Container Port Operational Performance Assessment
– A Rational Approach based on Internet Website Port Data

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Abstract: With today's rather comprehensive port infrastructure and facilities information made available on public-domain Internet websites by port authorities and operators, it is possible to collect very good quality detailed data and information from such sources alone. This paper presents a case analysis based on 40 major ports in East and Southeast Asia. It demonstrates that good quality port infrastructure and container handling facilities data obtained can be used to derive a statistically significant predictive model of annual port throughputs. The derived information offers meaningful port productivity evaluation and efficiency benchmarking among the 40 ports analyzed. The analysis makes use of the commonly available technique of statistical regression to establish the predicted level of performance. The simplicity of the approach, plus the fact that all required inputs are public domain data obtainable from port websites, permits owners/operators of individual ports or any other users to perform additional analysis if required.

Keywords: Container ports, Port infrastructure, Container handling facilities, Port throughput, Port productivity, Port efficiency

1. INTRODUCTION

The knowledge of the overall container handling performance of a container port is of great value to the operator of the port and the responsible authority or agency overseeing the port and maritime industry. In addition, information on the port's performance in comparison to other ports is equally valuable as such benchmarking information would offer a reference for identifying the strengths and weaknesses of the port. Performance targets may thus be set and effective strategies be formulated and implemented to bring about improvements to port operations.

Many researchers and professionals have proposed methods and measures to evaluate the performance of container ports (Bichou 2007, 2009; Gonzalez and Trujillo, 2009; Kaiser et al., 2006; Mithun and Song 2010). Bichou (2009) categorized the various practical and theoretical approaches to port performance benchmarking into three broad categories: performance metrics and index methods, economic impact studies and efficiency frontier approaches. A performance index or score is convenient to use for performance comparison across ports and benchmarking of ports. However, it is often difficult for users to retrieve the detailed performance data, their relationships with the performance score, and the physical meaning of the score. Economic impact studies offer an overall assessment valuable for higher level planning, but may not be easily applied for improving port operations. For the efficiency frontier approaches, including the stochastic and deterministic frontier approaches (Battese and Coelli 1992, 1995; Greene 1980; Meeusen and Van Den Broeck, 1977), the Data Envelopment Analysis (DEA) has been a relatively common technique adopted for port performance assessment (Cullinane and Wang, 2010; Kaiser et al., 2006; Roll and Hatuth, 1993). It establishes an empirical input-output relationship often presented in a graphical form showing the optimal outputs obtainable from given inputs. Both the economic impact analysis and the DEA approach require data and analytical skills which may make it difficult for users to perform additional analysis and interpretation on their own.

In the present study, taking advantage of the convenient accessibility of port websites put up by port operators, port owners and port authorities, a rational approach based on the commonly available technique of statistical regression is adopted to develop a performance benchmarking method using port website data. The main objective was to demonstrate the level of usefulness that open-source data can provide for the purpose of port benchmarking analysis. This increased level of usefulness of open-source data is now achievable because of the rather easy accessibility of such data today due to the wide-spread use of Internet by the public and commercial sectors in disseminating their public domain data.

The level of usefulness of the open-source data for port benchmarking analysis is also assessed by comparison with the analysis results using data from commercial sources. Similar port data could be obtained from commercial reports or databases. Relevant port data obtained from a commercial database were compiled, and a comparison analysis was performed to provide an assessment of the quality of the data and benchmarking analysis of the proposed approach.

2. PORTS DATABASE DEVELOPMENT

2.1 Data Compilation

There exists a large volume of useful port related data in the public domain that are valuable for research use and practical applications. At the Centre for Maritime Studies in the National University of Singapore, a database has been established that collects such data for 40 major ports in East and Southeast Asia (Chu et al. 2011). The data are presented in a format and platform convenient for public access.

Table 1 lists the 40 ports selected for the study. Each of the 40 ports selected satisfies at least one of the following criteria (Chu et al. 2012):

1) Total container throughput exceeding 3 million TEUs (Twenty-Foot Equivalent Units) based on 2010 data;
2) Total container throughput exceeding 1 million TEUs and total non-container cargo handled exceeding 100 million tones based on 2010 data;
3) At least two ports per country other than Cambodia, Singapore, and Sri Lanka;

The information included in the database contains two broad categories of data, namely port infrastructural and port operational data. For container ports, which are the topic of study in this paper, Table 2 lists the specific data items classified under each of these two broad categories.

