The effect of information technology on seaports efficiency and improvement for the Gulf region

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Abstract

The efficiency of a port depends critically on the management system and security, the services provided, and its location as well as the skill of labor in the process of loading and unloading in a record time, using modern equipment. It has been noted from the results obtained that use of modern technology (IT) in some countries led to Increasing productivity and, therefore, an important indicator in evaluating the efficiency of port production. This paper evaluates the efficiency, performance and management of the supplies in the Gulf region. The objective of the study is to apply the DEA, CCR and BCC models in the evaluation of production efficiency using a nonlinear linear programming method in packaging data analysis (DEA), using data collected for 6 years for the period (2000-2005).

Keywords: productivity, performance, DEA, seaports in GULF Countries, information technology, total quality management.

1. Introduction

The port is an important entity in the mobility of maritime activity and the exchange of various goods and services to support the national economy; today, it has become the engine actor of maritime trade in the national economy. The use of information technology (IT) will contribute to improving the quality of seaport services, giving them a competitive advantage, which means receiving all the giant modern ships of new generations. Analysis of the past data provides the basis for modern and quality management and operation of the port with high efficiency and contributes to raising the production capacity performance quality; it also allows the construction of a strong infrastructure and high-tech equipment and service facilities for all types of vessels. The application of information technology (IT) will contribute to a large extent in the management and operation of these seaports, improve the production capacity, enhance their capabilities and potentials and increase the strategic challenge of the logistics chains. The model selected in our study covers the region situated in the middle of the earth, namely Saudi Arabia, Yemen, Oman, United Arab Emirates, Kuwait and Iran. The strategic location of the region encourages the countries to gain an opportunity through quantum leap in the economic development in the logistic sector and information technology. This study attempts to predict the impact of the war on maritime transportation in the region, particularly, on seaports efficiency.

The seaports under study are located in the region which is presently witnessing significant economic development in various domains and some of these ports are distinguished because of their characterized infrastructure and equipment for transshipment purposes. These seaports and their characteristics are displayed in Table 1.1.

Table 1.1: Logistically Average characteristics of seaports in the Gulf Countries region

Port Name	Berth Length (m)	Equipment	Area (m^2)	Ships Call	Throughput (Tons)
Bander Abbas, Iran	5519	24	2209000	3916.33	1291234.67
Khor Fakkan, UAE	1330	26	50000	2049.33	12292704
Khalid, UAE	4296	14	341292	1506.16	1367404.167
Salalah, Oman	1780	54	1032692	1653	19874564
Mascut, Oman	1750	23	538898	1635.83	3836839.67
Dubai, UAE	4875	176	1948610	6352.33	66541267.83
Kuwait, Kuwait	4055	12	1586458	3147.5	16106155.33
Aden, Yemen	2004	34	665140	2462.66	14762085.7
Dammam, S. Arabia	8454	39	1843720	2781.5	16210109.17
Mukalla, Yemen	320	2	250567	397.66	1239633.167

The data in Table 1.1 are obtained from the annual statistics report of seaport authorities, as well as the internet sources (using Google earth and seaport web sites, such as martimechain.com Singapore, Seaports Harbors Marines Worldwide).

The present paper is organized as follows: section 2 presents the development of the region seaports, section 3 presents the methodology, section 4 provides the results determined, and finally section 5 which includes the conclusion and discussion are presented.

2. Development of the Region Seaports

Maritime transportation growth today is rapidly increasing as can be evidenced by the recent development and improvement of many seaports in the world. The average increase in millions tonnage of dead weight tonnages (dwt) for the African countries during 1970-1991 was 0.3%, while this increase has amounted to 3.7% for the Asian countries. In 1991, Kuwait and Saudi Arabia (in our study zone) were among the 35 most important maritime countries according to the data supplied by the shipping information services of Lloyd's. [(2)]

The selected four seaports concerned in this study and four more neighboring seaports, compared their efficiency and productivity.[(10)] He concluded that the seaports considered in this study are highly competitive, indicating the importance of these seaports.

