

# Discrete-Event Simulation and Data Envelopment Analysis in Port Efficiency Evaluation: A Bibliometric Analysis and Mapping of Combined Databases

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**Abstract:** This paper provides a bibliometric review and network analysis merging Scopus and Web of Science (WoS) databases on the port-related studies of discrete-event simulation (DES) or/and data envelopment analysis (DEA). 172 studies were published in 87 academic journals and authored by 432 scholars. The bibliographical data was examined with the R software Bibliometrix tool. Citation analysis metrics identified the most productive and influential articles, the top journals, the most productive and impactful authors, most relevant institutions, as well as the comparison of local citation score of articles published in Scopus and WoS databases. At the end of the analysis phase, the co-occurrence of influential keywords for Scopus, and WoS databases, and the collaboration networks of the authors, institutions, and countries are provided.

## 1 INTRODUCTION

After nearly three decades, there has been continuous and rapid growth in interdisciplinary interest in port studies. The port's long-term viability has become a global concern due to its importance in world trade, which drives the country's economy. Furthermore, the increased managerial interest in optimising the port performance and efficiency necessitates sustained efforts and a more result-oriented approach. The simulation and optimisation approach can be an interesting hybrid method to be implemented in port-related studies. It ensures the results to be more understandable through the mimicking process and provides the best decision by maximising or minimising the desired variables. These two methods complement each other because simulation is a difficult process for obtaining high-quality solutions, while optimisation can yield high-quality analytical solutions (Lee, 2017). Enormous advances in computational power encourage the development of techniques that integrated both methods (Figueira and Almada-Lobo, 2014).

Simulation has the ability to transcend the mathematical limitations of optimisation approaches. The simulation produces computer-generated techniques that are easier to comprehend and aid decision-makers

in their daily decisionmaking processes (Cartenì and Luca, 2012). It has been found in several port-related research, including operations (Petering, 2015; Ballis et al., 1997), planning and evaluation (Moon and Woo, 2014; Longo et al., 2015), and integration with optimisation models (Zeng et al., 2015; Sislioglu et al., 2019). In port-related studies, simulation is very helpful in assisting the operational sector in allocating facilities, proposing congested port alternatives, and enhancing port performance.

DEA, on the other hand, was made known by Charnes, Cooper and Rhodes (Charnes et al., 1978) (referred to CCR) in 1978 as a new alternative to measure efficiency. Since then, extensions of DEA were developed actively to address the shortcomings of the previous approach and has been widely applied in port studies. According to Ensslin et al. (Ensslin et al., 2018), DEA is the most frequently used performance evaluation technique for seaport. Güner (Güner, 2018) used DEA to estimate the port efficiency by incorporating expert opinions, while Mustafa et al. (Mustafa et al., 2021) analysed the technical efficiency of less examined by the Middle East and South Asian ports. A current topic on environmental efficiency has initiated a study conducted by Castelló-Taliani et al. (Castelló-Taliani et al.,

2021) to evaluate environmental efficiency. The authors revealed that environmental expenditures and investments could be linked to economic and operational efficiency. Meanwhile, Huang et al. (Huang et al., 2020) applied three stage DEA to investigate the pollutant emissions effects on port efficiency in a port development strategy.

Though few studies exist to assess the port performance using the simulation approach and optimisation method, most port-related studies focused on the method separately. The hybrid approach is unnew in the healthcare sector. For a long time, it has been applied in healthcare management studies in terms of ranking (Rabbani et al., 2016), scheduling (Aslani and Zhang, 2014), allocation (Yusoff et al., 2018; Yusoff et al., 2018; Yazdanparast et al., 2018) and optimising resources (Aminuddin et al., 2016; Al-Refaie et al., 2014). However, limited studies exist that hybridise these two methods in assessing port efficiency. The study of Sislioglu et al. (Sislioglu et al., 2019) revealed that the application of DES helps facilitates the selection of inputs for subsequent analysis of DEA. Pjevcević et al. (Pjevcevic et al., 2017) used the simulated data obtained from the DES on container handling processes to measure the efficiency using CCR DEA. Min and Park (Min and Park, 2008) used the simulation to estimate the terminal capacity data by mimicking the ships' duration of occupancy at berth and adopted window DEA to evaluate time series trends of efficiency ratings. Meanwhile, Pjevcević et al. (D. B. Pjevcevic, 2013) conducted a study in which simulation was used to provide the scenarios to assess the efficiency of dry bulk cargo handling using DEA. To the knowledge of the researcher's experience, no study of bibliometric approaches for documenting published research on port efficiency that reviews simulation or/and DEA use is accessible. Furthermore, the results obtained from these methods in Bibliometrix analysis showed only a 9.25% annual growth.

