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Game Theory Applications in Port Management –A Literature Review

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ABSTRACT

This paper aims to examine, systematize, and analyze relevant research on port operators and/or port authorities cooperation, competition, and capacity investment decisions. It also includes papers that model the dynamics of competition and cooperation under various management models using game theory. Our methodology employed a comprehensive search of English-language peer-reviewed journal articles across Web of Science, Scopus, and Google Scholar, which identified 69 peer-reviewed journal articles that were analysed through bibliometric methods to synthesize current trends and evaluate methodological approaches. The findings reveal that Bertrand and Nash models are predominantly employed, with a strong emphasis on inter-port competition, primarily concentrated in Asian and European regions, thus highlighting a regional disparity in the literature. However, there is a notable gap in exploring cooperative strategies and utilizing more complex, dynamic models to better understand port collaboration and evolving competitive dynamics.

1 Introduction

The COVID-19 pandemic and the war in Ukraine have significantly affected maritime trade, leading to a decline in global trade volumes. However, a recovery trend began in the latter half of 2022, with maritime trade increasing by 2.4% in 2023 [1]. In 2024, trade volumes reached 12,720 million tons, indicating a 2.2% growth [1]. Forecasts from UNCTAD (2024) [1] predict a modest 0.5% increase in 2025, with an average annual growth rate of 2% expected from 2026 to 2030. Despite these signs of recovery, challenges persist in many ports, notably longer ship dwell times, with a median stay of 1.04 days in 2022, exceeding pre-pandemic levels [1]. The shipping industry faces issues such as overcapacity, fluctuating freight rates, and rising debt, leading to alliances among shipping lines to share resources and reduce costs, thereby giving them greater bargaining power with ports. In response, terminal operators are also forming alliances [2]. In these complex conditions, game theory provides port operators with a more profound and strategically focused analysis, facilitating improved and more efficient decision-making in contexts characterized by multiple stakeholders and opposing interests.

The development of land transportation modes has enabled ports to serve larger areas of gravity, which has resulted in ports no longer having an exclusive hinterland [3] and competition between ports serving the same hinterland is becoming increasingly fierce [4]. When two or more ports are too close to each other and serve the same industry segments, such as containers, a "local commodity" situation arises where THC takes precedence [5].

Game theory provides a mathematical framework for analyzing strategic interactions among rational decision-makers, particularly in contexts involving multiple stakeholders, such as port management. It provides insights into the dynamic interactions among various players in the port environment, including shippers, forwarders, port authorities (PAs), and terminal operators (TOs).

This paper aims to provide a systematic bibliometric analysis of recent studies and research efforts in this field and to serve as a comprehensive reference manual. An additional goal is to identify gaps in current applications of game theory for modeling port actor behavior and to propose potential directions for future research.

To achieve these objectives, this review included 69 peer-reviewed articles published between 2008 and 2025. A content analysis was conducted to address the following research questions (RQ): RQ1) What types of game-theoretic models are most commonly employed? RQ2) How is the research geographically distributed across different regions? RQ3) What gaps and limitations exist in current game-theoretic modeling of port management?

The paper is organized as follows. Section 2 describes the literature review. Section 3 presents the methodology applied. Results of the bibliographic analysis are presented in Section 4. Discussion of the research questions is conducted in Section 5; conclusions are drawn, and the contribution is outlined in Section 6.