Table 2.1: Average Productivity of Selected Seaports Measured by Moves per Hour of Crane and Berth for Small and Large Vessels

Seaport	Crane productivity for small vessel	Berth productivity for small vessels	Crane productivity for large vessel	Berth productivity for large vessels
Dubai*	22	40	30	110
Khor-Fakkan*	20	32	28	100
Salalah*	N/A	N/A	29	90
Aden*	N/A	N/A	28	70
Singapore PSA	23	45	36	140
Nhava Sheva**	18	30	22	40
Jawahrlal Nehru**	16	24	20	36
Colombo-SLPA**	14	23	18	45

Small vessels: 400-800TEU. Source [(10)]

Large vessels: 1800 TEU and upwards.

*****: Seaports under study.

**** Neighboring seaports.**

N/A: data not available.

As can be seen in Table 2.1, the productivity of Arabian seaports in terms of moves per hour is greater by a factor ranging from 6-125, compared to some neighboring seaports, such as Indian seaports and Colombo (excluding Singapore), this indicates a progressive development. A 2000-2002 review of the United Nations Conference on Trade and Development [11] of maritime exhibits 50 seaports of developing countries. Table 2.2 reveals that Dubai, Saudi Arabia, Oman, Iran, Sudan, Tanzania, Djibouti, and Yemen had growth rates of: 0.05, 11.6, 14.6, 48.8, 28.2, 1.5, -6.4, and 52.1 in 2000-2001, respectively; while in 2001-2002 these rates amounted to 15.5, 15.1, 6.3, 30.8, 4.6, 10.0, 20.6, and 2.9, respectively.

Table 2.2: Growth Rate of Seaport Production for 2000-2002.

Year	Dubai	Saudi Arabia	Oman	Iran	Sudan	Tanzania	Djibouti	Yemen
2000-2001	0.5	11.6	14.6	48.8	28.2	1.5	-6.4	52.1
2001-2002	15.5	15.1	6.3	30.8	4.6	10	20.6	2.9

Source [12]

In 2003, the throughput at Salalah seaport increased by 56% where gross crane productivity averaged of 30.4 moves per hour, with peaks of 33 moves per hour. At this seaport, the addition of handling equipment (rubber–typed yard gantry cranes) resulted in the performance increase of the seaport by 70% during 2002 and 2003. {UNCTAD [14]}

The export and import at the seaport of Mombasa, Kenya, increased in the year 2000 from 1.7 to 2.5 dwt (millions), while in 2004 it increased from 7.2 to 10 dwt (millions). However, in March 2004, a delay surcharge of US $70.00 per TEU vessel in Mombasa was imposed due to the poor seaport production in terms of overall net income {UNCTAD. [12,13,14]}

During 2003, the overall performance of seaports in the study region was hampered by 4% to 6% for several reasons but most likely due to the Gulf War and related increases in insurance premiums or lack of insurance for same specific seaports of the region; in consequence, many international maritime companies avoided transshipment from these seaports.

In the past 5 years, a number of incentives and investment opportunities have been announced in order to develop and extend the infrastructure and handling equipment for the ultimate improvement of efficiency and performance at the Asian and European seaports {UNCTAD. [12,13,14]}.

3. Methodology

3.1Review of Concepts

DEA (Data Envelopment Analysis) is concerned with alternative decision making using DMUs (Decision Making Units) and these units are analyzed separately via a mathematical programming model which checks the performance of those units by decreasing the inputs and increasing the outputs. The models developed are called CCR (Charnes, Cooper and Rhodes) and the second BCC (Banker, charnes and Cooper).

3.2 Data Envelopment Analysis

The basic concept of efficiency measurement is the ratio of total outputs to total inputs. [3] was the first to introduce the DEA as a multi-factor productivity analysis module for measuring the relative efficiencies on decision making units (DMUs). This model cannot perfectly support competitive markets. To overcome this limitation, [1] described BCC model, to estimate the productivity level at the given scale of operation and identifies return to scale. The goal is to select a set of inputs and outputs which are relevant to the evaluation of performance and for which a moderate statistical relationship exists.