Bibliometrics is a fundamental methodology of analysing research articles that overview academic journals, academicians/scholars, research institutions, and countries in the specific field (Merigó and Yang, 2017). Since many of bibliometric studies have compared the databases for the analysis, this paper intends to merge the databases and find the best of the top ten from the analysis. A wide range of data can be found in the Scopus and WoS databases. While WoS gives a considerably larger range of years, Scopus offers a better number of journals and an intelligent interface (Goodman and Deis, 2007). Gavel and Iselid (Gavel and Iselid, 2008) estimated that WoS comprises 54% of the journal titles covered by Sco-

pus and that Scopus covers 84% of the titles of WoS. It indicates that Scopus offers more publishing coverage as well. Echchakoui (Echchakoui, 2020) contended that both databases are crucial, and it is essential to use both since one completes the other in order to conduct adequate bibliometric studies. These research findings have a number of academic and industry consequences. This provides a comprehensive overview of the research topic, introducing academics and practitioners to major studies, authors, universities, concepts, and methodologies fascinated by hybridising DEA and simulation research in port efficiency measurement. Integrating simulation in DEA research could develop a solid framework for implementing a strategised procedure in the operational domain. Port operators and management can use the defined concepts and methods to optimise resources usage and to plan ahead of the investment for new technologies and expansion of port capacity in improving the port efficiency.

The below is the format of the study's next portion. The data sources and procedures are described in Section 2, while the findings and outcomes of the bibliometric study are presented in Section 3 as tables, graphs, and networks. Section 4 discusses the findings as well as the global trend in port efficiency evaluation, and the final section concludes with conclusions and limits.

## 2 DATA SOURCES AND METHODS

Bibliometric analysis is a well-liked and exacting technique for investigating and analysing vast amounts of scientific data. The data sources for this study were collected from the Scopus and WoS databases on October 5, 2022. Scopus and WoS are two ever-updated databases for new articles, leading to slightly different results when the search process is performed on a different date. Scopus is one of the most reliable and established databases for abstract and citation since 2004, meanwhile, WoS is the world's most trusted publisher-independent global citation database and most powerful research engine for publication and citation networks. Most importantly, both databases were chosen as search engines because both are the most widely accepted and frequently used databases for the analyses of scientific publications (Nunen et al., 2018). Papers on applications related to port studies using DEA or / and DES were searched and retrieved from these databases. This bibliometric analysis uses a four-stage methodology to evaluate the research subjects, identify the most influential stud-

ies, and offer recommendations for future studies in the field. Figure 1 shows the four stages of obtaining data from the Scopus and WoS databases to initiate the data analysis.

### 2.1 Determine Search Keywords and Initial Search Results

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Page et al., 2021) (PRISMA) approach adopted to screen the articles for the whole process. In the first step, articles in the Scopus database were determined using the title, abstract, and keywords search. As opposed to prior works, the subject search in WoS is employed and combined with Scopus to supplement the search in the Scopus database. Topic search of WoS includes the articles based on the searched keywords in the title, abstract, author keywords, and Keywords Plus. Essentially, the same keyword search strategy was used in Scopus to ensure that the articles searched were within the scope and that the quality of the way of searching was the same for both databases. Keywords of "terminal efficienc\*" OR "port efficienc\*" OR "seaport efficienc\*" OR "yard crane\*" OR "quay crane\*" OR "truck turnaround time\*" OR "vessel turnaround time\*" OR "container handling" used in both databases resulted in 2843 and 1635 records in Scopus and WoS, respectively. Since this study focused on discrete event simulation or/and data envelopment analysis, the next step is using these two keywords in search within the results tab. By searching this way, Scopus filtered the records down to 429, while WoS narrowed the records down to 170. Then, these articles were retrieved for further filtration.

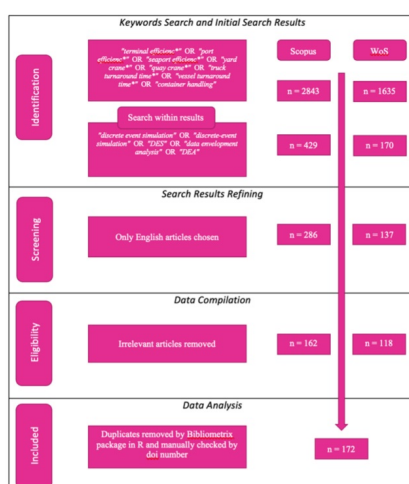


Figure 1: Diagram of extracting data from Scopus and WoS databases.

### 2.2 Refinement of Search Results

Records are re-filtered by only allowing publication types in the form of articles and must be in English. Thus, there are now 286 articles in Scopus that have been published, compared to 137 in WoS. Each publication from Scopus and WoS includes a plethora of information, including the publishing year, authors, affiliation of the authors, title, abstract, source of publications, subject categories, and references, which together form the fundamental components of the bibliometric analysis. The vital article data was retrieved from the databases; it is stored in xlsx format for WoS and csv format for Scopus. Basic details including the authors' names, article titles, publication years, doi numbers, abstracts, and keywords were required for filtration as part of the search results.