2 Literature review

The literature discussed in this paper primarily focuses on the field of TOs and/or PAs competition [6–41], cooperation [5,42–46], competition and cooperation combined [2,4,47–58], capacity investment [6,8,10,13, 16,18,21,25,27,33–35,39,40,43,47,59,60], and the modeling of dynamic interactions across various management structures [9,11,17,22,39,41,48,51,53,61]. This study is not the first to review the papers in this area. The most general review paper is Adler et al. [62], which conducted a broad review of game-theoretic applications across all transport modes, analysing 51 studies (1977–2020), including seven on port competition and cooperation (2008–2018). Review papers that focus solely on port competition and cooperation, such as those by [3,63,64] incorporate a variety of mathematical modelling techniques, including game-theoretical models, regression analysis, network analysis, logit models, Markov chain models, etc. Lagoudis et al. [63] reviewed 197 studies (1978–2011) on port competition and competitiveness, including three applications of game theory in port competition and cooperation. Munim and Saeed [64] analyzed 267 studies (1990–2018) on seaport competitiveness using bibliometric and content analysis. They identified key research themes—such as port competition, efficiency, pricing, and cooperation—and found seven studies (2010–2018) that applied game theory to topics including institutional transformations, competition, cooperation, and pricing. Luo et al. [3] reviewed 210 studies (1970–2019) on port competition, cooperation, and competitiveness. They found that 34 papers (16.2%) applied game theory—mainly in port competition (32%), less in cooperation (14.3%). By contrast, the review paper by Wan et al. (2018) offers a narrow-scope review, examining only 15 empirical studies (12 of which use game-theoretic models) on inland accessibility and urban congestion in relation to seaport competitiveness, rather than engaging with the broader spectrum of port competition and cooperation.

The remaining three review papers [65–67] featured articles that incorporated both port competition and cooperation, as well as game theory models. Wang et al. [67] is the most comprehensive, analyzing 172 journal articles on the strategic use of game theory in the maritime supply chain from 2004 to 2024 and offering a thorough analytical framework that encompasses multidimensional competition and both horizontal and vertical cooperative models among all participants in the maritime supply chain. The authors highlight current maritime industry concerns and changes, summarize existing research, and outline future research goals. Hidalgo-Gallego et al. [65] analyze 47 papers (1995-2014) that examine the application of game theory to port competitiveness and the strategies behind port management decisions. This study focuses solely on research involving governments, port managers, and TOs, excluding other entities involved in port activities, such as shipping lines and trucking companies. Authors emphasize ownership, the relationships between ports and their hinterlands, the interactions between TOs and PAs, investment choices for capacity enhancement, and port specialization. Pujats et al. [66] summarized 33 studies (2008-2019) where ports compete or cooperate over pricing, capacity investment, hinterland connections, and alliances. The authors categorize different game-theoretic models (e.g., cooperative vs. non-cooperative, static vs. dynamic) and discuss their assumptions and outcomes. They highlight that game theory helps explain how ports can achieve mutually beneficial cooperation while still competing, and they identify gaps for future research, such as incorporating environmental and policy factors into port strategy models.

This paper advances prior reviews by combining a bibliometric analysis with a critical, model-based synthesis of game theory applications in port management, focusing on two key stakeholders: TOs and PAs. We provide an analysis of prevalent models and research trends, and explicitly identify methodological and empirical gaps.