In DEA-CCR model, all observed production combinations can be scaled up or down proportionally; while in DEA-BCC model, the variables allow return to scale and is graphically represented by a piecewise linear convex frontier [5]. The DEA is normally applied to analyse the cross section data, where time is ignored and DMU are compared with the others at the same period. In this paper, we propose the output-oriented DEA model to maximize the output, while the given current inputs remain the same. The mathematical expression of the DEA models is as follows:

1) CCR Model. [3]

$$\text{Min } \phi_k$$

$$\begin{aligned} s.t \quad & \sum_{j=1}^{n} \lambda_j x_{ij} \le \phi_k \; x_{ik} && i=1,2,\ldots,m; \\ & \sum_{j=1}^{n} \lambda_j \, y_{rj} \ge y_{rk} && r=1,2,\ldots,s; \\ & \lambda_j \ge 0 && \forall \; j \end{aligned} \tag{1}$$

The equations in (1) are called CCR minimizing model where ϕ_k and λ_j are dual variables and ϕ_k is an optimal performance score value of DMU_k and λ_j is the weight.

The equations in (2) are CCR maximizing model.

$$\text{CCR} \quad \text{Max } \phi_k$$

$$\begin{aligned} s.t. \quad & \sum_{j=1}^{n} \lambda_j x_{ij} \le x_{ik} && i=1,2,\ldots,m; \\ & \sum_{j=1}^{n} \lambda_j \, y_{rj} \ge \phi_k y_{rk} && r=1,2,\ldots,s; \\ & \lambda_j \ge 0 && \forall \; j\,. \end{aligned} \tag{2}$$

By adding $\sum_{j=1}^{n} \lambda_j = 1$ to (2) BCC [1] is obtained.

Where n is number of DMU, *k* is the efficiency of the k-th DMU, x_j are i-th inputs of the j-th DMU, y_j are the outputs of j-th DMU and A_j is the weight of j-th DMU. The DEA technique requires a large number of medium-sized linear programming problems to be solved. The two models, as described previously, consist of two where the first is called CCR model (constant return to scale) which is a scale efficiency and technical efficiency, and the second is called BCC model (variable return to scale) which is a pure technical and scale efficiency. [7] That output-oriented efficiency problem can be written in the form of N linear programming system. [6] The technical efficiencies derived from the DEA-CCR and DEA-BCC models are frequently used to obtain a measure of scale for DMU, given by $SE_k = U_{CCR\_k} / U_{BCC\_k}$,[5] where U_{CCR_k} and U_{BCC_k} are the technical efficiency measures for DMU k derived from the application of the DEA-CCR and DEA-BCC models, respectively.

CCR score is called technical efficiency (TE), while BCC score is called pure technical efficiency (PTE). Scale efficiency is noted by (SE) with TE = PTE * SE. If $SE_k = 1$, then the score is efficient (constant return to scale), otherwise, the score is inefficiency if $SE_k < 1$ (Increasing or decreasing return to scale). The constant return to scale means that the unit is able to operate the inputs and outputs linearly without increasing or decreasing in scale. The increasing return to scale means that the unit is operating at lower scale sizes (needs to increase the output), while decreasing return to scale means that the unit is operating at higher scale sizes (needs to manage the inputs). Extensive literature on DEA already exists that is applied, in general, to a wide variety of economic fields. For example, [9] measured the efficiency of the Brazilian stock market along the period of Jan/2001 to Jun/2006. [8] used DEA-CCR and DEA-BCC to measure the relative efficiencies of 13 Credit Department of Farmers Associations in Taiwan, and found that most of the inefficient CDFAs present increasing returns to scale.

3.3 Data and variables

DEA focuses on the number of repeated observations on the events through the resources surroundings. To estimate the efficiency of the seaports under study, during the third Gulf war, we used data for the years 2000-2005. The measurement of output is indicated by two elements: (1) Ships and (2) movement of general cargo (dry and liquids, containers) load/unload. The measurement of the inputs is considered by the following indicators: total berth length, storage area, handling and equipment. The aim of this study is to compare the efficiency before and after the war. In this paper, we propose output-oriented DEA models seeking maximization of output, while the given current input remains the same. The efficiency of any seaport depends crucially on security system, services provided, easy entrance, labor skill, storage capacity and handling equipment which encourage ships arrival. The cargo throughput and ships call variables are important indicators of any seaport production considered as outputs. The results obtained from Tables 1and 2 predict that the selected model data to evaluate the efficiency is relatively consistent. The descriptive statistics of general cargo related to the 10 seaports for the years 2000-2005 are listed in Table 3.1.