### 2.3 Compile Statistical Data

Each article was manually checked to determine whether the scope of studies is within the port-related either by using DES or DEA. The end result was that 124 irrelevant articles were eliminated from Scopus, leaving only 162 articles, while 19 irrelevant articles were removed from WoS, leaving just 118 articles. This process avoids any out-of-scope studies and improves the quality of data. Again, the filtered articles were retrieved from each database, but this time, the full records offered by Scopus and WoS were chosen to be used in the subsequent data analysis. One hundred sixty-two and one hundred eighteen documents included and retrieved once again from the Scopus and WoS databases, respectively but now in different formats viz BibTex. Using the R command, both databases were converted into xlsx format. Following that, all of the articles in both databases were combined, and all duplicate articles were instantly deleted. 105 duplicate publications were eliminated, bringing the total down to 175 records. The records were saved using a single xlsx file. However, the doi number is used to manually verify for duplication. There are consequently three additional duplications that must be eliminated.

### 2.4 Data Analysis

The final data consists of only 172 records. Bibliometrix package in R remove all the duplications from WoS, and Scopus was made as reference data. A total of 108 papers are present in both databases, featuring 10 additional documents from the WoS database and 54 additional studies from the Scopus database. We can deduce that WoS only covers

66.67% of the articles in Scopus while Scopus covers 91.53% of the articles in WoS. Biblioshiny package in R software was used to run the data for the analysis. The raw data was uploaded into Biblioshiny in xlsx format before the analysis of 172 documents proceeded. This study performed the bibliometric analysis using output analysis, co-occurrence analysis, and network visualization on two methods, DEA and/or DES that have been applied in assessing the efficiency of the seaport.

### 3 BIBLIOMETRIC ANALYSIS AND FINDINGS

This section describes the publications on port performance based on DEA or/and DES without categorising them into different clusters. Most of the articles used either DEA or DES in their studies, while only a single study combined both methods. The details of the top ten for each category will be discussed in this section.

#### 3.1 Descriptive Analysis

Table 1: Primary information of selected articles. Source: Bibliometrix (Aria and Cuccurullo, 2017).

Description	Results
Timespan	1993:2022
Sources (Journals, Books, etc)	87
Documents	172
Annual Growth Rate %	9.25
Document Average Age	6.9
Average citations per doc	28.42
References	5593
Keywords Plus	644
Author's Keywords	497
Authors	432
Authors of single-authored docs	13
Single-authored docs	18
Co-Authors per Doc	3.06
International co-authorships %	2.326

This research reviewed DEA and DES studies in the port or seaport domain published between 1993 and 2022. Within these 29 years, Table 1 depicts that 172 relevant studies are published in 87 different sources, written by a total of 432 authors, with an average of 28.42 citations per document. Single-authored studies account for only 3(13 authors) and there were 18 documents written by only a single author, implying that there are the same authors wrote two or more articles individually. Table 2 shows the total number

of DEA and DES publications for each year, without distinction between the two. The output for the first 20 years (1993-2012) was 55 publications, significantly lower than 74 publications in the recent five years of publications (2018 – 2022). A low-single-digit publishing trend for early-stage research studies in port performance adopting DES or DEA. However, in 2009, it skyrocketed with 12 documents published. The highest number of publications was in 2021 with 23 documents. This suggests a rising level of interest in DES and data envelopment analysis in port-related studies. Table 2 also show higher average citations per publication and citations per year in the early years. Citations tend to increase with the small number of publications in the early years and the longer length of time an article is published.

Table 2: General citation structure according to the combined Scopus and WoS based on year (TP. Total Publications. TC. Total Citations).

Year	TP	TC	Avg Citation per Publication	Avg Citation per Year
1993	1	292	292.00	10.07
2001	2	537	268.50	12.79
2002	2	164	82.00	4.10
2004	3	335	111.67	6.20
2021	23	94.99	4.13	4.13
2022	13	7.02	0.54	

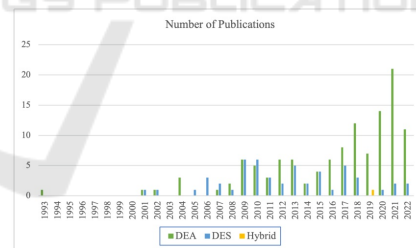


Figure 2: DEA vs DES vs Hybrid.

The yearly publication trend is presented in Fig. 2. The number of publications on DES or DEA in assessing port performance has been growing at a pace of 9.25% each year. Final filtration of the articles resulting 120 articles in DEA purview, 51 articles in DES, and 1 article hybridising both methods. The detail of the yearly publications of both methods can be seen in Fig. 2. The only article published in both databases applying both methods was in 2019 by Sislioglu and his co-authors (Sislioglu et al., 2019). In comparison to DES, DEA publications on port or terminal efficiency have a higher volume and appear to be increasing year after year. However, it is clear that between 1994 and 2000, as well as in 2003, neither

method produced any papers on port efficiency. This section entails the significant aspects based on bibliometric analysis, such as the top journals, the most cited and influential articles, the most prolific and impactful authors, and the most relevant institutions.