2.1 Ports/terminals competition

Competition between different ports for business, shipping lines, and cargo is inter-port competition. Factors that can influence this competition include geographical location, infrastructure, efficiency, and the services offered by each port. This has been the case for many ports around the world. Ports are usually composed of several terminals, each specializing in handling specific types of cargo (container terminals, general cargo terminals, liquid bulk terminals, etc.). Intra-port competition arises when these terminals compete for business, resources, and customers within the same port. Inter and intra-port competitions have recently attracted considerable academic attention. In their paper, Saeed and Larsen [29] present a study of competition between the four terminals of the two ports in Pakistan. The researchers divide the game into two stages. Each terminal must decide whether to act independently or join the alliance based on the first stage. Players who have decided to join the coalition will compete against non-members in a non-cooperative game in the second stage. Using unrealistic simplifications, the market shares and equilibrium THCs for each terminal are determined by solving the equilibrium of the Bertrand game. However, Zhou and Kim [58] found that even for the simplified case assumed in Saeed and Larsen [29,53], no explicit equations can be obtained from the first-order conditions. To find the Nash equilibrium, in this case, Zhou and Kim [58] proposed a coevolution-based procedure. To analyze the effects of using a more realistic operating cost function, including congestion costs, and the four rental fee systems on the total profit of Busan Port, they conducted numerical experiments. The solutions from the coevolution-based method were compared with those of [29]. It was found that the coevolution-based procedure produced the Nash equilibrium solutions more accurately. The research conducted by Ignatius et al. [50] used a game-theoretic framework to examine the competitive and cooperative tactics employed by the three major transshipment ports in Malaysia and Singapore. In their study, Dong and Zhong [15] develop a game-theoretic model to examine implicit cooperation among regional ports across three scenarios. They use a Bertrand model to investigate the pricing approach. The authors present an analysis of the Yangtze River Economic Belt to demonstrate the results. Nguyen and Kim [52] extended the research by Saeed and Larsen [53] on port competition. They used a Bertrand game model to estimate the equilibrium THCs and market shares of container ports in Northern Vietnam. The study considered both cooperative and non-cooperative scenarios. In a more recent study, Dimitriou [68] introduced an analytical framework that utilizes hierarchical mathematical programming to determine the most effective pricing strategies. This framework incorporates principles from game theory and network theory to capture interactions among actors accurately. The use of equilibrium programming with equilibrium constraints (EPEC) has been extended beyond Northern Vietnam to European ports, where terminal handling charges (THC) are a significant factor in strategic decision-making [68]. Additionally, applying the Cournot model to ports such as Tauranga and Auckland has provided valuable insights into competitive behaviour and THC optimization [14].

Competition between ports for the position of a hub is particularly intense, as this role brings significant economic benefits and influences global trade routes. When MSC Shipping decided to make the Port of Shenzhen the only port in South China in 1999 [38], the biggest competition for hub port status in this region began with Hong Kong [13]. Zhang et al. [69] proposed three practical solutions to end the competition between these two ports: the strategy of service differentiation, cooperation, and cost reduction. Do et al. [13] investigate a long-term strategy for these two ports to invest in capacity. They modelled a two-person game with uncertain payoffs and demand factors, which also provides insightful recommendations for the future competitive plans of these two ports. They also concluded that Shenzhen is the dominant port in this long-term strategy. In the Pearl River Delta region (Hong Kong and Shenzhen), Wang et al. [54] investigate the factors influencing the formation of alliances for ports serving a largely overlapping hinterland. They use a game-theoretic model to develop a framework that allows two ports to compete or form alliances. Anderson et al. [6] developed a two-stage game model that represents the current situation between the ports of Busan and Shanghai. The Bertrand model is used to determine the THC, and based on this, the profit and payoff are calculated for the standard form of the game between these two ports, where each port determines whether to invest or not. The competition between the ports of Kobe and Busan is modelled in [18].

Most game-theoretic analyses rely on static two-player models that assume instantaneous equilibrium. However, real port competition is dynamic and path-dependent, involving repeated interactions and evolving strategies. Therefore, the limited application of repeated, evolutionary, or learning-based game models results in significant long-term competitive dynamics remaining underexplored.

2.2 Ports/terminals cooperation

In contrast to ports that choose to compete and bid, some ports choose to cooperate. The port of Ningbo-Zhoushan, a key player in the regional port integration process, was also analyzed in Dong et al. [42] using a three-stage game model. It was found that a higher level of integration leads to lower THCs and higher container throughput, with a threshold effect observed. Xiao and Liu [56] present a two-stage oligopoly model that compares three strategies for the three ports of Northeast Asia: independent, alliance, and monopoly, with alliance proving to be the best for social welfare and coalition members. Feng et al. [43] examine port cooperation along the 21st century Maritime Silk Road, analyze opportunities and challenges, and develop a game-theoretic choice analysis for multi-win cooperation. Such was the situation on the U.S. West Coast for the ports of Seattle and Tacoma, which are only 30 miles apart. For decades, the ports of Seattle and Tacoma in the Pacific Northwest have been battling for dominance in the container market [5]. Therefore, two rival ports in the Pacific Northwest have formed the PNW Seaport Alliance to overcome a history of mistrust and resentment and strive for long-term cooperation [70].

