Approaching the Relative Productivity of Infrastructure in Mediterranean Container Terminals with the Use of DEA

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Introduction

The comparison of ports in terms of economic performance, infrastructure, marketing is an integral part of the strategic planning for policy makers, as well as for port managers and investors. In the functions of productivity and efficiency, some of the terms are defined in a deterministic way, while others, usually of a qualitative nature are estimated only subjectively. In addition, every port serves a different region or market or industry and enjoys different hinterland connections, status of ownership and management. Consequently the comparison of ports is a difficult and risky process with the use of only one model, if not impossible.

Mediterranean ports experience a very dynamic development. The tremendous effect of the globalisation of the international trade, the organisational changes and the technological advances in ship and cargo handling technology are only some of the many reasons transforming these ports. Some of the most important ones are the intermodal concept ruling the industry and the creation of a truly common market and the eager demand of the former Eastern bloc markets for goods. Consequently the Mediterranean ports ceased to serve only the regional trade, but have become part of the logistics chains to and from the European continent. As proof for the above, tariff and service competition becomes overt among the ports for attracting major carriers in the elastic market of transhipments. So, the results of management in a port is also examined through the efficiency of this node in the logistic chain and it is partly thoughtless and myopic to examine the efficiency in terms of 'balance sheet' or local employment. This changes also the regional attitude of the ports, where not only the neighbouring port is a competitor, but also another port in some other region. Big shipping companies using the advantage of improved transport networks may use the resources of a port in the Mediterranean, in order to exercise pressure in a well established northern European port, by increasing the percentage of transhipments in a link. The creation of North-South landbridges is only part of the 'new order' in the port market of the continent. Likewise, ports face the trend of privatisation, which follows institutional changes and the lust of the carriers to control nodal points, such as the ports.

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Infrastructure costs and investments are high and risky by definition. A port may invest in a crane capable to serve a specific size of vessels, which may never call the port due to the international competitiveness. Therefore any managerial team, state appointed or private, wishes to have an approach of the productivity of these resources and if it is possible, an approach for the competing ports. In many cases, such ratings assist strategic planning, marketing, managerial targets and self-evaluation.

DEA and port efficiency analysis

The performance of any port service involves the allocation of various resources and the control or supervision of their use. In theory and in the case of prudent management, the productivity of these resources determines also the cost of these services. However, resources have a very low productivity, which is not reflected in the cost, because the management 'subsidises' these functions from other cost or profit centres or because of the decision to follow a 'cost leader' strategy in order to eliminate other competitors from the market. It is very difficult to generalise such practices, with unique cost and effect results from port to port. From the port's viewpoint, the cost of providing any service is a function of port resources allocated. From the user's point of view, the cost of using the service is function of the time spent in port, the quality of the service (reliability and flexibility) and the cost in general. A typical example for the latter is that the port is expressing the productivity of a crane as 'TEUs per hour', while the carrier as 'TEU handled per hour along the ship'. The carrier does not care about the productivity of the specific mean, i.e. the crane, but only at the final result: number of TEUs per ship hour at berth.

In simple terms, there is cycle 'starting' when a port strategy is decided and 'ending' to the user cost. The scientific approach obliges a port strategy to be cost based. Therefore a cost based pricing system is directly affected by the performance of the port, i.e., by the productivity of each resource and of the whole. The control of the productivity differs from port to port, but what is the same is the result: any improvement of the productivity of any resource improves the utilisation of the fixed assets, reducing the cost of providing services to the vessel and the cargo. Such cost reductions allow the management to lower the charged tariffs and in general to enforce the competitiveness of the port. In addition, any improvement in the port performance reducing the average turnaround time at berth by increasing the amount of resources used will cause the port to increase its charges. However the cost-based pricing is not the only acceptable policy, and in many cases is not the best one, but it can be used for calculating the last negotiation trench or for setting the targets.

The control of productivity is a very complicated problem of measurements, statistics and sometimes of engineering too. Every port uses different indicators for measuring the productivity, and UNCTAD has provided in the past, valuable guidance and uniform methods for the collection of data and measurement of productivity. The relation of port performance and the port cost is not always clear. For any service, a mix of resources is used and an improvement may come by altering the mix or improving the utilisation of these resources. Typical example of such change can be the allocation of labour and equipment for the handling of general and containerised cargo. The improved performance leads not only to reduction of tariffs but also to the direct and indirect cost of the vessel while in port. This gain can be expressed as more utilisation time for the vessel, less costs for shippers and consignees and any kind of opportunity costs. Finally, the cost reduction for the user, expressing the consumption in time and money, is one of the main, if not the most important, attraction of customers and users, approving or disapproving the strategy adopted from the management. With this feedback link, closes the cycle of productivity and efficiency in a port.

