Cost	Optimal Asset	Optimal Equity	Optimal Employees	Optimal Total Cost
Al-Marghab cement plant	0.771	310961.081	1149649.028	209.000	31519031.649	123947.102	1373658.335	225.611	24308991.421
Libda cement plant	0.913	468133.175	2452570.206	747.000	102052874.775	262650.103	2721959.552	573.245	93166247.006
Zlitan cement plant	0.715	877864.702	2532066.560	601.000	139947502.662	285869.064	3040951.718	584.442	100098434.093
Souk Alkames cement plant	1.000	277584.200	2787089.333	651.000	94974908.304	277584.200	2787089.333	651.000	94974908.304
Banghazi cement plant	0.628	1130453.700	2695428.188	697.000	91731431.480	427687.865	2193650.236	631.180	57562025.445
El-Fataiah cement plant	0.671	1972554.520	4459932.437	599.000	82322018.635	506524.640	4107340.524	1014.714	55241143.257
Al-Hawari cement plant	0.563	2427759.409	3208986.278	545.000	100831272.582	877214.270	2132066.377	875.531	56771236.069
Al_kyaas of cement plant	0.201	455204.889	3103089.148	109.000	14108971.093	69176.502	720855.137	148.992	2836270.068
Anapip Bangazi Plant	0.740	373269.725	920106.057	432.000	27978591.611	175582.124	930254.151	264.377	20706084.090
Anapip Halazoon Bangazi Plant	0.767	315843.614	831858.782	365.000	24268939.067	147107.321	892803.875	241.579	18609437.972
Anapip Rawi Bangazi Plant	1.000	412792.191	1003290.053	412.000	26971146.631	412792.191	1003290.053	412.000	26971146.631
Swany Baked brick Plant	0.464	139095.405	532986.172	211.000	11013768.733	48168.466	539047.095	84.509	5112362.420
Reinforced Concrete Plant	1.000	64932.852	627268.026	151.000	4536174.879	64932.852	627268.026	151.000	4536174.879
Marble Plant	0.536	50119.154	227967.368	125.000	3837182.776	22236.015	227045.728	47.143	2058519.922
Tiles Plant	0.567	34168.134	169761.900	125.000	2678714.865	16732.109	168996.441	36.164	1519874.726
Janzoor Baked brick Plant	0.114	940157.253	269204.725	154.000	12835521.772	27251.400	267663.348	61.728	1457568.631
Samaka painting Company	1.000	127728.145	1440361.137	220.000	8283598.189	127728.145	1440361.137	220.000	8283598.189
plant of Aziziyah flat glass	0.738	272910.712	458724.765	295.000	25515574.591	156165.129	379558.828	155.865	18826470.329
plant of Aziziyah hollow glass	0.808	151124.701	216648.716	159.000	14053450.992	79990.527	194416.712	79.837	11349980.132
Direct reduction plant (steel)	0.560	1982471.710	3516183.200	951.000	413067571.377	418315.731	3346374.603	829.918	231301341.082
steel melt shop No.1	0.628	2014089.006	3559610.712	883.000	417430392.252	431785.171	3886026.436	933.097	262234882.983
Steel Melt Shop No. 2.	0.609	1745678.347	3177797.716	786.000	371446704.071	339609.242	3409852.927	796.463	226184667.329
Bar and Rod Mills. (steel)	0.638	1747023.764	2682200.176	667.000	315092618.667	343088.797	3035023.820	732.085	200880018.638
Lught and medium section Mill	0.625	2335509.088	3826577.070	968.000	457793881.824	427415.869	4291476.999	1002.390	286256612.432
Hot Strip Mill. (steel)	0.694	2015434.423	3030665.849	769.000	363574864.006	510951.176	3598434.437	927.139	252495990.459