While ports are increasingly collaborating on green initiatives such as emissions monitoring and decarbonization, most game-theoretic models focus on pricing, investment, or throughput competition, leaving a gap in the analysis of cooperative environmental strategies.

2.3 Port management models and game theory

Since the 1980s, port management has undergone a significant shift from owners to terminal lessors and from the public management model to alternative organizational structures, including mixed ownership and/or management models involving both public and private participation in port operations. Saeed and Larsen [29] analyze the impact of concession contract type on port users' surplus and TOs' profits across five terminals in three ports in Pakistan. Yip et al. [61] present a non-cooperative game model in which TOs compete for concessions in neighbouring ports, with profits increasing with market power, suggesting that TOs prefer to control more terminals in the same region. Zheng and Negenborn [39] compare the centralization and decentralization modes of port regulation. The decentralization mode is described as a Stackelberg game between the public PA and the private PO. The optimal THC, port capacities, and efficiency levels are determined. The results are applied to container terminals in the port of Shanghai, China. Sensitivity analyses and comparative studies show that THC, efficiency levels, service demand, and social welfare are higher under decentralization. Czerny et al. [11] examine the effects of port privatization on two ports in different countries, each competing for transshipment traffic from a third region. The two-stage game involves governments deciding on the mode of port operation (privatization or no privatization) and setting THCs in the second stage to maximize the objective function. It shows that, in equilibrium, privatization is chosen and the national welfare of each port country is higher than with public ports. They also show that the port country with the smaller domestic market has a comparatively large incentive to choose a private port. Focusing on maximizing traffic volume, Chen and Liu [9] examine the optimal concession contracts offered by a landlord PA to container TOs. They describe how the PAs and TOs interact through a two-stage game. Lee et al. [22] compare Bertrand and Cournot competition and examine how port privatization and public ports affect the port's THC and social welfare in a third market. The study Cui and Notteboom [48] examines the impact of landlord and fully private port competition/cooperation on capacity, THC, profits, and welfare in a mixed duopoly. Results show that both private objective and service differentiation levels significantly influence port competition and cooperation settings. Han et al. [17] investigate the optimal concession contracts for PAs, considering two objectives: maximizing fee revenue and benefits, and maximizing social welfare. The authors show that PAs would be better served by subsidizing TOs rather than charging fees if the objective is to increase social welfare. Researchers have not yet found this result in the literature. Munim et al. [51] explore the potential gains and losses for port users' surplus and TOs' profits by transforming port governance from the tool port model to the landlord port model. They use a Bertrand game model in hypothetical scenarios, focusing on four Bangladeshi container terminals. Zhou and Kim [41] propose two revenue-sharing schemes for concession contracts, offering financial benefits for container TOs, attracting high container traffic volumes. The two-stage game model involves the PA setting the discount parameters, while TOs compete to maximize profit by determining container volume.

Existing research predominantly examines competition or cooperation within individual management models, such as hierarchical control or alliance networks, without providing a comprehensive comparison across different structures. There is a notable gap in the use of integrative game-theoretic frameworks that account for regulatory heterogeneity, political influences, and governance nuances to understand better how various port management models generate distinct strategic behaviours.