Table 3.1: Characteristics of the Variables for Seaports

	Ports	Range	Minimum	Maximum	Sum	Mean	Std. Deviation
Equipments	10	174.00	2.00	176.00	404.00	40.4000	49.85802
Area	10	2159000.00	50000.00	2209000.00	10466377.00	1046637.7000	790179.21295
berth Length	10	8134.00	320.00	8454.00	34383.00	3438.3000	2460.64332
Ship call	10	5954.67	397.66	6352.33	25902.30	2590.2300	1644.51171
through put	10	65301634.66	1239633.17	66541267.83	153521997.70	15352199.7704	19370191.80639

3.4 Correlation and regression analysis

The data analysis of input and output variables shown in Table 3. 2 indicates that they are highly interrelated and statistically significant at 0.01 level of probability. The multiple regressions are used to determine if there is relationship between the input and the output variables. Table 3.2 shows that the R^2, as the proportion of variation in the dependent variable ship call and throughput explained by the regression model; which are 0.795 and 0.870.

The statistics and its significant value are used to test the null hypothesis that the regression coefficient is zero which means there is a linear relationship between the dependent (ship call and throughput) and independent (berth length, equipment and area) variables. If the significant value is small (less than, say, 0.05), then the coefficient is considered significant. The partial correlations of each independent variable with the dependent variable in the model are obvious except for the berth length.

Table 3.2: Regression Results on Input and Output Variables of Seaports

Inputs	Outputs	
	Ship Call	Through put
Berth Length	0.051	-892.372
Handling Equipment	21.059	313237.607
Storage Area	0.001	6.737
Constant	2729.3 82	11063516.439
R^2	0.795	0.870

Table 3.3: Correlation Coefficients with Inputs and Outputs of Seaports

	Berth Length	**Equipments**	**Area (m^2)**	**Ship Call**	**Total Tons**
Berth Length	.000				
Equipments	0.253	1.000			
Area M sq	0.769	0.455	1.000		
Ship Call	0.545	0.810	0.768	1.000	
Total Tons	0.234	0.963	0.443	0.799	1.000

Correlation is significant at the 0.05 level.

4. Results

DEA was applied to the efficiency score of the seaports using the DEAP software version 2.1 [(4)] with two models analyses, namely DEA-CCR and DEA-BCC. DEA is carried out on 10 seaports for the period of 6 years shown in Table 4.1 as follows:

1. Weak correlation of 0.253 for the berth length versus equipment and 0.234 for Berth length versus total tons can be seen in Table 3.3. The same table displays moderate correlations of 0.445 and 0.443 for the birth length versus total tons and area versus total tons, respectively.
2. The score report shows that, for the year 2000, 3 and 6 seaports are efficient and DEA-BCC models, respectively. In 2001, 3 and 7 are efficient under DEA-CCR and DEA-BCC; in 2002, 3 and 7 are efficient under DEA-CCR and DEA-BCC; in 2003, 5 and 6 are efficient under DEA-CCR and DEA-BCC; in 2004, 4 and 5 are efficient under DEA-CCR and DEA-BCC and in 2005, 6 and 7 are efficient under DEA-CCR and DEA-BCC.
3. The output-oriented approach is applied in this paper to select the seaports specification in terms of equipment and sophisticated management. Theoretically, the output of technical efficiency is given by $TE_k=1/U_k$ for k term of DMU, where the seaports under study must increase their product on average to 1.108 times for the same inputs duration of the 6 years.
4. The scale properties of seaports production in 2000 show 2 seaports with constant returns to scale, 0 seaports with increasing returns to scale, and 8 with decreasing returns to scale. In 2001, the efficient seaports are 3 and 6 under CCR and BCC, with the average value of 0.858 and 0.862, the increasing product average of 1.555 times and scale properties of 2 constant returns to scale, 2 increasing returns to scale and 6 decreasing returns to scale. In 2002, the efficient seaports are 3 and 7 under CCR and BCC with the average value of 0.794 and 0.917, the increasing product average of 1.162 times and scale properties of 2 constant returns to scale, 2 increasing returns to scale and 6 decreasing returns to scale. The decline starts to appear in 2003 for medium seaports where the efficient seaports are 3 and 6 under CCR and BCC with the average value of 0.838 and 0.883, the product average of 1.053 times and scale properties of 3 constant returns to scale, 2 increasing returns to scale and 5 decreasing returns to scale. On the other hand, the improvement reappears in 2004 (Figure 1) where the efficient seaports are 4 and 5 under CCR and BCC with average value of 0.816 and 0.872 for CCR and BCC models respectively, with product average of 1.068. Compared to the previous years, the improvement of production has increased 0.015 times, in 2005, as shown in Figure 1 , where the efficient seaports are 6 and 7 under CCR and BCC with the average value of 0.860 and 0.924 with product average of 1.074 and scale properties of 5 constant returns to scale, 1 increasing returns to scale and 4 decreasing returns to scale.
5. The results show that the efficiency appears very clearly in countries that use the modern technology (IT) leading to increasing productivity, which is an important indicator of port efficiency.