### 3.2 Top Journals

A total of 172 DES and DEA research in port-related topics have been published in 87 academic journals. In Table 3, the journal “Maritime Economics and Logistics” had the most articles published, with 21. This journal also dominates the top chart in terms of its index. “Maritime Policy and Management” is in the second rank with 11 documents published, followed by “OR Spectrum” with 7 articles. The other academic journals that have published at least five articles on DES or DEA in the port sector are listed in the following ranking: “Asian Journal of Shipping and Logistics”, “International Journal of Shipping and Transport Logistics”, “Sustainability (Switzerland)”, “Transport Policy”, and “Transportation Research Part A: Policy and Practice”. The remaining two in the top ten list are “International Journal of Transport Economics”, and Transportation Research Part D: Transport and Environment. Table 3 reveals that the top two academic outlets are journals within the scope of the area itself. Meanwhile, the third-ranked journal is concerned with the operations research methods, which simulation and optimisation area are included.

Table 3: Most relevant publication outlets (TP. Total Publications, TC. Total Citations).

Rank	Sources	TP	h-index	TC
1	Maritime Economics and Logistics	21	12	670
2	Maritime Policy and Management	11	7	527
3	OR Spectrum	7	7	321
4	Asian Journal of Shipping and Logistics	6	4	105
4	International Journal of Shipping and Transport Logistics	6	5	161
6	Sustainability (Switzerland)	5	3	38
6	Transport Policy	5	4	197
6	Transportation Research Part A: Policy and Practice	5	5	705
9	International Journal of Transport Economics	4	4	55
9	Transportation Research Part D: Transport and Environment	4	4	115

Articles published in “Transportation Research Part A: Policy and Practice”, on the other hand, have the highest total citation count, with 705 total citations. The first article appeared in “Transportation Research Part A: Policy and Practice” applying DEA in the port study. The article titled “Efficiency measurement of selected Australian and other international ports using data envelopment analysis” by Tongzon (Tongzon, 2001) was published in 2001. This paper individually has 437 citations. “Mar-

itime Economics and Logistics” has 670 citations, published its first article on port performance titled “An alternative approach to efficiency measurement of seaports” in 2004 by Park and De Prabir (Park and Prabir, 2004). Meanwhile, another journal in the top three of total citations is “Maritime Policy and Management”, with 527 citations. Roll and Hayuth (Roll and Hayuth, 1993) contributed the first article in “Maritime Policy and Management” on port performance comparison applying DEA.

### 3.3 Most Cited Influential Articles

Scientific work with a higher number of citations is widely acknowledged to have a greater impact on other articles. Table 4 reports the papers that have received the most citations. Since Scopus acts as the master data, the number of duplicate article citations is based on information from Scopus, unless the publications were retrieved from the WoS since they were not in the Scopus database. From the combined databases, the most cited article has 437 citations. The article written by Tongzon (Tongzon, 2001), implemented DEA to compare port performance of four Australian ports with twelve international container ports. Roll and Hayuth’s (Roll and Hayuth, 1993) article in 1993 is the second most cited, and Barros and Athanassiou’s (Barros and Athanassiou, 2004) in 2004 is third. All these articles report their findings using DEA. The first DES article by Shabayek and Yeung (Shabayek and Yeung, 2002) is listed in the fourth rank. Six of the top ten documents are within the DEA scope, while the rest are within the DES scope. Herein, simulation research in port studies can be classified as later studies because all the first articles in the top three journals focused on DEA in their studies.

Annual impacts are citations for each publication per year. Since it takes time for research to impact, studies published in recent years have received few citations. Global citation score (GCS) and local citation score (LCS) are two well-known citation terms in calculating annual impact. According to Munim et al. (Munim et al., 2020), a bibliometric indicator, GCS is the total of all citations to a study in the relevant database. In contrast, LCS is a citation metric that indicates the volume of research that cite a specific set of publications within a single database. However, as Scopus did not provide a GCS number and it is challenging to calculate the GCS for the merged databases, it was disregarded for this research. From the perspective of most influential articles, they were obtained by calculating the annual citations. Reportedly, Tongzon’s (Tongzon, 2001) article also domi-

Table 4: Details of Most Cited Articles (TC. Total Citations. AC. Annual Citations).