2.4 Port capacity investment

Port capacity expansion is the process of increasing a port's capabilities and capacity to handle more cargo and ships. This expansion is usually necessary due to increasing trade volumes, the need to accommodate larger ships, or to meet market demand better. Luo et al. [27] analyze the transition from monopoly to duopoly by developing a two-stage model for pricing and capacity decisions for two ports with different price sensitivities and investment costs. They apply the model results to the container port competition between Hong Kong and Shenzhen, following the development of the Shenzhen port. Ishii et al. [18] developed a theoretical model of a non-cooperative game in which THCs are set at the time of investment in capacity expansion. Ports alternately choose to invest in capacity expansion and THCs when demand is uncertain. They derive the Nash equilibrium and apply the model results to port competition between Busan and Kobe. Kaysi and Nehme [21] investigate the optimal investment strategy for PAs to attract freight forwarders. They use a mathematical model and a game-theoretic approach to model competition and show that the optimal strategy depends on the port's position, resource availability, expected profitability, and other ports' reactions. Wan et al. [33] investigate the strategic investment decisions of local governments on regional landside accessibility in the context of competition between seaports, focusing on two seaports and a common landlocked country, a unique setting in the literature. Balliauw et al.[8] investigate the flexible investment decision of two ports, focusing on the leader-follower timing game of quantity under demand uncertainty and congestion, influenced by geographical location and services offered. Wang et al. [34] analyze investment expansion strategies for container ports to improve efficiency and cope with port congestion by using a non-cooperative game model and determining optimal equilibrium outcomes between investment expansion and constant strategies. Jiang et al. [19] developed a model that combines the nested-logit model with Stackelberg's game-theoretic model. A problem similar to that in Zhang et al. [37] is modeled: two ports successively build a multimodal network, considering shippers' preferences and dry port capacity. To obtain the Stackelberg equilibrium, two algorithms are modified. To test the proposed models, they present a case study of the multimodal transportation network architecture for the Dalian and Yingkou ports in Liaoning. Recently, Xu et al. [70] investigated the impact of capacity sharing strategies on the performance of competing ports using benchmark, passive, and proactive models. It compares berth capacity and profits under daily base operation, passive sharing mode, and proactive sharing mode, providing a new perspective on port cooperation.

Existing capacity-investment research predominantly models competition between two ports using symmetric assumptions. Such frameworks overlook the complexity of contemporary maritime systems—characterized by multi-port interactions, carrier alliances, and hub–feeder network configurations—highlighting a significant gap in the literature.

3 Methodology

This section presents the methodology for collecting publications for bibliometric analysis. This review was conducted according to the Preferred Reporting Items