Cold Rolling Mill (steel)	0.632	1695885.496	3797982.023	678.000	314898093.420	592593.865	3498490.974	955.805	198958938.824

Table 3: Proportion (%) of inputs to reach optimal cost

DMU	Difference Asset	Difference Equity	Difference Employees	Asset %	Equity %	Employees %	Change cost Asset	Change cost Equity	Change cost Employees
Al-Marghab cement plant	-187,013.979	224,009.307	16.611	-60.14063842	19.48501688	7.948039347	-3211.323786	233.6565233	42917.21631
Libda cement plant	-205,483.072	269,389.346	-173.755	-43.89414867	10.98396065	-23.26031254	-3280.706458	288.6466109	-81367.23481
Zlitan cement plant	-591,995.638	508,885.158	-16.558	-67.43586301	20.09762168	-2.755060158	-5914.618483	479.5703045	-11607.31397
Souk Alkames cement plant	0.000	0.000	0.000	1.10089E-11	1.10271E-11	1.12115E-11	1.70901E-09	1.97826E-10	3.24328E-08
Banghazi cement plant	-702,765.835	-501,777.952	-65.820	-62.16670662	-18.61589021	-9.443330634	-2182.109305	-345.3234312	-27794.19738
El-Fataiah cement plant	-1,466,029.880	-352,591.913	415.714	-74.32138707	-7.905768042	69.40131278	-1295.711473	-79.76792629	339788.8923
Al-Hawari cement plant	-1,550,545.139	-1,076,919.901	330.531	-63.86733107	-33.55950471	60.64785404	-1128.173077	-575.1887354	327893.4115
Al_kyaas of cement plant	-386,028.387	-2,382,234.011	39.992	-84.80321645	-76.7697574	36.68952778	-1478.450617	-148.4387081	58223.76853
Anapip Bangazi Plant	-197,687.601	10,148.094	-167.623	-52.96105938	1.102926568	-38.80162828	-1938.490003	16.57606499	-43802.91575
Anapip Halazoon Bangazi Plant	-168,736.293	60,945.093	-123.421	-53.42400017	7.326374912	-33.81406571	-1955.43464	103.0532276	-93326.84452
Anapip Rawi Bangazi Plant	0.000	0.000	0.000	1.08859E-11	1.11276E-11	1.12583E-11	3.32785E-10	1.46294E-10	3.17484E-08
Swany Baked brick Plant	-90,926.939	6,060.923	-126.491	-65.3701959	1.137163186	-59.94814797	-3963.581847	4.046116736	-194223.3805
Reinforced Concrete Plant	0.000	0.000	0.000	1.10037E-11	1.10055E-11	1.16698E-11	5.57811E-10	1.50001E-11	3.01082E-08
Marble Plant	-27,883.139	-921.640	-77.857	-55.63369897	-0.404285925	-62.28561011	-3299.617948	-1.185375976	-97775.98613
Tiles Plant	-17,436.025	-765.459	-88.836	-51.03007656	-0.450901242	-71.06848173	-3097.328082	-1.238608874	-78750.59516
Janzoor Baked brick Plant	-912,905.853	-1,541.377	-92.272	-97.10139979	-0.572566839	-59.91678933	-1200.28457	-2.272453976	-56670.87158
Samaka painting Company	0.000	0.000	0.000	1.10283E-11	1.0992E-11	9.99927E-12	5.17613E-10	8.18472E-12	5.52771E-08
plant of Aziziyah flat glass	-116,745.583	-79,165.937	-139.135	-42.77794093	-17.25782924	-47.16426042	-1214.447521	-629.6483767	-164879.2712
plant of Aziziyah hollow glass	-71,134.174	-22,232.004	-79.163	-47.06985234	-10.26177516	-49.78803945	-876.0984658	-505.3416377	-179027.3607
Direct reduction plant (steel)	-1,564,155.979	-169,808.597	-121.082	-78.89928373	-4.829344417	-12.73210725	-8679.22535	-262.8312109	-48519.05451
steel melt shop No.1	-1,582,303.835	326,415.724	50.097	-78.56176318	9.169983753	5.673506404	-8596.277574	498.1834285	23531.32426