As the complexity of the factors affecting the port performance leads to considerable difficulties in determining the efficiency of resources and the direct comparison of ports is rather impossible, a method assisting to attack the problem in a more scientific way is the data envelopment analysis (DEA). Roll and Hayuth applied DEA in an imaginary set of data, proving that DEA is capable to provide satisfactory answers. In a 1996 publication, productivity functions have been used for the evaluation of port performance (Sachish, 1996). Such attempts may give good results, but demand very careful monitoring of the ports and that is in many cases very difficult, if not impossible under the modern blatant competition among ports, where no helpful data are published or exchanged. These cost functions cannot in general overcome the aggregation problem (i.e. case-mix) easily. Yet, the most important is that there is a hidden assumption, 'hoping' that all ports use the same production function.

The methodology and the DEA method

The transition from local port services to regional or global ones, makes the problem of productivity more complicated. The management is not so interested in 'absolute' results but to higher profits and comparative advantages over the rest ports. A figure, such as the higher throughput of cargoes, may be indifferent or less desirable any more than it used to be; more cargoes mean more environmental burdens and may result in higher berth occupancy leading to longer waiting times, disadvantages, which can become advantages for the competitors. On the other hand, the port is nowadays considered as a profit making centre, either of the public or a private interest, therefore what really matters is the return on the invested capital, therefore the port seeks for providing adding value services.

According to Sachish, there are five methods:

1. the index approach,
2. the econometric approach,
3. the accounting approach,
4. the data envelopment method (DEA), and

5. the engineering method (Sachish, 1996).

The method of DEA is not a new one and has been already applied in many cases, especially in evaluating public sector's productivity, since the late '70s. The method will not be presented again, since it is very well described in other papers (Charnes, et. al., 1978), but owes its popularity in the fact, that it provides results, where conventional approaches fail to offer satisfactory findings. The method aims at providing relative efficiency measurements and not a deterministic result. In such a relative environment absolute measurements may not be really meaningful, and the application of this model might give interesting results. The other methods could not be applied without special consideration on the consistency of the input-data, because of the lack of 'uniformity'.

Taking a short look at the other methods, the index method is very sensitive in terms of input-data, since the comparison is based on ratios between inputs and outputs, and in many cases ports do not collect the same data or more essentially they serve different market segments. The econometric approach is applicable, where the ports serve the same market, for instance the same country, but in the Mediterranean case, the port market has just been integrated, and even in the future it is expected to have different regional profiles, due to the population and industrial distribution. Finally the accounting and engineering methods are approaching the port as a production plant.

The above mentioned methods have provided in many cases sound results, but in the specific case, where relativity is at the point, DEA is considered as more suitable. Roll and Hayuth, list the advantages of the method against the conventional ones, as following:

a) simultaneous analysis of several outputs and inputs,

b) enables the use of qualitative factors,

c) it does not require a production function, and

d) there can be an individual or sub-group approach, making comparisons meaningful (Roll and Hayuth, 1993).

Points a) and d) are considered as very important; DEA is the only method dealing with all the ports at the same and allows the sub-group approach. The method has been criticised, as any other else, but still provides an image. As mentioned above, the intention is to approach the productivity issue, and not to come to an absolute result, because the method includes a subjective factor: the set of upper and lower bounds. In addition the grouping of the data as a whole or the breaking down to subgroups affects the final image, and therefore it is wise not to extract firm conclusions.

The methodology followed is the following:

1. A group of 11 ports in the Mediterranean have been selected. This group of ports is not exhaustively complete, because of complete lack of data for others or inconsistency of data among several sources.

2. All input data have been taken out of reliable sources (Containerisation, 1996 and ISL, 1997) and compiled with data provided from other sources, such as the web sites of the ports.
3. The method is applied several times for different groups. This will provide a better consideration of the available data.

The data and the results of the model

A difficulty met by almost all researchers is the collection of data, capable to be transformed to information. The data regarding infrastructure has been collected from major publications such as *Fairplay* and *Containerisation Today*. The data do not differ significantly from other sources. However there were some differences with data provided in several official port websites and leaflets. Therefore, only the consolidated data of a source have been used as input.