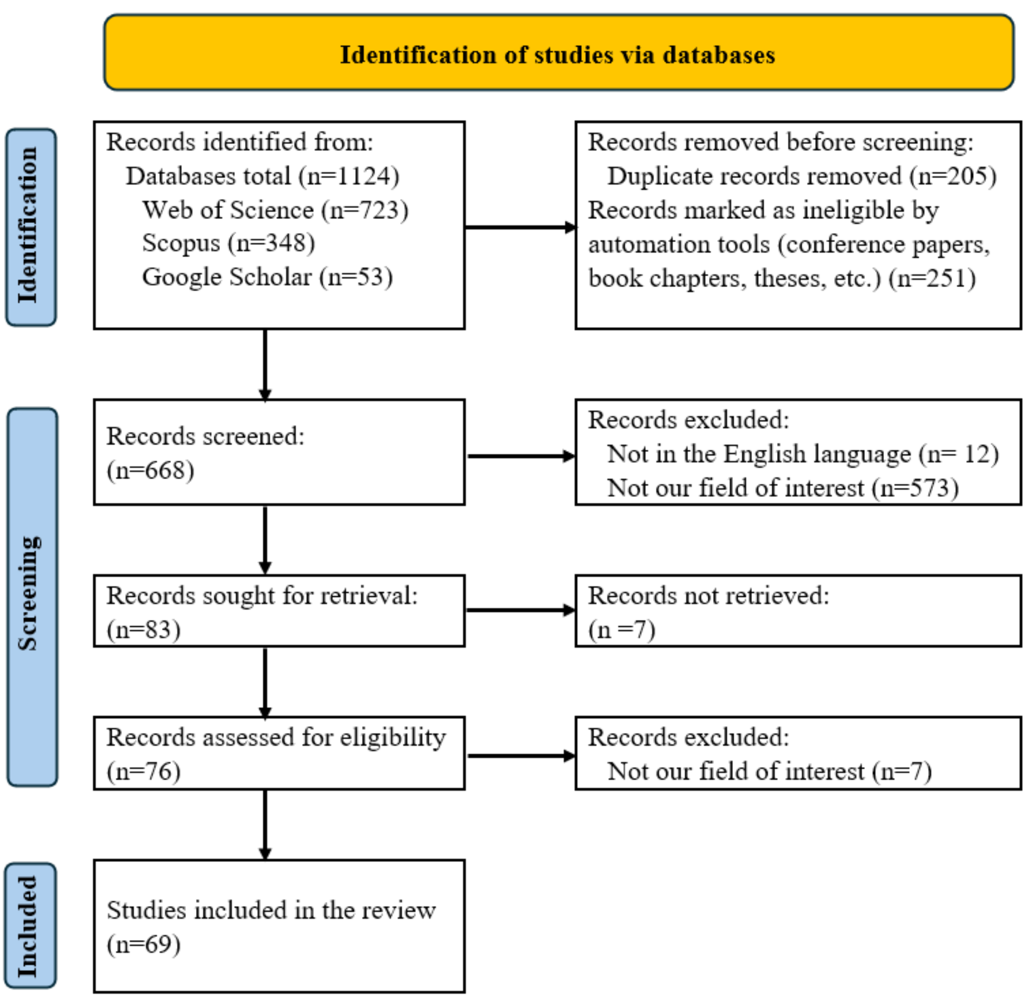

Figure 1 PRISMA flow diagram for new systematic reviews that included searches of databases and registers only (Source [72], Accessed November 2025.) The authors made all literature exclusions in this paper.

for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines [71]. The PRISMA flow diagram detailing the process of identification and screening of research papers is shown in Figure 1.

After determining our direct field of interest and defining the research questions, we searched databases extensively to identify relevant records using various keywords and their combinations. Data was downloaded on November 7th, 2025. We then compiled all found records, removed ineligible and duplicate records, and compiled the remaining records. We included peer-reviewed journal articles written in English.

In the screening phase, we manually assessed abstracts and removed all records that were not directly relevant to our research field. After the initial screening, we attempted to retrieve all compiled records and read them to determine whether each fell within our direct field of interest. All records that passed through the screening process are included in the review.

A thorough literature search was conducted across three related databases: Web of Science (WoS), Scopus, and Google Scholar. The search strategy employed a comprehensive set of keywords: “game theory ports”, “game theory port competition”, “game theory port cooperation”, “game theory port co-opetition”, “game theory terminal operator”, “game theory shipping alliance”, “cooperative game theory port”, “non-cooperative game port”, “Bertrand game port”, “Cournot game port”, and “Stackelberg game port”. These keywords were combined using ‘AND’ and ‘OR’ operators to ensure both breadth and depth. For example, searches such as (“game theory” AND “port competition”) OR (“game theory” AND “port cooperation”) were systematically conducted to capture multifaceted studies.

A total of 1,124 records were initially detected across all three databases. We found 205 duplicate records, which were removed from the dataset. Our inclusion criteria were established to include solely peer-reviewed journal publications published in English. Consequently, 251 more records were removed from the original dataset, leaving 668 articles available for screening.

During the screening process, we evaluated the abstracts to confirm that the records aligned with our specific field of interest. During this step, we eliminated an additional 575 articles, retaining only those pertinent to our area of interest. Consequently, we identified 93 items for retrieval, of which seven could not be accessed. At this stage, we analyzed the complete text of the remaining 86 articles. After reviewing all papers, we eliminated 17 additional ones for not aligning with our specific field of interest.