Table 1 40 Ports Considered in Present Study

1. Bangkok	11. Hong Kong	21. Mumbai	31. Singapore
2. Busan	12. Incheon	22. Nagoya	32. Taichung
3. Chennai	13. Jawaharlal Nehru	23. Nanjing	33. Tanjung Pelepas
4. Colombo	14. Kaohsiung	24. Ningbo	34. Tanjung Perak
5. Dalian	15. Keelung	25. Osaka	35. Tanjung Priok
6. Fuzhou	16. Kobe	26. Port Klang	36. Tianjin
7. Guangzhou	17. Kolkata	27. Qingdao	37. Tokyo
8. Gwangyang	18. Laem Chabang	28. Shanghai	38. Xiamen
9. Hai Phong	19. Lianyungang	29. Shenzhen	39. Yantai
10. Ho Chi Minh	20. Manila	30. Sihanoukville	40. Yokohama

2.2 Sources of Data

It was the intention of the database development project to collect and compile only data available in the public domain. It was believed that the modern day wide-spread use and accessibility of the Internet has opened up a new avenue of data flow and dissemination. Practically all seaports in operation today have published some form of official websites providing vital infrastructural and operational capability information to attract commercial users and customers. Many ports also made available their annual reports on their Internet websites. It appears appropriate to investigate if such open information available through public domain channels would be sufficient to permit meaningful analysis to be performed for the purpose of port benchmarking.

The original plan of the database development in this project was to obtain all port-related data from the following sources:

1) Open sources such as official Internet websites of maritime transportation, logistics or other related ministries, port authorities, port owners and port operators, and their publications such as annual reports, project reports, and brochures.
2) Survey questionnaires by mail to port operators, port owners and port authorities.
3) Visits to ports and interviews with operators, port owners and port authorities.
4) It turned out that the main bulk of the data collected in the process was obtained from Internet websites. Most printed publications of ports were found to duplicate information already available on websites. As for survey questionnaires, the return rate was disappointingly low. Only 8 partially completed questionnaires were returned. The information gathered from the returned questionnaires was also not found to be of better value than those obtainable directly from Internet websites. It was decided by the study team subsequently to exclude the use of this method in the development of the database. Physical visits to ports and interviews with port operators, port owners and port authorities were useful in certain aspects, particularly in clarifying facts and figures obtained from websites. However, this mode of data collection is costly and not time effective due to the limited amount of data that could be obtained in each visit.

Table 2. List of data items included in database for container ports

Main Data Category	Specific Data Items
Infrastructural data	• Number of terminals • Area of each terminal, and total port terminal Area • Number of berths of each terminal • Berth length & draft of each terminal, and total port berth length • Quay length of each terminal, and total port quay length • Container yard area of each terminal, and total port yard area • Yard storage capacity per terminal, and total port yard storage capacity • Covered Storage Area • Number and size of quay cranes each terminal, and total number of port quay cranes • Number, type and size of yard cranes each terminal, and total number of port yard cranes • Number and size of straddle carriers each terminal, and total number of port quay cranes • Number of prime mover tractors and trailers each terminal, and total number for the port • Number of types of other transporters or stacking devices each terminal, and total number for the port (e.g. reach stackers, forklifts, top-lifters, side-lifters, etc.)
Operational data	• Annual throughput of each terminal in TEUs • Total annual port throughput in TEUs • Annual export throughput each terminal, and total for the port • Annual import throughput each terminal, and total for the port • Annual ship calls in number • Annual ship calls in tonnes

The conclusion by the study team was that information and data obtained from official websites are the single most useful form of data for the database. For the purpose of database development and the ease and consistency of long-term continuity of database updating, it was decided that Internet websites would be the only data source to be used for developing and updating the database. For easy access and manipulation by the general users, the database was developed using Microsoft Excel software which is commonly available to most personal computer users. More details of data compilation can be found in the article by Chu et al. (2012).

The database records only data that are obtained directly from the data source. It does not contain any form of derived data or computed data. For each data item, the dates that the data were collected and the sources of data were systematically recorded in the database. Hence, all the data that appear in the database can be checked and verified directly by accessing the indicated sources.

3. PORT PERFORMANCE ANALYSIS CASE STUDY

3.1 Methodology Adopted

There are two main aspects by which the performance of a port is commonly measured: productivity and efficiency (OECD 2001). The concept of productivity is commonly defined as a ratio of the volume of output to the amount of input committed. The term efficiency, on the other hand, is a concept often measured in a relative sense. For example, the efficiency of a port can be measured by comparing its productivity performance compared to a benchmark. In this paper, the productivity performance of a port is assessed in terms of its annual container throughput in TEUs against its available port infrastructure and facilities. The efficiency comparison is made based on a benchmarking analysis making use of the commonly available technique of statistical regression based on the port data of the 40 ports in the database. The regression analysis will give a predictive model of expected annual throughput for a given set of port infrastructure and facilities. For each port, this predictive model will provide an expected level of throughput which could be used as the reference average level of throughput.