Regarding the traffic data, things were more complicated. The figures about the total traffic have been available in many sources, but not the breakdown for local movements and transhipments. Nevertheless in many cases a transhipment percentage was given; in several cases where there was no available information a 'soft' assumption has been made: specifically the percentages of transhipment in Genoa and in La Spezia are considered as the same with 1997 (known), while the percentages in Marseilles, Goia Taurus and Marsaxlokk as same with 1996.On the other hand the nautical traffic was presented in a very incovenient way, giving as output the aggregated GRT (in several cases NRT) of the vessels served in all terminals, including bulk, oil and passenger terminals, making the breakdown impossible. The lack of these data restricted also the analysis in year 1996. The following table 1 is presenting the figures for 1997:

Table 1

	Total '97	*Transit '97*	%	*Local '97*	*Vessels*
Algeciras	**1,537,627**	1,294,611	84.2%	243,016	
Barcelona	971,921	202,280	20.8%	769,641	
Valencia	831,510	97,714	11.8%	733,796	
Marceilles/Foss	621,580	51,073	8.2%	570,507	
Goia Taurus	1,448,531	**1,437,544**	99.2%	10,987	1,361
La Spezia	615,000	64,000	10.4%	551,000	
Genoa	1,179,954	139,313	11.8%	**1,040,641**	
Piraeus	683,969	176,316	25.8%	507,653	2,733
Marsaxlokk	600,000	521,068	86.8%	78,932	
Limassol	237,300	97,635	41.1%	139,665	
Average	872,739	408,155	40.0%	464,584	2,047
Max	**1,537,627**	**1,437,544**		**1,040,641**	2,733
Min	237,300	51,073		10,987	1,361

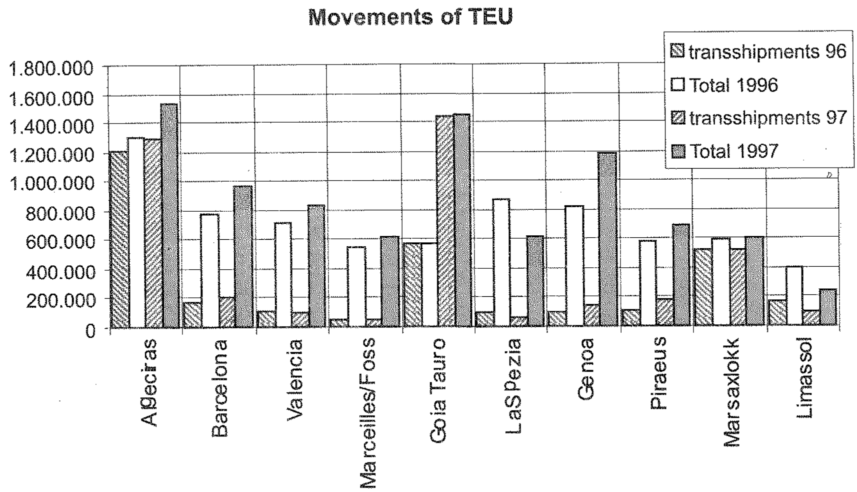
Algeciras is the port with highest figure in total traffic of TEU, while Goia Taurus serves the highest percentage of transhipments (99.2%). In the inelastic 'local' traffic Gènoa serves more than 1 million TEUs per year. In terms of total traffic Algeciras, Goia Taurus and Genoa serve more than 1million TEUs per annum, while there is band around 600-700,000 TEUs pa served by Piraeus, Marseilles, La Spezia and Marsaxlokk, which consist a group with different hinterland connections and traffic characteristics. La Spezia and Marseilles serve mainly local traffic, having a transhipment percentage of about 10%, while Marsaxlokk serves mainly transhipments and Piraeus is striving for a higher percentage to establish the port in the Mediterranean logistics map. In addition Marsaxlokk and Piraeus are isolated nodal points, since there is no hinterland connection; Malta is an island and Piraeus is lacking rail connections, while the Greek road network is not directly connected to European markets. Closing this limited presentation, it is obvious that the ports of Valencia, Barcelona, Marceilles and Gènoa are attracting more traffic, since they serve commercially active markets and offer adequate connections to inner markets. The next table 2 presents the data for 1996, the ones feeding the model:

Table 2

	Total '96	*Transit '96*	*%*	*Local '96*	*Vessels*	*TEU/Vessel*
Algeciras	**1,306,825**	**1,202,279**	92.0%	104,546	492	2,444
Barcelona	767,236	166,945	21.8%	600,291	2,654	63
Valencia	708,332	104,768	14.8%	603,564	2,412	43
Marceilles/Foss	547,667	45,000	8.2%	502,667	2,374	19
Goia Tauro	571,951	567,613	99.2%	4,338	1,309	434
La Spezia	871,100	90,651	10.4%	**780,449**	740	123
Genoa	825,752	97,494	11.8%	728,258	785	124
Piraeus	575,256	110,414	19.2%	464,842	2,656	42
Marsaxlokk	593,013	515,000	86.8%	78,013	676	762
Limassol	398,600	164,000	41.1%	234,600	1,530	107
Average	716,573	306,416	40.5%	410,157	1,563	416
Max	1,306,825	**1,202,279**		**780,449**	2,656	2,444
Min	398,600	45,000		4,338	492	19