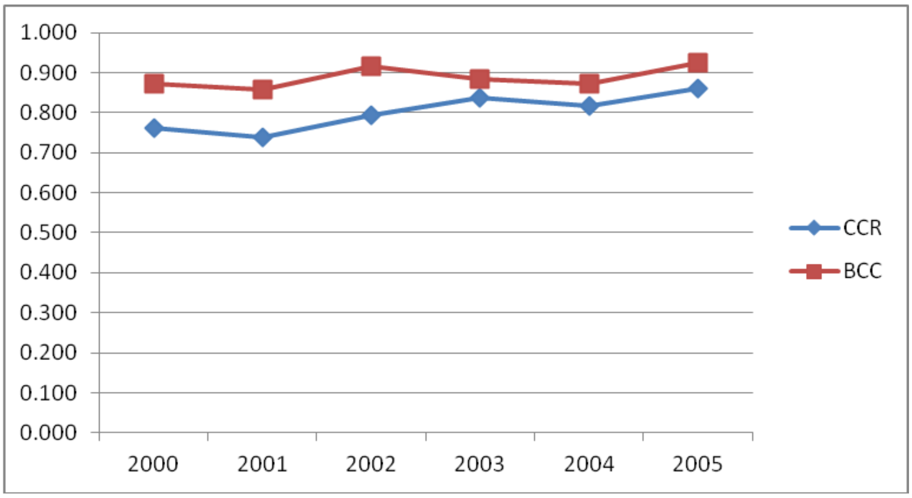

Figure 1: The General Cargo Efficiency for both Models

5. Conclusion

1. The article provides one of the first examinations of the economic consequences of the Gulf region and its impact on seaport production.
2. The aim of this paper is to evaluate the efficiency of the seaports situated in the Gulf region. DEA analysis allows us to determine the relative efficiency of the above seaports and shows the variation of this efficiency over the period of 2000-2005.
3. Port development projects targeting increase and berth length and cargo handling equipment are to be given priority as indicated by low correlation coefficients in Table 3.3. Increase in berth length besides adding further storage area will certainly improve the total tonnage, thereby improving the moderate correction coefficients between the relevant inputs (Table 3.3).
4. Table 4.1 shows that the efficiency of some countries in the region is declining under the CCR and BCC models where the efficiency decreases by 33% and 31% under CCR and BCC (Figure 1) respectively, during the period of 2000-2005. In addition, the scale efficiency decreases by 31% (Figure 1). The decline of seaports efficiency leads to a great loss in the national income of the countries in the region. This would lead to internal and external economic burden ending in serious results.
5. These declining economic conditions would force these countries to resort to foreign loans which would eventually lead to economic crisis and foreign pressures in the long run. This deterioration was observed during the Third Gulf War in 2003.
6. The non-use of information technology (IT) in some countries in the region has lead to drop in efficiency.
7. There is a decrease in ship calls in some seaports of the region because of poor security of ships against maritime mines and the increase of insurance charges. The use of information technology (IT) will contribute to improving the quality of seaport services and increase the efficiency.

Finally, this region is rich in raw crude oils/minerals; this may allow easy cooperation between the regional governments on one hand with the sea transports companies to establish good relationship towards improving the efficiency of the regional seaports. Furthermore, there are certain advantages where the sea transport system (shipping lines) will gain in traveling time, handling cost, and transshipment. Investment by the public and private sectors will greatly help to develop and expand the inefficient seaports in the region, while ships lines must create policies to encourage ships to load/unload at these seaports.