3.2 Choice of Parameters

The productivity performance of a container port or terminal is influenced by a wide range of factors. Not all the factors that influence port productivity can be controlled by port or terminal operators or owners. Those factors that are internal to the port and are under the control of the operators or owners are of interest in this study. They include terminal configuration and layout, terminal infrastructure and facilities, as represented by the infrastructural data items listed in Table 2. These infrastructure data items have been shown by researchers to have significant influence on port throughput (Bichou 2009, Mithun and Song 2010). They are consolidated as the independent variables in Table 3.

In the present case study, the regression predictive model for port productivity has the port annual throughput as the dependent variable, and the various port infrastructure and facility items as the independent variables. A check of the database indicated that not all 40 ports contained the full set of values for the data items listed under Infrastructure Data in the database (see Table 2). For example, not all the infrastructure data in all the terminals of the 40 ports were available. The infrastructure data at the overall port level for the 40 ports were most complete for the year 2010. Hence, 2010 was chosen as the year of analysis, and the corresponding final set of parameters used in the regression analysis is summarized in Table 3.

Table 3. Parameters Used in Regression Analysis

Variable	Parameter and Unit
Dependent variable	Port annual throughput (TEUs)
Independent variables	• Total berth length (m) • Port draft (m) • Total terminal area (m^2) • Total container yard area (m^2) • Total number of quay cranes • Total number of yard cranes • Total number of straddle carriers • Total number of prime mover tractors • Total number of trailers • Total number of lifters/stackers

4. REGRESSION ANALYSIS OF PRODUCTIVITY AND EFFICIENCY PERFORMANCE

4.1 Analysis of Correlation Matrix

For the 40 ports analyzed, a statistical correlation analysis produced Table 4 which gives the correlation relationships between the dependent variable with each independent variable, and also between each pair of independent variables. The following observations can be made:

(a) In the order of decreasing values, the variables that have the best correlation coefficient, r, with the dependent variable Y (i.e. port annual throughput) are:
- Number of quay cranes (r = 0.933)
- Total berth length (r = 0.866)
- Number of yard cranes (r = 0.737)
- Total terminal area (r = 0.688)

(b) The pairs of independent variables that are found to be relatively highly correlated are:
- Number of quay crane and total berth length (r = 0.904)
- Total terminal area and total yard storage area (r = 0.812)
- Number of yard cranes and total terminal area (r = 0.761)
- Number of quay crane and number of yard cranes (r = 0.655)
- Number of yard cranes and total berth length (r = 0.646)
- Number of quay cranes and total terminal area (r = 0.606)

The four variables that have the highest correlation with annual port throughput are two key yard infrastructure dimensions (berth length and terminal area) and two key container handling equipment (quay cranes and yard cranes). These results are in line with the general expectation related to container port operations. The berth length directly governs port capacity in terms of the number of ships that can berth annually, while the terminal area gives the port space for moving and storage of containers. The number of quay cranes directly controls the capacity of a port in moving containers to and from the ships berthed. On the other hand, the number of yard cranes determines a port’s capacity in container storage and retrieval.

Those pairs of independent variables that are relatively highly correlated are within expectation too. The number of quay cranes and yard cranes, respectively, are correlated with berth length and terminal area. As expected, the storage yard area is highly correlated with the terminal area. It is noted that the number of quay cranes is well correlated with the number of yard cranes, which is expected as a yard is usually equipped to provide a capacity matching the capacity of the quay cranes.

Table 4. Correlation matrix of regression analysis

	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
Y	1										
X_1	0.863	1									
X_2	0.469	0.508	1								
X_3	0.686	0.588	0.340	1							
X_4	0.525	0.438	0.237	0.812	1						
X_5	0.924	0.904	0.477	0.606	0.567	1					
X_6	0.733	0.646	0.314	0.761	0.506	0.655	1				
X_7	0.189	0.363	0.074	0.234	0.154	0.216	0.428	1			
X_8	0.369	0.327	0.250	0.563	0.350	0.293	0.574	0.325	1		
X_9	0.077	0.213	0.026	0.182	0.126	0.170	0.308	0.384	0.428	1	
X_{10}	0.118	0.134	0.069	0.103	0.076	0.116	0.019	0.237	0.085	0.127	1