The final dataset comprises 69 peer-reviewed journal articles included in our systematic review. For each chosen article, we recorded information including the authors’ names, paper title, publisher, journal name, year of publication, citation count, and abstract. Afterwards, we categorized each article according to its study topic(s), implemented game-theory model(s), and identified game competitors. We also categorized case study articles by port name, country, and continent.

4 Results

This section presents the results of the bibliographic analysis, outlining the main patterns and findings derived from the reviewed studies.

The total number of articles from each database is approximately equal. Around 36% of publications in the final dataset were indexed across all three databases, 32% across two, and 35% in only one. The database that indexes the most unique publications is Google Scholar. The distribution of papers across databases in the final dataset is shown schematically in Figure 2.

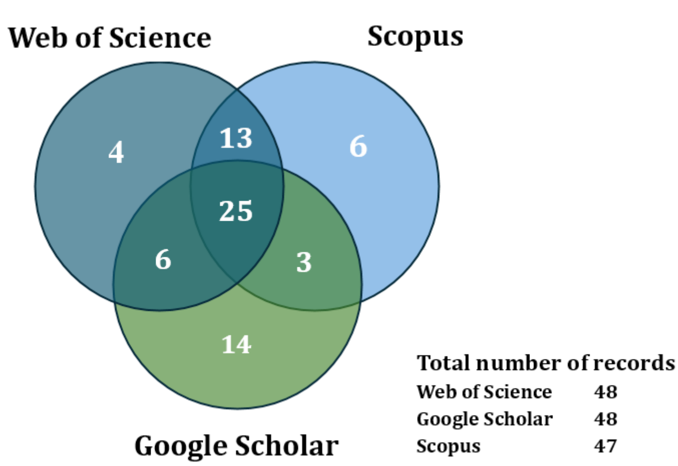

Figure 2 Distribution of papers across databases

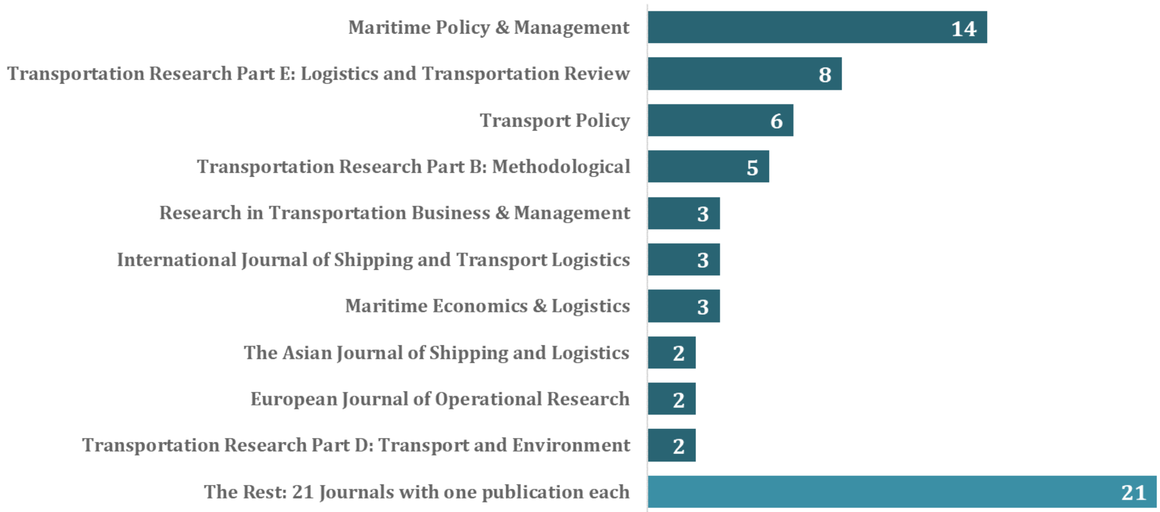

Figure 3 Total number of articles per journal

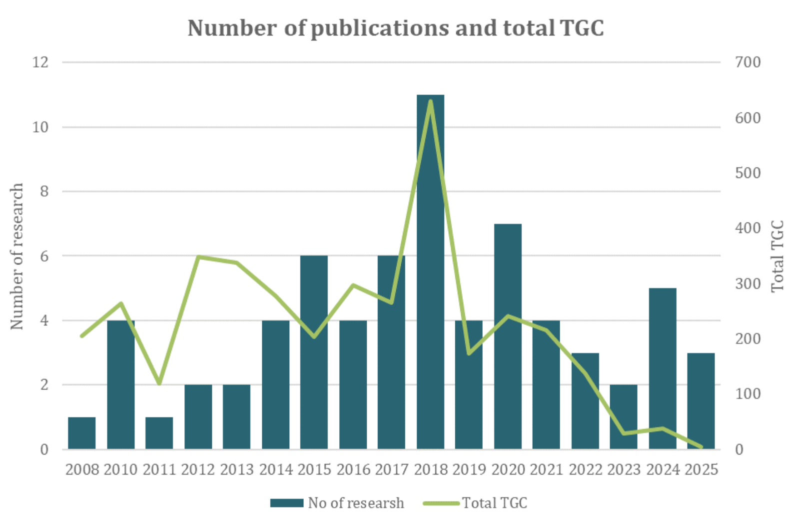

Figure 4 Number of publications and total TGC

Based on the data presented in Figure 3 Maritime Policy and Management (Taylor & Francis Ltd.) is the primary source in this research domain, accounting for 14 articles (20% of the total output). Following this, three journals collectively constitute a substantial