6. Acknowledgements

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Table 4.1: The relative efficiency of general cargo for 2000-2005 using CCR and BCC models

	2000			2001			2002			2003			2004			2005		
Seaport	CCR	BCC	Scale	CCR	BCC	scale	CCR	BCC	scale	CCR	BCC	scale	CCR	BCC	scale	CCR	BCC	scale
Bander Abbas	0.746	1.000	0.746 Drs	0.824	1.000	0.824 drs	0.708	1.000	0.708 Drs	0.685	0.937	0.730 drs	0.794	1.000	0.794 drs	0.689	1.000	0.689 drs
Khor Fakkan Sharjah	1.000	1.000	1.000 Cte	1.000	1.000	1.000 Cte	1.000	1.000	1.000 Cte	1.000	1.000	1.000 Cte	1.000	1.000	1.000 Cte	1.000	1.000	1.000 Cte
Khalid	0.779	0.826	0.943 Drs	0.921	0.940	0.980 Irs	0.959	0.980	0.976 Irs	0.599	0.622	0.963 irs	0.648	0.663	0.978 irs	0.950	0.960	0.989 irs
Salalah Oman	0.576	0.591	0.975 Drs	0.329	0.360	0.906 drs	0.607	0.650	0.941 Drs	1.000	1.000	1.000 Cte	0.679	0.684	0.992 irs	1.000	1.000	1.000 Cte
Mascut Oman	0.483	0.594	0.814 Drs	0.524	0.550	0.946 drs	0.675	0.720	0.936 Drs	0.736	0.745	0.987 drs	0.764	0.770	0.992 drs	0.623	0.692	0.900 drs
Dubai	0.838	1.000	0.838 Drs	0.642	1.000	0.642 drs	0.831	1.000	0.831 Drs	0.994	1.000	0.994 drs	1.000	1.000	1.000 Cte	1.000	1.000	1.000 Cte
Kuwait	0.988	1.000	0.988 Drs	1.000	1.000	1.000 Cte	1.000	1.000	1.000 Cte	1.000	1.000	1.000 Cte	1.000	1.000	1.000 Cte	1.000	1.000	1.000 Cte
Mukalla Yemen	1.000	1.000	1.000 Cte	0.819	1.000	0.819 Irs	0.806	1.000	0.806 Irs	0.974	1.000	0.974 irs	1.000	1.000	1.000 Cte	1.000	1.000	1.000 Cte
Aden Yemen	0.819	1.000	0.819 Drs	0.833	1.000	0.833 drs	0.865	1.000	0.865 Drs	0.783	0.806	0.972 drs	0.740	0.760	0.973 drs	0.735	0.820	0.897 drs
Dammam Saudi	0.388	0.724	0.536 Drs	0.489	0.730	0.669 drs	0.487	0.820	0.597 Drs	0.612	0.720	0.849 drs	0.538	0.840	0.641 drs	0.605	0.770	0.785 drs
mean	0.705	0.845	0.844	0.710	0.850	0.826	0.725	0.880	0.822	0.741	0.822	0.907	0.752	0.855	0.885	0.743	0.843	0.887

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تأثير تكنولوجيا المعلومات على كفاءة الموانئ البحرية وتحسينها لمنطقة الخليج

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الملخص

إن كفاءة الموانئ يعتمد بشكل حاسم على إدارة نظام و أمن الموانئ، والخدمات المقدمة، وموقعه وكذا مهارة العمالة في عملية الشحن والتفريغ في زمن قياسي باستخدام المعدات الحديثة, وقد لوحظ من النتائج المتحصل عليها أن استخدام تقنية حديثة (تكنولوجيا المعلومات) لدى بعض الدول أدى إلى رفع الكفاءة الإنتاجية، وبالتالي فان كل ذلك يشكل مؤشراً مهماً في تقييم كفاءة إنتاج الموانئ. هذه الورقة تقيم كفاءة وأداء وإدارة الموانئ في منطقة الخليج العربي. الهدف من الدراسة هو تطبيق نموذج النوافذ DEA في تقييم كفاءة الإنتاج باستخدام طريقة البرمجة الخطية غير حدودي في تحليل البيانات التغليف (DEA)، باستخدام البيانات التي تم جمعها لمدة 6 سنوات للفترة (2000- 2005).

الكلمات المفتاحية: الإنتاجية، الأداء، الموانئ البحرية في دول الخليج، تكنلوجيا المعلومات، إدارة الجودة الشاملة.