Notes: Y = Annual port throughput (TEUs); X_1 = Total berth length (m); X_2 = Port draft (m) X_3 = Total terminal area (m^2); X_4 = Total yard storage area (m^2); X_5 = Total number of quay cranes; X_6 = Total number of yard cranes; X_7 = Total number of straddle carriers; X_8 = Total number of prime mover tractors; X_9 = Total number of trailers; X_{10} = Total number of lifters/stackers

Quay cranes and yard cranes are the key equipment used in all the 40 ports. It is observed that the number of straddle carriers, prime mover tractors and trailers, lifters and stackers, are not highly correlated with the annual port throughput. For the case of straddle carriers, it was found that most of the 40 ports studied did not make use of this form of container transporter. Similarly, lifters and stackers were not the main form of container handling devices in the 40 ports. As for prime mover tractors and trailers, while they were the primary container transports in the 40 ports studied, their numbers could have an impact on the turnaround times of containers, but appear not to have a direct influence on the annual port throughput.

4.2 Statistical Predictive Model for Annual Throughput

A stepwise regression analysis (Montgomery and Runger 2011) was performed for the 40 ports with the dependent variable Y and the 10 independent variables given in Table 4. The final form of the statistically significant model obtained using this procedure consists of only 2 independent variables, namely the number of quay cranes and the number of yard cranes, as depicted in the following equations:

$$Y \text{ (Annual Throughput TEU)} = 128{,}306\, N_{QC} + 16{,}172\, N_{YC} \qquad (r^2 = 0.912) \qquad (1)$$

where Y is the annual port throughput in TEU; N_{QC} is the number of quay cranes, and N_{YC} is the number of yard cranes.

From Equation (1), based on the performance of the 40 ports, on average the productivity of a quay crane was (128206/365) = 351 TEU per day, or 175 FEU (Forty-Foot Equivalent Units); and the average productivity of a yard crane was 44 TEU per day, or 22 FEU per day.

4.3 Comparative Port Efficiency Performance Analysis

Equation (1) derived in the preceding section provides the expected annual port throughput for the port infrastructure and facilities available. For the present case, only the number of quay cranes and the number of yard cranes are required for the computation of the expected annual throughput (see Equation 1). Table 5(a) shows the expected and actual throughput of the 40 ports for the analysis year of 2010. These values are plotted in Figure 1 which clearly depicts the usefulness of such an analysis. The data point represented by a numeric (ranging from 1 to 40) refers to the code number assigned to the port as indicated in Table 5(a). The regression line drawn in Figure 1 can be considered to represent the average throughput performance trend based on the throughput performances of the 40 ports.

The expected annual throughput computed using Equation (1) can be interpreted as the average performance value one would expect based on the overall performance of the 40 ports analyzed. For a port with its actual throughput value higher than its expected throughput, it means that the port had performed better than the average performance of the 40 ports, and vice versa. Table 5(b) groups the ports according to their efficiency performance based on the comparison of expected and actual annual throughput. Table 5(c) re-computes the list based on the percentage of difference instead of the magnitude of difference between expected and actual throughput. Tables 5(b) and 5(c) show that the top performing ports are dominated by ports in the Yangtze Delta and the Pearl River Delta of China where a strong growth of freight volumes heavily stresses the capacity of the ports; while Singapore, Hong Kong and Kaoshiung also fared very strongly in view of their leading positions as regional shipping hubs. The under-performing ports are mostly those that could not attract enough freight volumes for the port capacity provided.

The benchmarking information provided in Tables 5(b) and 5(c) are gross assessments based on regression analysis. It does not provide further details as to what actually contributes to the discrepancies between expected and actual throughputs. For example, a port with actual throughput falling behind its expected throughput could be due to the low efficiency of its shipping berth (e.g. congested channel) and/or container handling operations (e.g. inefficient quay crane and yard crane operations). However, it could also be a case where infrastructure and facilities are provided ahead of demand in preparation for future growth of freight volume. While the former case presents problems for the port concerned to worry about, the latter case is simply a result of the good practice of planning ahead. On a similar reasoning, when a port has its actual throughput surging far ahead of its expected throughput, giving a higher than par efficiency of its operations, it could in fact signal a strain on the existing port infrastructure and facilities. This means that it would be time for the port concerned to consider plans for upgrading and expansion.

Based on the results of the benchmarking analysis, each individual port could follow up to conduct an internal evaluation on the actual reasons why their port is under-performing or performing better than other ports. This is possible because the port itself would have all the detailed internal information that permits them to carry out an in-depth self-analysis. It is for this reason that the authors believe this simple benchmarking analysis would have practical significance for the port authorities and operators.