Steel Melt Shop No. 2.	-1,406,069.105	232,055.211	10.463	-80.54571491	7.302390879	1.331203522	-9043.954123	395.6484162	5522.361376
Bar and Rod Mills. (steel)	-1,403,934.967	352,823.644	65.085	-80.36152659	13.15426219	9.757937606	-7652.113388	715.9005349	40442.86271
Lught and medium section Mill	-1,908,093.219	464,899.929	34.390	-81.69924188	12.14923732	3.552724871	-8454.194957	673.4091139	14742.08683
Hot Strip Mill. (steel)	-1,504,483.247	567,768.588	158.139	-74.64808727	18.73412038	20.56423651	-7109.59008	1041.167343	85298.98102
Cold Rolling Mill (steel)	-1,103,291.631	-299,491.049	277.805	-65.05696488	-7.885530972	40.97425351	-6238.235636	-308.2595331	230356.9925

Table 4: Cost efficiency scores of individual firms across years and average cost efficiency

Company	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Average	*Before	*After
Al-Marghab cement plant	0.771	0.870	0.485	0.884	0.966	0.753	0.885	0.911	0.698	0.592	1.000	0.801	0.816	0.763
Libda cement plant	0.913	0.997	1.000	0.885	0.954	0.930	0.887	0.860	0.847	1.000	0.913	0.926	0.928	0.920
Zlitan cement plant	0.715	0.800	0.335	0.668	0.797	0.904	0.910	1.000	0.930	0.957	0.758	0.798	0.766	0.882
Souk Alkames cement plant	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Banghazi cement plant	0.628	0.621	0.235	0.725	0.705	0.653	0.666	0.735	0.697	0.499	0.420	0.598	0.621	0.539
El-Fataiah cement plant	0.671	0.687	0.316	0.694	0.682	0.678	0.602	0.555	0.593	0.615	0.518	0.601	0.611	0.576
Al-Hawari cement plant	0.563	0.611	0.221	0.671	0.675	0.672	0.501	0.595	0.416	0.412	0.396	0.521	0.564	0.408
Al_kyaas of cement plant	0.201	0.289	0.261	0.225	0.442	0.348	1.000	0.539	0.253	0.898	0.419	0.443	0.413	0.523
Anapip Bangazi Plant	0.740	0.697	0.255	0.640	0.604	0.649	0.387	0.734	0.657	0.778	0.691	0.621	0.588	0.709
Anapip Halazoon Bangazi Plant	0.767	0.732	0.249	0.643	0.942	0.649	0.410	0.636	0.538	0.596	0.559	0.611	0.628	0.564
Anapip Rawi Bangazi Plant	1.000	1.000	0.723	1.000	1.000	1.000	0.736	1.000	1.000	1.000	1.000	0.951	0.932	1.000
Swany Baked brick Plant	0.464	0.459	0.430	0.231	0.243	0.258	0.253	0.323	0.302	0.307	0.303	0.325	0.333	0.304
Reinforced Concrete Plant	1.000	0.858	0.721	0.438	0.438	0.448	0.474	0.564	0.569	0.660	0.664	0.621	0.618	0.631
Marble Plant	0.536	0.378	0.378	0.275	0.219	0.578	0.263	0.849	0.531	1.000	0.227	0.476	0.435	0.586
Tiles Plant	0.567	0.451	0.505	0.283	0.230	0.262	0.194	0.233	0.147	0.199	0.183	0.296	0.341	0.176
Janzoor Baked brick Plant	0.114	0.115	0.090	0.112	0.128	0.153	0.161	0.142	0.098	0.303	0.103	0.138	0.127	0.168
Samaka painting Company	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
plant of Aziziyah flat glass	0.738	0.801	0.175	0.777	0.722	0.772	0.376	0.533	0.306	0.338	0.260	0.527	0.612	0.302
plant of Aziziyah hollow glass	0.808	0.792	0.171	0.800	0.783	0.851	0.388	0.774	0.585	0.514	0.378	0.622	0.671	0.492
Direct reduction plant (steel)	0.560	0.595	0.163	0.589	0.520	0.541	0.487	0.544	0.480	0.783	0.704	0.542	0.500	0.656
steel melt shop No.1	0.628	0.673	0.207	0.651	0.589	0.541	0.485	0.533	0.373	0.776	0.700	0.560	0.538	0.616