Article	Author(s)	Year	Source	Approach	TC	AC
Efficiency measurement of selected Australian and other international ports using data envelopment analysis	Tongzon (Tongzon, 2001)	2001	Transportation Research Part A: Policy and Practice	DEA	437	19.86
Port performance comparison applying data envelopment analysis (DEA)	Roll and Hayuth (Roll and Hayuth, 1993)	1993	Maritime Policy & Management	DEA	292	9.73
Efficiency in European seaports with DEA: Evidence from Greece and Portugal	Barros and Athanassiou (Barros and Athanassiou, 2004)	2004	Maritime Economics and Logistics	DEA	204	10.74
A simulation model for the Kwai Chung container terminals in Hong Kong	Shabayek and Yeung (Shabayek and Yeung, 2002)	2002	European Journal of Operational Research	DES	131	6.24
An alternative approach to efficiency measurement of seaports	Park and De Prabir (Park and Prabir, 2004)	2004	Maritime Economics and Logistics	DEA	127	6.68
Effect of block length and yard crane deployment systems on overall performance at a seaport container transshipment terminal	Petering and Murty (Petering and Murty, 2009)	2009	Computers & Operations Research	DES	120	8.57

nated the average number of citations per year. Interestingly, while his paper is about DEA, the second most influential yearly citations is authored by Zehendner and Feillet (Zehendner and Feillet, 2014), applied DES to improve the service quality of transportation in seaport. Other notable studies in terms of total citations per year include Barros and Athanassiou's (Barros and Athanassiou, 2004), with 10.74 citations per year.

Table 5 and 6 show the LCS of both databases. The top three articles in Scopus database applied DEA in their studies, however, in WoS database, a study by Zehendner and Feillet (Zehendner and Feillet, 2014) succeeded in breaking through the DEA cluster and finished third. To summarise, Tongzon's (Tongzon, 2001) article is one of the most influential publications in the port domain. With the highest local citation scores in both databases, his article is one of the earliest papers to address port efficiency using DEA. In Scopus, Wu and Goh's (Wu and Goh, 2010) article received more citations than Zehendner and Feillet's (Zehendner and Feillet, 2014) article, but both received the same number of citations in the WoS. Table 4 shows that the top three cited articles are DEA clusters. Thus, simulations may benefit from DEA hybridization. The fact that all three of these publications have received the most citations in the Scopus database also indicates that more papers in Scopus have cited the top three. When comparing the two databases, articles published in Scopus received more citations than WoS.

### 3.4 Most Prolific and Impactful Authors

The 172 publications from the shortlist of the WoS and Scopus databases were authored by 432 authors. Three hundred fifty-nine authors (83.10%) only featured once in the publications, fifty-seven authors (13.19%) appeared twice, eleven authors wrote three articles, four authors had four appearances, and only one author published 5 documents. Only Matthew Petering published 5 articles, three of which were his

own original writings. The top ten productive authors were determined based on the frequency with which each author contributed to publications. In searching for the top ten prolific authors, the author's full name should be carefully checked because the last name and first initials used may belong to different person. The most productive author with five articles published is Matthew Petering, followed by Pasquale Legato and Chang Young-Tae with four publications each. The top two author adopted DES method, while the next in the ranking assessed port efficiency by adopting the DEA method. Authors with also a similar number of publications are Khalid Bichou, Jose Tongzon, Rina Mary Mazza, Beatriz Tovar, Nguyen Hong-Oanh, Halvor Schøyen and Lee Suhung with 3 articles each. Although there are more authors with three articles, the authors in the top ten rankings are ranked based on fractionalized articles, which quantifies the individual author's contribution to a published article. The proportion of each author decreases when an article has multiple authors. This clarifies the second and third rankings of four published articles, as well as the fourth through tenth rankings of three articles. Due to their contributions to a set of articles, for instance, Pasquale Legato is ranked second, and Chang Young-Tae is ranked third. The higher value of fractionalized articles is preferable because it denotes that the author contributes more, even though both authors have four articles that have been published.

Table 7 presents the most impactful authors in the port-related studies using either simulation or DEA. In terms of total citations, Jose Tongzon is the fore-runner, while Matthew Petering is the first in terms of annual citations. Both also are the most influential authors with the highest yearly citation of 24.27 for Jose Tongzon and 27.57 for Matthew Petering. However, Jose Tongzon is considerably ahead of Matthew Petering, with hundreds of citations. In conclusion, research in simulation produces the most productive author. In contrast, studies in DEA produces the most impactful author.

Table 5: LCS of Scopus Database.

Authors	Article Title	Year	Journal	LCS
Tongzon (Tongzon, 2001)	Efficiency measurement of selected Australian and other international ports using data envelopment analysis	2001	Transportation Research Part A: Policy and Practice	437
Roll and Hayuth (Roll and Hayuth, 1993)	Port performance comparison applying data envelopment analysis (DEA)	1993	Maritime Policy and Management	292
Barros and Athanassiou (Barros and Athanassiou, 2004)	Efficiency in European seaports with DEA: Evidence from Greece and Portugal	2004	Maritime Economics and Logistics	204
Shabayek and Yeung (Shabayek and Yeung, 2002)	A simulation model for the Kwai Chung container terminals in Hong Kong	2002	European Journal of Operational Research	132
Park and De Prabir (Park and Prabir, 2004)	An alternative approach to efficiency measurement of seaports	2004	Maritime Economics and Logistics	127

Table 6: LCS of WoS Database.