It is very interesting to notice that in 1996 Algeciras was concentrating almost the bulk of the transhipment movements, while the ports of Goia Taurus and Genoa did not concentrate cargoes of more than 1million TEUs. In the Italian side, La Spezia was the more attractive port. From the ratio of TEU per vessel is also obvious that Algeciras is serving the big carriers as nodal point, and the same conclusion can be drawn about to an extent for Marsaxlokk and Goia Taurus. All the other ports served more or less feeders, and in the case of Limassol, La Spezia and Genoa, the statistical image is vague about the main service, i.e. whether if it is feeder or mother service. The next graph is summarising the traffic:

Graph 1



The average traffic has grown by ≈22% (872,739 TEU in '97 and 716,573 in '96), while the transhipments by ≈33% (408,155 in '97 and 306,416 in '96), which is caused mainly due to the dramatic increase of total movements in Goia Taurus, which comprises mainly of transhipments and due to the increase of transhipments in Piraeus accompanied by an increase in the total movements. The negative figures in other ports should mainly express the market niche they lost because of Goia Taurus. The following table 3, presents also a comparison of 1996 and 1997 movements as well as the significance of local and transhipment movements in 1996:

Table 3

	1996 - 1997		**1996**	
	Movements	***Transhipments***	***Transhipment / Local***	***Total/Local***
Algeciras	7.7%	-8.5%	11.50	12.50
Barcelona	21.2%	-4.4%	0.28	1.28
Valencia	-6.7%	-20.5%	0.17	1.17
Marceilles/Foss	13.5%	0.0%	0.09	1.09
GoiaTauro	153.3%	0.0%	130.8	131.84
La Spezia	-29.4%	0.0%	0.12	1.12
Genoa	42.9%	0.0%	0.13	1.13
Piraeus	59.7%	34.3%	0.24	1.24
Marsaxlokk	1.2%	0.0%	6.60	7.60
Limassol	-40.5%	0.0%	0.70	1.70
Average	33.2%	-1.3%	15.07	16.07
Max	153.3%	34.3%	130.84	131.84
Min	-40.5%	-20.5%	0.09	1.09

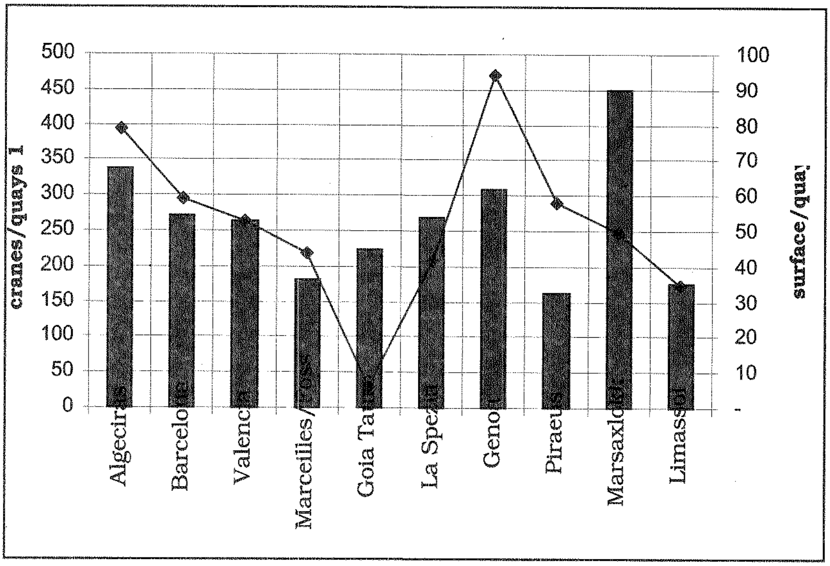
The last table 4 is giving information about the available infrastructure in every port. The data has been collected from only one source as discussed above, because the author assumes that the source publication has solicited data under a uniform format, in order to avoid misconceptions and misleading the user. Under the term quays, the collected data specifies the currently available meters in the container terminal. In addition by cranes it is meant all the cranes servicing the terminal and by storage the available open air surface for the handling and storage of TEU. The issue of rail connections is very sensitive and it cannot be presented adequately by figures. In these sources every terminal has a note about the tracks passing through; in several ports the reader can get the information of even 32 or 48, but that does not mean anything really, because these lines may serve only drayage. A figure that it would be of a great help is the total cargo moved by this mode or figures about the occupancy rate and the utilisation. Therefore, in the model this field will contain values of 0 or 1, indicating the rail connection, where possible.