Steel Melt Shop No. 2.	0.609	0.633	0.120	0.667	0.594	0.545	0.510	0.536	0.478	0.784	0.710	0.562	0.527	0.657
Bar and Rod Mills. (steel)	0.638	0.648	0.186	0.667	0.610	0.596	0.542	0.489	0.371	0.630	0.704	0.553	0.547	0.568
Lught and medium section Mill	0.625	0.639	1.000	0.639	0.638	0.632	0.557	0.649	0.494	0.796	0.619	0.662	0.672	0.636
Hot Strip Mill. (steel)	0.694	0.754	0.196	0.804	0.650	0.610	0.558	0.494	0.481	0.680	0.688	0.601	0.595	0.616
Cold Rolling Mill (steel)	0.632	0.637	0.264	0.706	0.724	0.795	0.763	0.735	0.682	0.812	0.708	0.678	0.657	0.734
Maximum value	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Minimum value	0.114	0.115	0.090	0.112	0.128	0.153	0.161	0.142	0.098	0.199	0.103	0.138	0.127	0.168
Mean	0.676	0.682	0.411	0.641	0.648	0.647	0.577	0.652	0.559	0.690	0.601	0.617	0.617	0.616

***After** is the average scores efficiency after open market and / ***before** is the average scores efficiency before open market

Table 5: Proportion (%) of input reduction to get optimal cost

Company	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Al-Marghab cement plant											
Asset	-60.141	-39.682	-28.421	-37.542	-17.990	-52.029	-29.490	-12.290	-42.515	-60.062	0.000
Equity	19.485	16.497	-88.854	17.988	13.198	14.059	11.827	1.274	-15.732	-5.834	0.000
Employees	7.948	-4.076	19.270	62.625	34.866	-12.665	-0.084	-43.197	-2.854	-22.893	0.000
Libda cement plant											
Asset	-43.894	-14.373	0.000	-47.714	-26.638	-34.795	-41.231	-18.769	-46.469	0.000	-36.244
Equity	10.984	5.630	0.000	5.179	4.265	7.087	0.403	-10.138	-2.990	0.000	18.926
Employees	-23.260	29.691	0.000	25.040	-0.139	-15.533	15.052	-52.431	17.607	0.000	-5.268
Zlitan cement plant											
Asset	-67.436	-52.318	-48.657	-67.450	-42.874	-35.518	-27.214	0.000	-11.475	-16.883	-31.163
Equity	20.098	16.430	-88.299	1.119	5.703	12.021	0.195	0.000	-11.919	-0.022	8.874
Employees	-2.755	18.809	-7.008	74.286	101.653	116.785	140.681	0.000	95.040	64.150	35.549
Souk Alkames cement plant											
Asset	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Equity	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Employees	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Banghazi cement plant											
Asset	-62.167	-62.391	-60.127	-49.442	-55.889	-70.247	-48.954	-38.901	-30.040	-25.858	-42.086
Equity	-18.616	-20.382	-90.204	-10.644	-10.282	-7.640	-21.556	-14.867	-32.062	-68.773	-75.516
Employees	-9.443	-31.890	-36.008	-62.652	-69.434	-81.859	-52.498	-53.995	1.690	-46.698	-38.979
El-Fataiah cement plant											
Asset	-74.321	-57.590	-48.249	-61.317	-66.403	-68.788	-59.554	-74.276	-3.531	-57.751	-70.452
Equity	-7.906	-19.203	-90.377	-11.680	-10.369	-6.925	-26.242	-23.477	-71.221	-32.623	-31.221
Employees	69.401	59.315	42.871	-10.804	-24.728	-42.057	-42.067	-14.147	118.025	65.085	18.556
Al-Hawari cement plant											
Asset	-63.867	-62.998	-69.286	-88.268	-82.169	-79.319	-19.484	-89.177	-54.772	-60.224	-84.352
Equity	-33.560	-28.037	-89.114	2.779	-1.504	0.430	-73.109	-0.674	-66.022	-62.721	-39.187