Authors	Article Title	Year	Journal	LCS
Tongzon (Tongzon, 2001)	Efficiency measurement of selected Australian and other international ports using data envelopment analysis	2001	Transportation Research Part A: Policy And Practice	261
Panayides et al. (Panayides et al., 2009)	A critical analysis of DEA applications to seaport economic efficiency Measurement	2009	Transport Reviews	103
Zehendner and Feillet (Zehendner and Feillet, 2014)	Benefits of a truck appointment system on the service quality of inland transport modes at a multimodal container terminal	2014	European Journal Of Operational Research	94
Wu and Goh (Wu and Goh, 2010)	Container port efficiency in emerging and more advanced markets	2010	Transportation Research Part E: Logistics And Transportation Review	94
Petering and Murty (Petering and Murty, 2009)	Effect of block length and yard crane deployment systems on overall performance at a seaport container transshipment terminal	2009	Computers & Operations Research	93

### 3.5 Most Relevant Institutions

The impact of various institutions was investigated, and the top ten most productive ones are listed in Table 9. Shanghai Maritime University is rated first with 9 publications (5.14%), followed by the Inha University and National University of Singapore with 8 publications each (4.57%). The other top productive universities are Dalian Maritime University, Erasmus University Rotterdam, Korea Maritime and Ocean University, University Belgrade, University of Valencia, University of Wisconsin-Milwaukee, and Aalborg University. In terms of total publications in the top 10, two universities in China are leading with a total of 15 publications. These Chinese universities are marine universities with a focus on nautical studies. China participates in global trade through 34 major ports and approximately 2000 minor ports. Furthermore, numerous multinational companies have relocated their manufacturing sites to China, and in order to meet the needs of those companies supply chains, intermediaries or final products are shipped by sea to various parts of the world (Yuen et al., 2013). This has resulted in a significant increase in demand for seaport services in the region. It explains the large number of port-related studies conducted by academics and practitioners in that country.

### 3.6 Network Analysis

The figure above illustrates the visualization of the most influential keywords used by the authors of Scopus and WoS. There are 4 clusters of keywords

Co-occurrence Network

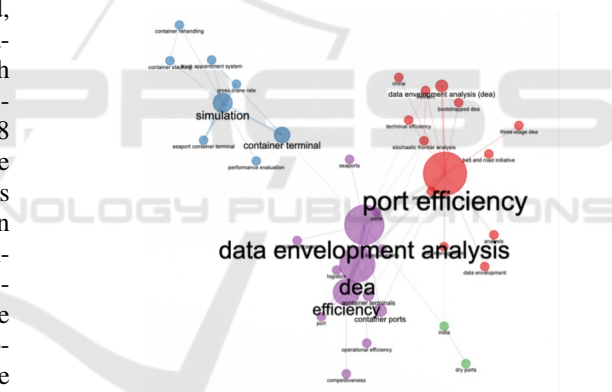


Figure 3: Co-occurrence of Author’s Keywords.

(red, purple, blue, and green) used in the combined databases, Scopus and WoS. When the nodes are displayed in the same color, relevant keywords are widely used together. The figure shows that port efficiency, data envelopment analysis or DEA, and simulation are the main keywords in the Scopus and WoS databases. Besides, container terminal, container ports, port productivity and stochastic frontier analysis are closely related and frequently co-occur.

### 3.7 Collaboration Network

The collaboration between authors, institutions, and countries was analysed and displayed using colourful node mapping. Collaboration analysis was conducted on the basis of downloaded data to estab-

Table 7: Details of Most Impactful Author (Rank by TC. TC. Total Citations. TP. Total Publications. AC. Annual Citations).

Rank	Author	TC	TP	AC	Publication year (No. of articles)
1	Jose Tongzon	534	3	24.27	2016 (1), 2010 (1), 2001 (1)
2	Matthew Petering	386	5	27.57	2011 (1), 2010 (1), 2009 (3)
3	Yehuda Hayuth	292	1	9.73	1993 (1)
4	Yaakov Roll	292	1	9.73	1993 (1)
5	Carlos Pestana Barros	260	2	13.68	2008 (1), 2004 (1)
6	Manolis Athanassiou	204	1	10.74	2004 (1)
7	Mark Goh	165	2	11.79	2010 (1), 2009 (1)
8	Khalid Bichou	147	3	12.25	2013 (1), 2011 (2)
9	Chang Young-Tae	135	4	19.29	2021 (1), 2018 (2), 2016 (1)
10	Bram Borgman	134	2	10.31	2013 (1), 2010 (1)

Table 8: Most relevant publication outlets (TP. Total Publications, TC. Total Citations).