Table 5 Port performance efficiency benchmarking

(a) Actual and computed expected throughputs

Port Code	Port Name	Actual TEU Throughput	Expected TEU Throughput
1	Bangkok	1,222,000	3,424,330
2	Busan	14,190,000	17,866,730
3	Chennai	1,523,000	2,681,473
4	Colombo	4,080,000	4,741,882
5	Dalian	5,260,000	7,084,808
6	Fuzhou	1,490,000	2,555,314
7	Guangzhou	12,550,000	8,238,488
8	Gwangyang	2,253,000	4,366,697
9	Hai Phong	790,000	1,481,422
10	Ho Chi Minh	4,110,000	5,940,860
11	Hong Kong	23,700,000	21,940,103
12	Incheon	1,880,000	1,301,379
13	Jawaharlal Neh	4,617,000	4,920,851
14	Kaoshiung	9,180,000	3,774,757
15	Keelung	2,402,780	4,044,322
16	Kobe	2,540,000	5,029,765
17	Kolkata	526,474	838,818
18	Laem Chabang	5,190,000	7,105,273
19	Lianyungang	3,870,000	3,453,456
20	Manila	3,250,000	3,618,399
21	Mumbai	72,472	2,236,158
22	Nagoya	2,550,000	4,368,843
23	Nanjing	1,400,000	1,123,482
24	Ningbo	13,140,000	10,991,165
25	Osaka	2,500,000	3,821,128
26	Port Klang	8,870,000	11,104,297
27	Qingdao	12,010,000	10,389,418
28	Shanghai	29,070,000	22,952,525
29	Shenzhen	22,510,000	25,920,883
30	Sihanoukville	224,206	1,204,344
31	Singapore	28,430,000	26,756,630
32	Taichung	1,193,943	2,460,426
33	Tanjung Pelepas	6,540,000	7,877,255
34	Tanjung Perak	2,643,518	3,421,111
35	Tanjung Priok	4,720,000	5,435,148
36	Tianjin	10,080,000	10,245,014
37	Tokyo	4,280,000	5,783,429
38	Xiamen	5,820,000	6,995,360
39	Yantai	1,541,000	2,747,236
40	Yokohama	3,260,000	5,861,071

(b) Port ranking based on throughput difference

Port Name	Throughput Difference (TEU)
Shanghai	6,117,475
Kaoshiung	5,405,243
Guangzhou	4,311,512
Ningbo	2,148,835
Hong Kong	1,759,897
Singapore	1,673,370
Qingdao	1,620,582
Incheon	578,621
Lianyungang	416,544
Nanjing	276,518
Tianjin	-165,014
Jawaharlal Nehru	-303,851
Kolkata	-312,344
Manila	-368,399
Colombo	-661,882
Hai Phong	-691,422
Tanjung Priok	-715,148
Tanjung Perak	-777,593
Sihanoukville	-980,138
Fuzhou	-1,065,314
Chennai	-1,158,473
Xiamen	-1,175,360
Yantai	-1,206,236
Taichung	-1,266,483
Osaka	-1,321,128
Tanjung Pelepas	-1,337,255
Tokyo	-1,503,429
Keelung	-1,641,542
Nagoya	-1,818,843
Dalian	-1,824,808
Ho Chi Minh	-1,830,860
Laem Chabang	-1,915,273
Gwangyang	-2,113,697
Mumbai	-2,163,686
Bangkok	-2,202,330
Port Klang	-2,234,297
Kobe	-2,489,765
Yokohama	-2,601,071
Shenzhen	-3,410,883
Busan	-3,676,730

(c) Port ranking based on % throughput difference

Port Name	%Throughput Difference (TEU)
Kaoshiung	143.19
Guangzhou	52.33
Incheon	44.46
Shanghai	26.65
Nanjing	24.61
Ninbo	19.55
Qingdao	15.6
Lianyungang	12.06
Hong Kong	8.02
Singapore	6.25
Tianjin	-1.61
Jawaharlal Nehru	-6.17
Manila	-10.18
Shenzhen	-13.16
Tanjung Priok	-13.16
Colombo	-13.96
Xiamen	-16.8
Tanjung Pelepas	-16.98
Port Klang	-20.12
Busan	-20.58
Tanjung Perak	-22.73
Dalian	-25.76
Tokyo	-26.00
Laem Chabang	-26.96
Ho Chi Minh	-30.82
Osaka	-34.57
Kolkata	-37.24
Keelung	-40.59
Nagoya	-41.63
Fuzhou	-41.69
Chennai	-43.2
Yantai	-43.91
Yokohama	-44.38
Hai Phong	-46.67
Gwangyang	-48.4
Kobe	-49.5
Taichung	-51.47
Bangkok	-64.31
Sihanoukville	-81.38
Mumbai	-96.76