Employees	60.648	67.302	14.815	0.395	-16.230	-57.892	-13.867	-47.125	38.500	24.885	-4.993
Al_kyaas of cement plant											
Asset	-84.803	-76.455	-64.068	-85.193	-54.846	-77.798	0.000	-61.528	-74.123	-37.628	-55.119
Equity	-76.770	-67.368	-91.248	-73.049	-60.497	-53.175	0.000	-30.568	-81.812	17.171	-72.175
Employees	36.690	4.803	40.320	1.049	23.187	-18.814	0.000	36.375	24.386	83.314	62.651
Anapip Bangazi Plant											
Asset	-52.961	-57.474	-62.462	-66.139	-82.228	-78.163	-82.589	-66.388	-28.065	0.690	-7.909
Equity	1.103	1.750	-88.047	-0.042	13.727	20.466	77.974	17.862	-40.094	-43.050	-52.185
Employees	-38.802	-44.829	-60.318	-74.073	-71.606	-79.776	-73.978	-63.332	-39.825	-37.493	-40.031

Company	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Anapip Halazoon Bangazi Plant											
Asset	-53.424	-55.173	-65.681	-77.186	-23.775	-76.659	-79.622	-58.154	-30.478	-23.956	-18.876
Equity	7.326	6.898	-86.573	15.674	17.811	18.597	75.863	-10.895	-61.565	-54.819	-67.605
Employees	-33.814	-35.693	-63.708	-77.017	-22.849	-52.775	-68.221	-58.488	-41.933	-52.697	-47.148
Anapip Rawi Bangazi Plant											
Asset	0.000	0.000	0.358	0.000	0.000	0.000	-32.936	0.000	0.000	0.000	0.000
Equity	0.000	0.000	-65.277	0.000	0.000	0.000	19.403	0.000	0.000	0.000	0.000
Employees	0.000	0.000	50.373	0.000	0.000	0.000	-63.834	0.000	0.000	0.000	0.000
Swany Baked brick Plant											
Asset	-65.370	-59.501	-54.303	-85.756	-90.250	-94.547	-85.988	-80.037	-73.114	-72.432	-69.307
Equity	1.137	-31.673	-83.071	-17.548	-26.073	-2.823	-35.598	-40.650	-65.301	-63.995	-74.152
Employees	-59.948	-26.193	4.322	-45.595	-59.307	-75.297	-79.211	-51.232	-31.918	-36.193	-36.018
Reinforced Concrete Plant											
Asset	0.000	-10.406	-47.540	-75.719	-66.866	-81.701	-53.094	-45.646	-39.077	-31.762	-29.521
Equity	0.000	-41.504	61.577	78.952	-35.656	32.903	-48.049	-49.689	-66.501	-52.547	-55.711
Employees	0.000	6.827	-3.335	8.340	-8.903	-41.827	-58.802	-16.290	-7.378	-4.474	-1.391
Marble Plant											
Asset	-55.634	-66.739	-59.608	-76.849	-87.946	-84.489	-77.444	-83.447	-83.362	0.000	-79.814
Equity	-0.404	-38.466	-79.915	-39.623	-42.851	113.768	-59.150	191.864	44.505	0.000	-70.496
Employees	-62.286	-61.782	-37.978	-52.015	-72.223	-72.339	-88.113	-77.806	-77.752	0.000	-77.268
Tiles Plant											
Asset	-51.030	-57.202	-44.629	-75.755	-86.342	-83.699	-87.737	-85.882	-89.467	-82.508	-82.591
Equity	-0.451	-41.427	-78.728	-39.779	-42.924	-38.292	-55.038	-48.814	-74.641	-72.226	-78.335
Employees	-71.068	-66.604	-41.054	-65.784	-75.796	-77.173	-91.953	-86.166	-90.151	-84.985	-86.403
Janzoor Baked brick Plant											
Asset	-97.101	-93.315	-92.292	-95.185	-92.619	-95.149	-87.888	-89.830	-93.694	-91.217	-92.772
Equity	-0.573	-39.913	-82.841	-17.475	-27.521	30.971	-41.069	-46.809	-57.841	152.663	-61.934
Employees	-59.917	-57.837	-43.096	-74.032	-63.071	-65.691	-71.351	-52.554	-58.431	-57.353	-62.709
Samaka painting Company											