Rank	Institution	Country	TP	Percent
1	Shanghai Maritime University	China	9	5.14
2	Inha University	South Korea	8	4.57
2	National University of Singapore	Singapore	8	4.57
4	Dalian Maritime University	China	6	3.43
5	Erasmus University Rotterdam	Netherlands	4	2.29
5	Korea Maritime and Ocean University	South Korea	4	2.29
5	University Belgrade	Serbia	4	2.29
5	University of Valencia	Spain	4	2.29
5	University of Wisconsin-Milwaukee	USA	4	2.29
10	Aalborg University	Denmark	3	1.71

among them. The font size indicates the frequency of the publications, where the fewer co-authored publications, the smaller the size. After eliminating the isolated nodes, eleven clusters emerge, demonstrating the strong collaboration among authors. Therefore, with five writers, the red cluster depicts the most prominent and substantial author collaboration network. The results show strong collaboration between Chang Young-Tae, Nguyen Hong-Oanh, Jose Tongzon, and Lee Suhyung. Their research studies mainly focused on DEA in ports. Chang Young-Tae, Lee Suhyung and Jose Tongzon are from Inha University, South Korea, while Nguyen Hong-Oanh is from the University of Tasmania, Australia. Only two writers are represented another ten clusters, indicating a lack of interaction. There is no interconnection between the clusters, showing that this area could be explored widely by the authors. Figure 5 displays the institutions' collaboration networks. The institutions are the nodes, while the edges represent research relationships between pairs of nodes. The red cluster is the largest and most powerful, which consists of seven universities. Figure 5 also shows that the blue and red clusters are linked, implying that the institutions in each cluster work closely together. The linked red and blue clusters shown in the network also show that there is space to progress overall author collaboration within the simulation and DEA in port-related studies. Based on Fig. 5, a strong collaboration can be seen between Inha University and several universities such as Shanghai Maritime University, Dalian Maritime University, Nanjing University of Information Science and Technology, Korea Maritime Institute, Aalborg University, and University of Tasmania. The authors who collaborated the most in Fig. 5 are those from the same university. Figure 6 presents the bibliographic network as well as a network of international partnerships. The information from the networks shows three clusters of collaboration between countries. Red cluster is the strongest in this field, with four countries included. A lot of collaboration going on in China, Canada, Thailand, Cyprus. The other clusters, green and blue, consist of only two countries, showing weak collaboration.



Figure 4: Collaboration Network of Authors.

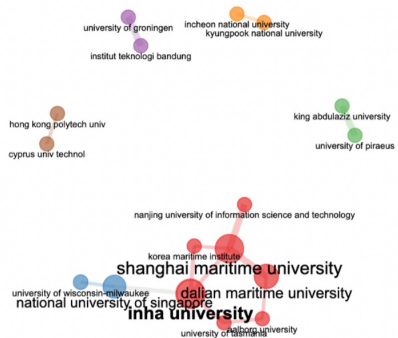


Figure 5: Collaboration Network of Affiliations.

lish bibliographic networks that represent collaboration links between authors, institutions, and countries. The authors' collaboration network is shown in Fig. 4, with the nodes representing the authors and the edges representing the co-authorship relation



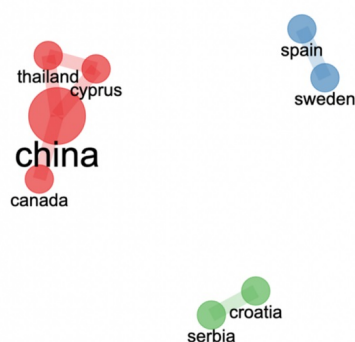


Figure 6: Collaboration Network of Countries.

## 4 DISCUSSIONS

This bibliometric analysis contributes to the literature on DES or/and DEA in port-related studies. Based on the keywords used to retrieve data from the Scopus and WoS databases, only one study combined simulation and DEA in their research while the rest were conducted separately, either using DES or applying DEA.

### 4.1 Merged Databases and Analysis Difficulties

In conducting the merger of Scopus and WoS, several uniqueness of both databases was presented. Several things can be deduced from the author's data analysis utilising the full record collected from both databases. First, Scopus only considers local citations, but WoS includes both local and global citations. Kulkarni et al. (Kulkarni et al., 2009) emphasised WoS was the only practical way to obtain citation counts. Since there is no information from one of the databases, calculating the total global citation score is rather difficult. Thus, only local citations were considered in this analysis. Kumpulainen and Seppänen (Kumpulainen and Seppänen, 2022) agreed and only discussed about local citations score in their article. Second, both databases provide author keywords, which the author selects the best possible keywords to convey the essence of the text. However, Scopus also provides indexed keywords, whereas WoS provides keywords plus. Indexed keywords, as opposed to author keywords, take into account plurals, other spellings, and synonyms. Scopus chose the keywords, which are standardised to vocabularies drawn from thesauri owned or licenced by Elsevier. In contrast, keywords plus includes words or phrases that commonly appear in the titles of references to articles, and excludes the title of the article itself. To prevent unintentional

keyword misinterpretation for merged databases, the analysis can be performed on author keywords. Third, WoS offers a hyperlink that allows users to access the article immediately from an excel file, whereas Scopus only provides a link that must be copied and pasted into the search engine. However, by manually changing it to hyperlink, the link can be directly linked to the article. Fourth, although both databases combined authors and affiliations in a single column, Scopus went above and beyond by separating the authors and their affiliations into separate columns.