Note: Difference = Actual – Expected Note: % difference = 100(Actual – Expected)/Expected

5. COMPARISION WITH COMMERCIAL DATABASES

The port data collected in the database developed for this study can also be obtained from commercial databases. One of the most established commercial databases for container ports is the Containerisation International Yearbook series (Containerisation International 2011). For the purpose of the present study, port infrastructure and facilities data for year 2010 were extracted from the Containerisation International Yearbook (2011). The Yearbook 2011 contains a Ports and Terminals Guide that offers details of berths and terminal facilities of over 600 ports and 760 terminals.

The same technique of analysis, as described in the preceding sections for the development of port throughput predictive model and benchmarking analysis, is applied to the year 2010 data compiled from the Containerisation International Yearbook 2011. The results of analysis are presented in Figure 2 which displays a very similar pattern of scatter plot to that of Figure 1. Similar conclusions to those in the preceding section can be made from Figure 2 regarding the relative performances of the 40 ports studied. A correlation analysis between the two sets of predicted port annual throughput TEUs for the 40 ports, one based on the Containerisation International Yearbook data and the other from the database developed in this study from Internet sources, yields a correlation coefficient of $r = 0.984$. Some differences are observed between the two due to discrepancies in data values since their respective data sources are not the same.

The comparison analysis clearly demonstrates that the proposed approach based on open-domain data from Internet sources is adequate for performing meaningful port productivity performance and efficiency benchmarking analysis. It is able to generate useful information compatible with those obtainable from established commercial databases. Hence, it may be concluded that the approach proposed in the present study can be employed meaningfully to study the relative port productivity performance with respect to the port infrastructure and container handling resources available in the ports.

6. CONCLUSION

This paper has demonstrated that, with today's rather comprehensive volume of port infrastructure and facilities information made available in public-domain Internet websites by authorities and operators, and the very high accessibility of Internet from most parts of the world, it is possible to collect good quality detailed data and information from such sources alone. A case analysis based on 40 major ports in East and Southeast Asia has been presented. The results of analysis confirm that the proposed concept is workable, and a meaningful and statistically significant predictive model of annual port throughput can be derived using the port infrastructure and container handling facilities information obtainable form Internet public-domain sources. The case analysis illustrates that productivity evaluation and efficiency benchmarking of ports could be made based on the analysis. Although the analysis was applied to Asian ports, it is clear that the concept and approach presented is equally valid for analyzing performance of ports in other parts of the world.

The analysis makes use of the commonly available technique of statistical regression to establish the expected level of performance and the average level of performance. The simplicity of the approach, plus the fact that all required inputs are public domain data obtainable from port websites, permits owners/operators of individual ports or any other users to perform additional analysis if required. This will enable them to gain direct insights into the level of performance of their ports in comparison with other ports, and conduct more in-depth analysis of their own strengths and weaknesses.

REFERENCES

Battese, G.E. and Coelli, T.J. (1992) Frontier production functions, technical efficiency and panel data: with application to paddy farmers in India. Research Report, Department of Econometrics, University of New England. 34pp.

Battese, G.E. and Coelli, T.J. (1995) A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*, 20, 325-332.

Bichou, K. (2007) Review of performance approaches and a supply chain framework to port performance benchmarking. In Brooks, M. and Cullinane, K. (eds.), *Devolution, Port Governance and Port Performance,* in *Research in Transportation Economics*, 17, 567-599.

Bichou K. (2009) A benchmarking study of the impacts of security regulations on container port efficiency, PhD Thesis, Imperial College London.

Chu L. J., Fwa T. F. and Nishijima H. (2011) Interim Report: Database for East Asian and Southeast Asian Ports. Centre for Maritime Studies, National University of Singapore.

Chu L. J., Fwa T. F. and Nishijima H. (2012) Issues in Port Database Development -- A Case Study on East Asian and Southeast Asian Ports. Paper presented at the Fourth T-LOG Conference, Busan, Korea, 23-25 August 2012.

Containerisation International (2011) *Containerisation International Yearbook 2011*. Containerisation International, London, UK

Cullinane K. and Wang T. F. (2010) The efficiency analysis of container port production using DEA panel data approaches. *OR Spectrum*, 32(3), 717-738

González M. M, and Trujillo L. (2009) Efficiency measurement in the port industry: A survey of the empirical evidence. *Journal of Transport Economics and Policy*, 43(2), 157-192.