Table 4

	Quays[m]	*Cranes*	*Storage[m²]*	*Rail connection*	*C/Q 10⁻³*	*S/Q*
Algeciras	1,184	8	467,140	1	6.76	395
Barcelona	2,020	11	595,000	1	5.45	295
Valencia	2,090	11	549,000	1	5.26	263
Marceilles/Foss	2,750	10	600,000	1	3.64	218
Goia Tauro	**3,144**	14	90,000	1	4.45	29
La Spezia	1,297	7	270,000	1	5.40	208
Genoa	2,920	**18**	**1,373,000**	1	6.16	**470**
Piraeus	3,100	10	900,000	0	3.23	290
Marsaxlokk	1,000	9	247,000	0	**9.00**	247
Limassol	1,980	7	342,500	0	3.54	173
Average	2,149	11	543,364	1	5.29	259
Max	**3,144**	**18**	**1,373,000**	1	**9.00**	**470**
Min	1,000	7	90,000	0	3.23	29

The last two columns provide two indices; the cranes per quay meter and storage surface per quay meter. The aim of the first index is to show the density of handling facilities at the quay length; the other index aims in providing an image of the storage surface supporting each meter of quay. The authors are aware that these indices cannot aid in extracting sound results, but it is a measurement against the cargo handling capacity of the terminal and the attractiveness of the infrastructure.

Graph 2



From the above table 4 and the resultant graph 2, it is quite clear, that Marsaxlokk has such an attraction for the shipping companies, since the crane/quay index is the highest; in other main transhipment ports this index is also very high comparatively: over 6 in Algeciras and Genoa. In addition the storage/quay index is leading to the same conclusions, more or less. It is very interesting to notice, that the newly built, constructed and operated port of Goia Taurus has comparatively low indices, especially the storage/quay ratio, leading to the conclusion of very good land and superstructure utilisation.

The results

The whole idea of DEA model is the definition of an hypothetical port as a linear combination of the ports in the reference set of every port under examination. This hypothetical port is viewed as a single prototype that the port under evaluation should reproduce. The port under evaluation should reduce all inputs by a common factor $(1 - \theta)$ to become technically efficient or increase the outputs by $(\varphi - 1)$ for the same input mix. By giving just a numerical example, if the value of θ equals to 0.75, that means that this port can achieve the same output by reducing the input mix to 75% of the current, i.e. to reduce by 25% the input. In analogous way, if φ equals to 1.3, then it is possible to proportionately augment the outputs by 30% in order to use as efficiently as possible the input mix.

Along with these two 'scores' there are two more: I for the inputs and O for the outputs. I is obtained by standardising the total weight distance between the observed and projected points by the virtual input. The same for O, but the standardisation is obtain by the virtual output. What does it really mean? If I is equal with 1 then the port is efficient; if I is less than 1, 94% for example, then the port is inefficient and one could reply that the port should reduce the inputs to about 94% of the current inputs, in order to become efficient. What is the primary difference between θ and I? Both scores are measures of input inefficiency. θ measures only the portion of the inefficiency that can be realised by a proportional reduction of inputs, while I measures the total inefficiency in terms of proportional input reduction. Similar φ and O are measures of output inefficiency.

A sensitive point in the whole analysis is the issue of factor weights and their bounds. Since the factor weights are strongly related to the units used to measure the perspective factors, the technique of normalisation of all data has been used. Also the ratios and constraints between factor weights reflect the point of view and perception of the analyst as to relative importance accorded to factors and allowed variability (Roll and Hayuth, 1993). Therefore the weights used in this example are permitting almost 'unlimited' variability by setting very high upper and very low lower limit. The ratios for the output used, were between the total movements the transhipments and the [OS1]local ones as well as the vessels. Similarly for the input, and the ratios were between the cranes, the storage and the quays.

Table 5

	Input		Output	
	I	**θ**	**O**	**φ**
Algeciras	1	1	1	1
Barcelona	0.48765	0.49903	1.89428	1.87038
Valencia	0.44944	0.45563	2.04973	2.0344
Marceilles/Foss	0.37161	0.3747	2.46841	2.45724
Goia Tauro	1	1	1	1
La Spezia	0.88703	0.9098	1.02928	1.01501
Genoa	0.35824	0.363	2.57212	2.55358
Piraeus	0.85381	0.87483	1.09601	1.06999
Marsaxlokk	1	1	1	1
Limassol	0.85346	0.87792	1.11923	1.08842

The model has run for input and output oriented analysis and given the results as per table 5. The analysis has been based, taking as output: the total, transhipment and local movements as well as the number of the vessels called the port. As input all rest infrastructure, i.e. quays, cranes, storage and rail. The sensitivity test gave as expected most of the ports as efficient when the bounds were removed.