Merging data through Bibliometrix package in R can be arguable. First, in the Scopus database, the number of local citations is misconstrued for the number of global citations. The local citations become zero as a result, and global citations take the place of the actual local citations. Second, the deletion of duplicate articles. Few articles in Scopus contained the end of "oa" in the article titles, Interestingly, all related articles were published in "Maritime Economics and Logistics" journal in 2017. The purpose of the term is unknown since all the related articles not the open access type. Scopus itself has column in its database indicating whether the paper is of the open access type or not. Due to the duplicated articles that contained "oa" cannot be erased when merging both databases using Bibliometrix package in R, they can only be manually removed from the data by identifying the doi number. Third, although the initials and family name used by authors most likely belong to a different person, Bibliometrix may mistakenly infer that they are the same person. This can cause a mistake in the analysis of the top 10 authors in terms of publications and citations. One should personally review the article to guarantee the accuracy of the data as just initials and a family name were provided in the final analysis.

### 4.2 Leveraging DES and DEA in Port Efficiency Evaluation

Due to the market's intense competition and the rapid development of logistics and container transportation technologies, understanding container port performance is more crucial than ever. Precise and useful measures of seaport efficiency are becoming a challenge [34]. Since container terminals are infamous for being stumbling blocks in the global supply chain, even a 1% increase in efficiency at a major terminal might have a big impact on businesses all over the world (Petering and Murty, 2009). Operations in container terminals have been researched for a variety of ways to improve port service quality. However, prior research has the propensity to oversimplify reality.

In the simulation, the objective of establishing the model is very important. Container terminals have to deal with a varying workload and irregular truck arrivals over the day. As trucks coordinate operations between the quayside and the yardside, poor performance of this type of resource worsens the port condition. Zehendner and Feillet (Zehendner and Feillet, 2014) agreed and stressed that the performance and service quality of the entire terminal may decrease if the peak of truck arrivals coincides with heavy workload periods for vessels, barges and trains. In order to maximise productivity at the port, truck allocation and scheduling are two areas that can be investigated using simulation. Despite the increasing prominence of other modeling techniques, simulation has achieved significant development throughout the last few decades and has increased its impetus in port and terminal research. Resource allocation, the appointment system, and the schedule of unloading and loading operations, which are linked to the preponderance of discussions about how to improve port service quality to reduce congestion and improve vessel turnaround times. Thus, these scopes can be explored more for the further analysis including movement of containers within the terminal and issues related to other resources such as quay gantry crane and yard crane. In addition, simulation has the advantage of providing data envelopment analysis possibilities for further efficiency analysis. Adoption of DEA may lead to the consideration of alternative techniques for the measurement of port efficiency in the perspective (Yuen et al., 2013). The DEA's weakness is that it is unable to show a complete picture of the flow of the port operations. By combining both methods, it complements each method. As mentioned by Figueira and Almada-Lobo (Figueira and Almada-Lobo, 2014) these two approaches of simulation and optimisation results in highly demanding methods in terms of computational effort. In terms of publications, combining both methods in port studies appears to be relatively low.

While simulation studies are more focused on specific operations, DEA studies are broader in scope. To fill the gap, it is encouraged to use DEA to evaluate the efficiency of detailed operations in ports. DEA provides trends in efficiency values, and thus provides a solid basis for continuous benchmarking, appraisal, and improvement (Lin and Tseng, 2007). In the previous studies that combined DES and DEA, one thing that connected both methods was the inputs used. Inputs were treated as suggested scenarios in the simulation, thus producing the alternative solutions for DEA. The alternative solutions were then evaluated by DEA to determine the efficiency. In the top 10

highest citation articles in DEA, most of the articles investigated port efficiency. The specific operations in container terminal are rarely studied using DEA. Surprisingly, only one paper combining DEA and DES was found in this bibliometric analysis. Furthermore, the aforementioned article investigated the potential alternatives for port expansion in Turkey. Thus this paper suggesting the combination of two methods in assessing specific operations in container terminal.

## 5 CONCLUSIONS

A bibliometric review of 172 articles on DES or/and DEA in port performance evaluation is presented in this paper. These articles were published in 87 publication journals between 1993 and 2022, derived from the Scopus and WoS databases. The results show the increasing trend of publications throughout the selected years. In terms of total publications by an author, DES is leading. Interestingly, the number of citations per author for the two approaches was compared, and DEA came out on top with hundreds of citations. Not only that, DEA dominates the top ten most cited articles, indicating that previous studies have influenced a significant number of research. The study also reveals that authors in this research field prefer to publish their findings in the "Maritime Economics and Logistics" journal. However, "Transportation Research Part A: Policy and Practice" journal is leading in terms of total citations.

This research has several restrictions. First, this study limits the research to specific keywords, and only DES and DEA were considered to measure the port efficiency. Second, the merging of two databases raised few issues, the Scopus was set as a reference, thus several information was dropped from the analysis. Therefore, for the next evaluation, the data from the WoS and Scopus can be analysed separately to ensure more detailed comparisons can also be explored for future studies in port efficiency.

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