Greene, W. (1980) Maximum likelihood estimation of econometric frontier functions. *Journal of Econometrics*, 13, 27-56.

Kaiser E. I., Pathomsiri S. and Haghano A. (2006) Efficiency measurements of US ports using data envelopment analysis. National Urban Freight Conference, Long Beach, CA., February 1-3, 2006.

Meeusen, W. and Van Den Broeck, J. (1977) Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review,* 18(2), 435-444.

Mithun J. S. and Song J. Y. (2010) Benchmarking optimization and attribute identification for improvement of container terminals. *European Journal of Operational Research*, 201(2), 568–580.

Montgomery D. C. and Runger G. C. (2011), *Applied Statistics and Probability for Engineers*, 5th Ed., John Wiley & Sons, Inc

OECD (2001) *Measuring Productivity - OECD Manual*. Organisation for Economic Co-Operation and Development, Paris.

Roll, Y. and Hayuth, Y. (1993) Port performance comparison applying data envelopment analysis (DEA). *Maritime Policy and Management*, 20, 153 - 161.

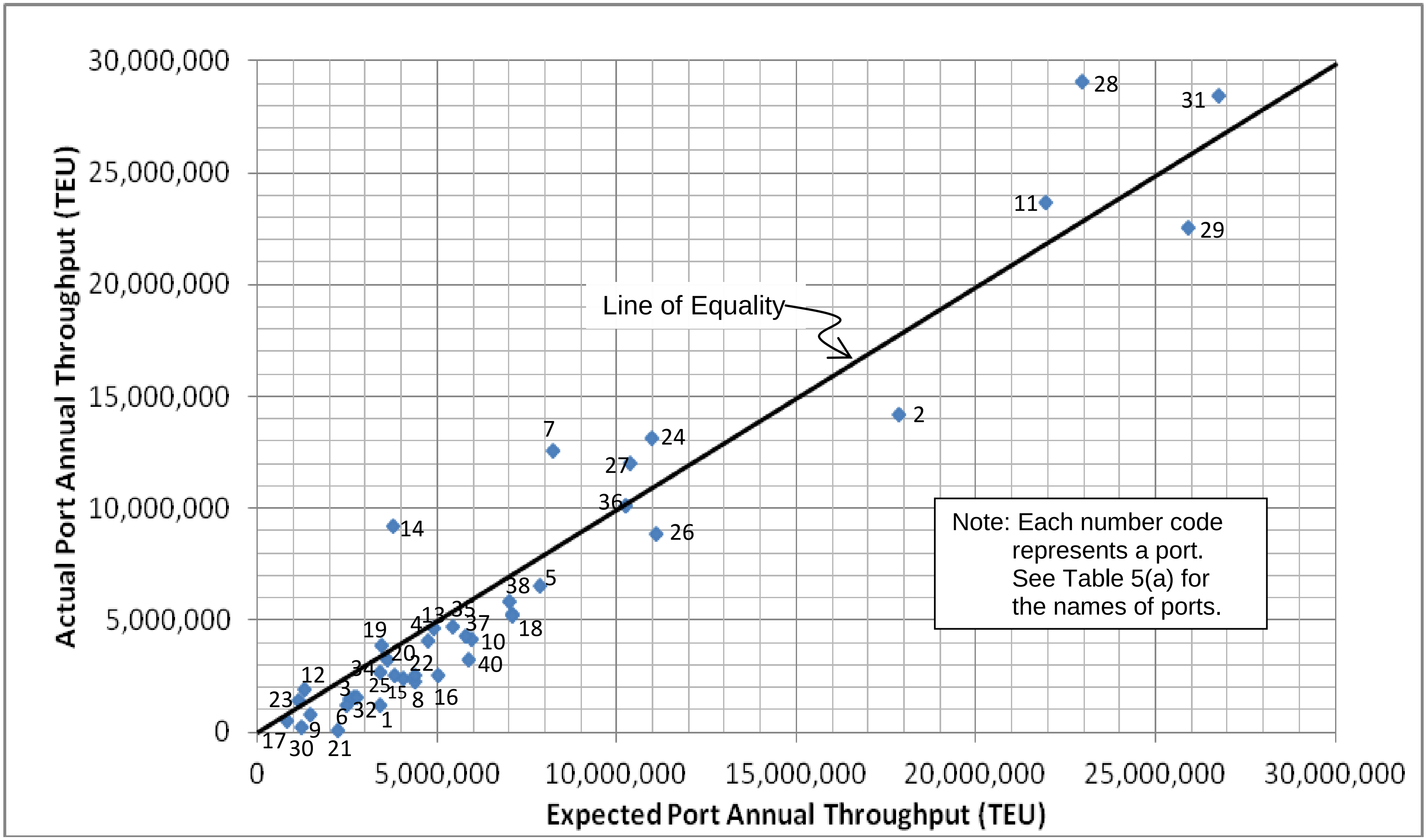

Figure 1 Comparison of actual and expected port throughputs based on Internet data