From the efficiency scores table, it is obvious that the ports of Algeciras, Goia Taurus and Marsaxlokk are evaluated as relatively efficient in terms of infrastructure. The results for the ports of Piraeus, Limassol and La Spezia look 'normal' while the results for the ports of Valencia, Barcelona, Marseilles and Genoa look very low. However a closer look to the input and output can justify such low results. These ports serve less traffic with more infrastructure. That means in terms of infrastructure, lower utilisation or productivity. However this does not necessarily mean that these ports are the 'bad' ones. Each port faces different markets and 'lives' in different conditions.

It seems somewhat odd to dismiss the inefficiency results as an effect of the different local condition. Perhaps this suggests, it is worth reconsidering the choice of the mix of inputs and outputs, or to examine the local policy choices or needs in the past as well as the actual utilisation of this infrastructure. What is statistically gathered in various sources or declared does not necessarily represent the facts and the practices; a crane may be considered as operational but very few times used within the year.

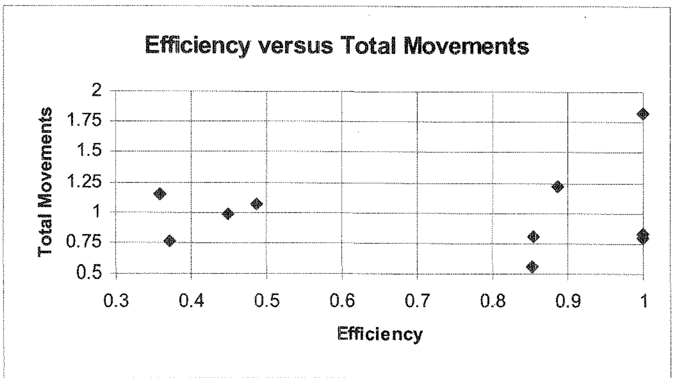
Examining the correlation of the inputs and the outputs as a set of data with the efficiency, some interesting conclusions can be drawn. The correlation for the input and the output is given in the following table:

Table 6

	Total Movements	*Transhipments*	*% of transhipments*	*Vessels*
correlation	1.1%	38.1%	56.2%	25.3%
	Quays	*Cranes*	*storage*	*rail*
correlation	15.8%	23.6%	41.5%	19.7%

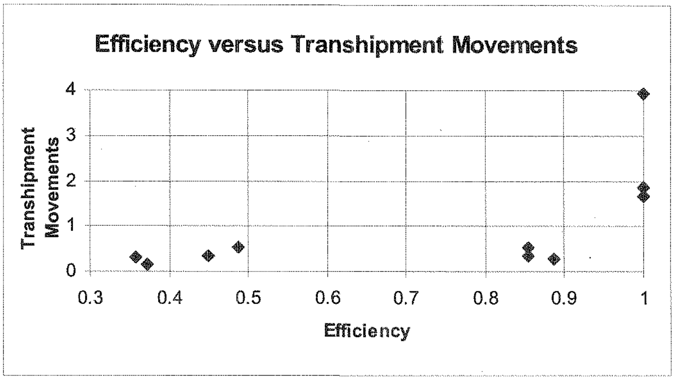
It is very interesting to notice that the percentage of transhipments gives a better correlation with efficiency, from the output group. On the other hand its very interesting to note the heavy influence of storage as parameter towards efficiency. Nevertheless the correlation is not a very strong one, indicating once again, that what is important is the 'correct' mix of resources and not a single resource. Plotting the scattered graphs of some outputs and inputs against efficiency a more unbiased qualitative approached is presented.

Graph 3



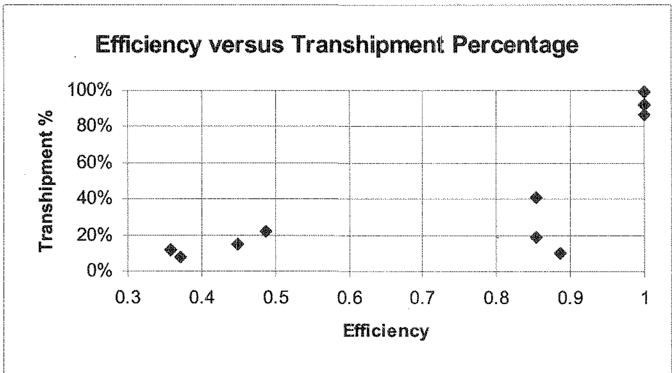
An efficient port does not necessarily facilitate high total traffic. Two out of the three efficient port facilitate relatively low traffic. But this is not the case for the transhipments.