Asset	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Equity	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Employees	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
plant of Aziziyah flat glass											
Asset	-42.778	-50.640	-73.123	-15.489	-35.997	-82.272	-48.311	-69.341	-78.327	-77.189	-51.344
Equity	-17.258	-6.417	-87.224	-25.273	-20.318	21.260	-69.642	-30.707	-63.930	-59.277	-87.545
Employees	-47.164	-52.200	-63.314	-43.963	-50.737	-86.919	-84.050	-65.433	-71.544	-72.565	-79.252

Company	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
plant of Aziziyah hollow glass											
Asset	-47.070	-53.915	-71.638	-9.652	-6.358	-15.441	-48.778	-58.614	-68.274	-66.601	-29.519
Equity	-10.262	-13.897	-86.554	-22.952	-29.196	-14.090	-66.562	-0.324	-26.935	-38.678	-79.363
Employees	-49.788	-54.148	-60.274	-38.481	-26.624	-26.932	-83.774	-52.296	-57.328	-58.821	-68.030
Direct reduction plant (steel)											
Asset	-78.899	-74.847	-79.129	-88.941	-83.249	-77.870	-25.089	-64.305	-70.186	-47.826	-57.679
Equity	-4.829	-3.980	-89.235	5.905	-11.909	-12.835	-73.520	-27.369	-34.469	5.199	-0.426
Employees	-12.732	-69.289	-34.620	-38.837	-32.651	-48.312	-35.211	-5.295	58.540	48.167	62.671
steel melt shop No.1											
Asset	-78.562	-75.858	-73.724	-87.569	-82.421	-77.362	-25.487	-66.552	-87.855	-48.389	-58.123
Equity	9.170	12.344	-86.401	20.212	1.023	-13.337	-73.576	-27.575	-37.425	3.646	-1.798
Employees	5.674	-22.168	-9.902	-24.060	-12.164	-47.061	-35.570	-1.719	20.983	61.686	77.023
Steel Melt Shop No. 2.											
Asset	-80.546	-72.927	-89.760	-85.191	-81.367	-75.759	-23.459	-66.191	-75.914	-46.825	-56.301
Equity	7.302	-2.380	-87.688	21.218	0.953	-14.103	-73.661	-27.421	-29.528	3.393	-1.786
Employees	1.331	-30.095	-18.220	-26.237	-13.241	-44.482	-35.565	-2.987	63.989	61.565	77.155
Bar and Rod Mills. (steel)											
Asset	-80.362	-74.192	-77.694	-85.301	-83.268	-84.503	-20.459	-82.775	-53.451	-66.925	-63.837
Equity	13.154	5.227	-86.709	21.311	6.065	-2.342	-67.518	-19.300	-76.845	-7.279	5.091
Employees	9.758	-21.304	-12.059	-23.235	-9.695	-60.420	-21.001	-32.956	82.113	67.905	93.093
Lught and medium section Mill											
Asset	-81.699	-72.302	0.000	-86.656	-83.287	-83.077	-16.315	-83.479	-45.806	-70.524	-67.635
Equity	12.149	1.391	0.000	16.841	11.966	11.699	-68.179	11.910	-59.858	31.372	-8.577
Employees	3.553	-22.287	0.000	-21.809	-11.697	-60.250	-23.551	-40.800	95.189	62.095	71.204
Hot Strip Mill. (steel)											
Asset	-74.648	-71.610	-76.418	-79.646	-82.096	-83.617	-18.424	-84.086	-42.599	-69.435	-68.594
Equity	18.734	24.257	-85.915	32.332	13.142	7.723	-66.285	-17.038	-67.983	4.623	5.623
Employees	20.564	-13.407	-7.104	-5.276	-10.126	-58.162	-18.920	-37.991	124.735	79.968	102.958
Cold Rolling Mill (steel)											
Asset	-65.057	-66.623	-47.115	-68.858	-59.816	-53.004	139.173	-60.115	53.952	-56.738	-64.119
Equity	-7.886	-8.829	-89.207	-0.450	-3.948	-6.560	-73.196	-12.719	-68.469	5.109	-3.904
Employees	40.974	-10.547	34.588	-26.308	-35.480	-53.103	-14.457	-39.464	107.039	68.346	91.986