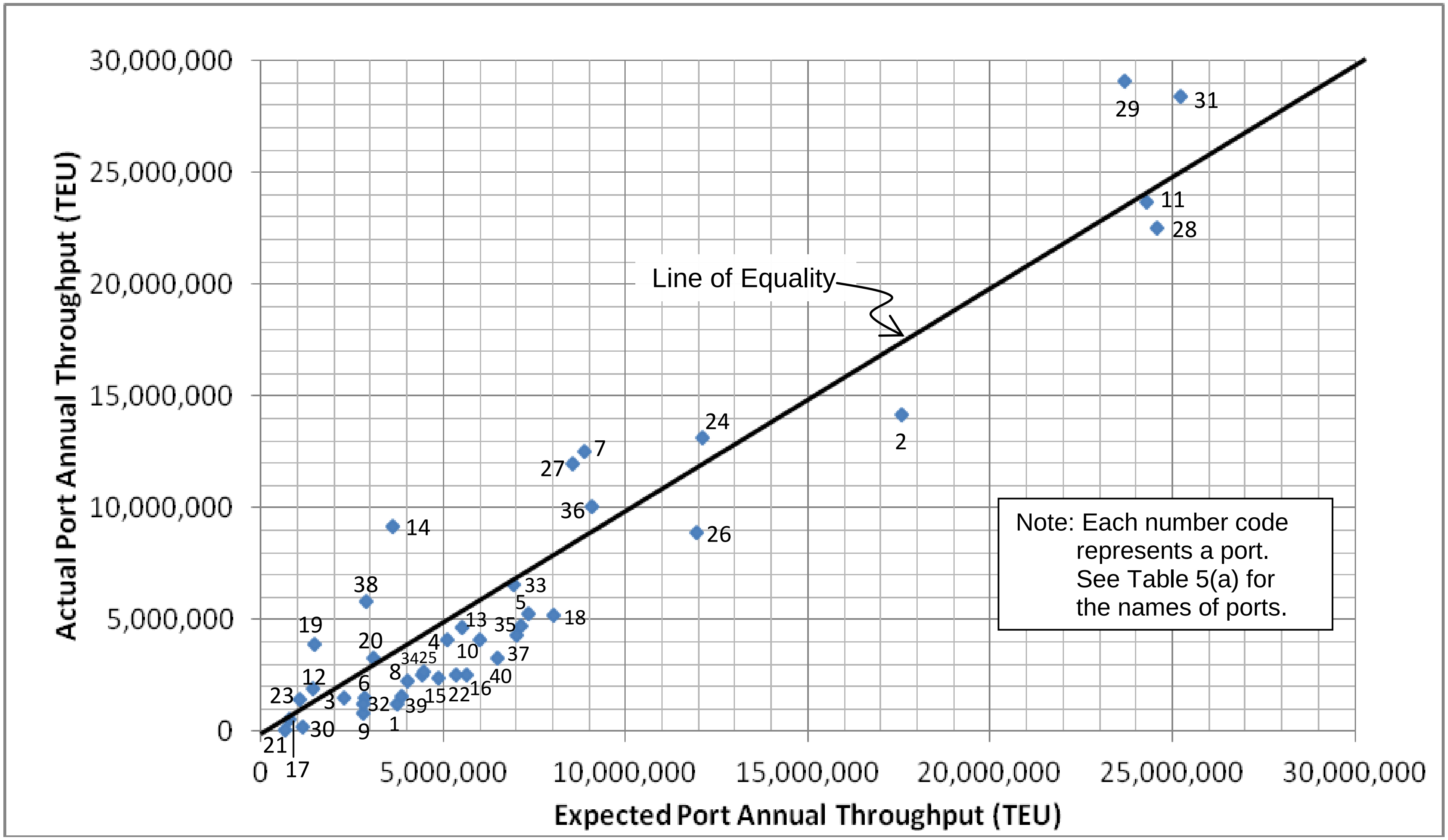

Figure 2 Comparison of actual and expected port throughputs based on commercial database data