Graph 4



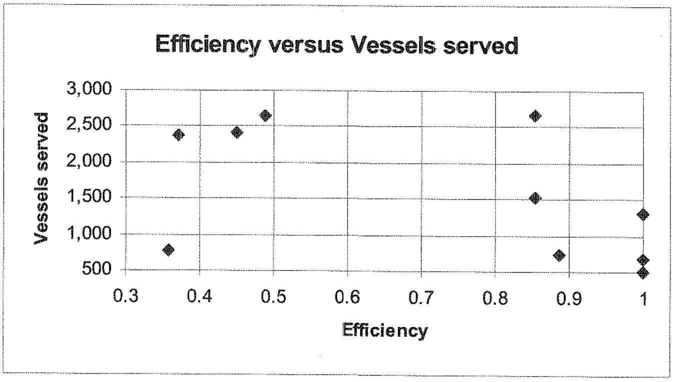
The most efficient ports are servicing many transhipments. However there are relatively efficient ports in the range of 80-90% which serve few transhipments. The next graph 4 is more indicative about the relationship of efficiency and transhipments. The three efficient ports facilitated over 80% of the total movements as transhipments, while the less efficient ports had a percentage of about 20% and less.

Graph 5



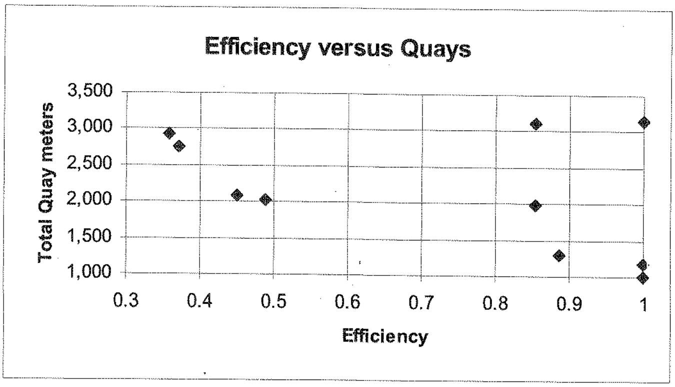
This result was also expected, as discussed previously. At this point the subjective judgement is crucial; is the efficiency of the port itself, which attracted the carriers, or the high demand from the carriers obliged the ports to rationalise or improve the use of infrastructure? Referring to the efficient transhipment centres it should be also noted, once again, that serve also less ships, so it is out of real interest to notice it again. Yet, the interesting observation is that in the range of 80-90% of efficiency, all the range of vessel number has been served.

Graph 6

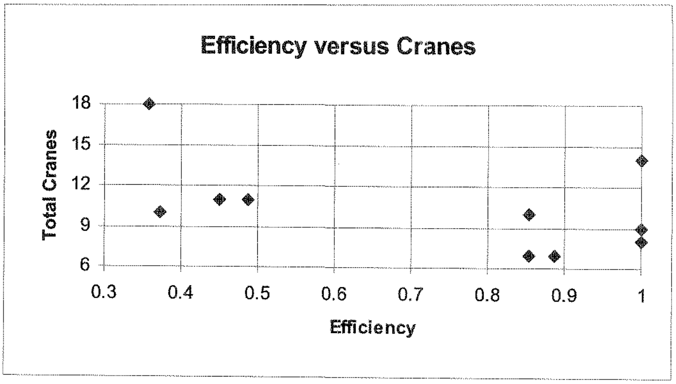


The results do not differ much for the inputs. In graph 6, one gets the result that efficiency is rather irrelevant with the total number of quays, from graph 7, it gets that usually fewer cranes are strongly correlated with efficiency. The actual meaning is that few cranes, properly managed and utilised may give better results than many under-utilised. The same can also be said for the storage facilities.

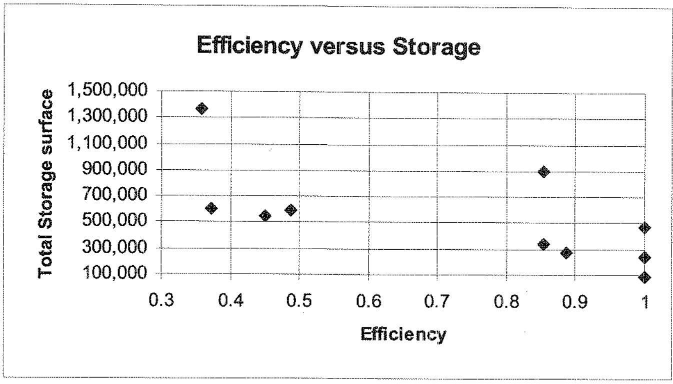
Graph 7



Graph 8



Graph 9



A final attempt to correlate all these infrastructure parameters with efficiency is the regression analysis. An approach can be the following equation:

$$\{\text{efficiency}\} = 1.135325288 - 5.93904 \cdot 10^{-5} \cdot \{\text{quays [m]}\} + 0.013589009 \cdot \{\text{cranes}\} - 4.63865 * 10^{-7} \cdot \{\text{storage } [m^2]\} - 0.246054612 \cdot \{\text{rail}\}$$

This regression formula gives relatively good results, with an r^2 equal to 58% and the several t-Stats well above 1. However this is just a mindless approach on a very difficult and complicated subject.

Analysing a little bit further the results, it can be said that Barcelona and Valencia could serve the same traffic with almost half of the infrastructure provided, while the ports of La Spezia, Piraeus and Limassol utilise almost well their resources. In their case an improvement of less than 10% can give them the 'tag' of the efficient port. On the other hand the 'efficient' ports of this sample are those dedicated to transhipments. These ports are by definition more efficient, that is why it is quite unfair to compare other ports with them. In the model they shaped the efficient envelope under which all other ports look inefficient. Therefore a subgroup analysis is following, just for the input oriented model. The two groups are the efficient transhipment ports and the rest.

In the next table the results of the subgroup analysis are presented, following the example of Roll (Roll and Hayuth, 1993). It is again expressed that Algeciras and Marsaxlokk are the more efficient in their group, while Goia Taurus is considered as less efficient because it provides more cranes and quays for almost the same movements as Algeciras.

Table 7

	I (All)	**I (group)**	**Subgroup analysis I(All)/ I(group)**
Algeciras	1	*1*	*1*
Barcelona	0.48765	0.85061	0.573294
Valencia	0.44944	0.79967	0.562032
Marceilles/Foss	0.37161	0.68454	0.542861
Goia Taurus	1	*0.7511*	*1.3314*
La Spezia	0.88703	1	0.88703
Genoa	0.35824	0.51781	0.691837
Piraeus	0.85381	0.95336	0.89558
Marsaxlokk	1	*1*	*1*
Limassol	0.85346	1	0.85346

Yet the ports of the other group have improved their efficiency, and as expected Limassol and La Spezia are considered as the most efficient in their group. Nevertheless, in a qualitative approach the same comments as above, can be expressed. An interesting observation is that the average efficiency of the group is about 72.6%, while the average for the group of Algeciras, Marsaxlokk and Goia Taurus is 91.7% and for the rest ports is 82.9%. The subgroup analysis column is actually presenting the ratio of the low efficiency gained in the group with the improved efficiency within the subgroup. The case of Goia Taurus, where it is more efficient in the group than in the subgroup, is giving a figure over 1. However the average for this subgroup is therefore 111.05% and for the rest ports becomes 71.5%.

Conclusions

Coming to conclusions, the application of the DEA is possible in actual port comparisons, completing part of the discussion as invoked by Roll and Hayuth in 1993. Other more interesting mixes of inputs or a higher number of ports could provide more interesting results from a commercial point of view, but this was not possible, due to lack of the relevant information. However it is rather difficult to disconnect the efficiency of a port from the complexity of the real world. This group of inputs was comparatively easy to be collected form various sources, while other data, such as of labour force in the yard and in the offices, capital invested, maintenance and many other issues is rather impossible to be collected. Finally, the method needs a larger number of inputs in order to provide more sound statistical results.

The method gave good results in terms of expectancy. No surprises were revealed, yet the relative quantification has doomed some very attractive ports as relatively inefficient. The correlation of the data gave also a good image of the importance of infrastructure in formulating this efficiency measure.

The presentation concludes with a suggestion for further research. This method can be carefully applied for evaluating also the efficiency of ports from the past till today. Such an analysis will not be restricted to the available infrastructure data, because the port management is aware of most important data, such as labour and capitals and because the characteristics of infrastructure do not change year by year, since they demand heavy investments. In addition, port comparison within a region may be a valuable tool to the hands of the management not only for re-allocation of resources towards improved efficiency, but also as negotiation or advertisement vehicle.

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