share of the literature: Transportation Research Part E: Logistics and Transportation Review (8 articles), Transport Policy (6 articles), and Transportation Research Part B: Methodological (5), totaling 28% combined. Figure 3 shows the number of publications per journal.

The number of publications varies over the years. The number of articles increased until 2018, when it reached its peak, after which studies in our fields of interest began to decline. The total global citations (TGC), which indicate how frequently each research article was cited outside our sample of 69 articles, were retrieved from the Google Scholar database on November 12th, 2025. Figure 4 illustrates the change of academic interest in our fields, based on the sample analyzed. We present the annual publication count of articles and the total TGC for each year.

Figure 5 shows ten publications with the highest average TGC per year. The two publications with the highest average annual citation rates are review articles.

To explore patterns in the literature, we used VOSviewer [73] software to analyze and visualize bibliographic data and generate maps of keyword co-occurrence. During initial keyword analysis with VOSviewer, the software identified 225 distinct keywords in the dataset. Among them, 37 were not connected, so the most extensive connected set consists of 188 items. A map of the connected keywords by year is shown in Figure 6.

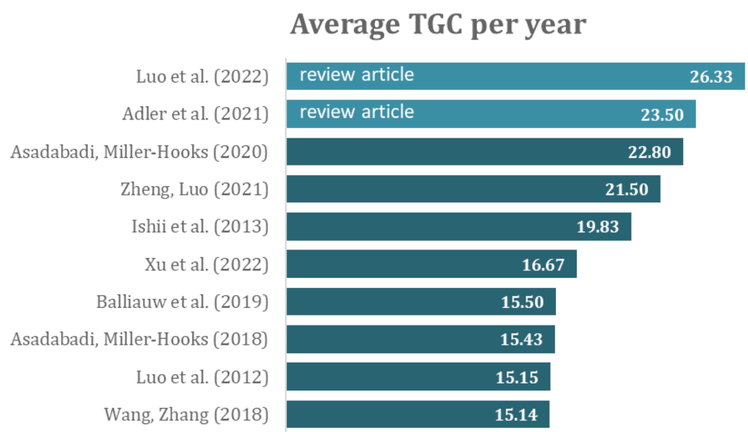

Figure 5 Publications with the highest average TGC per year

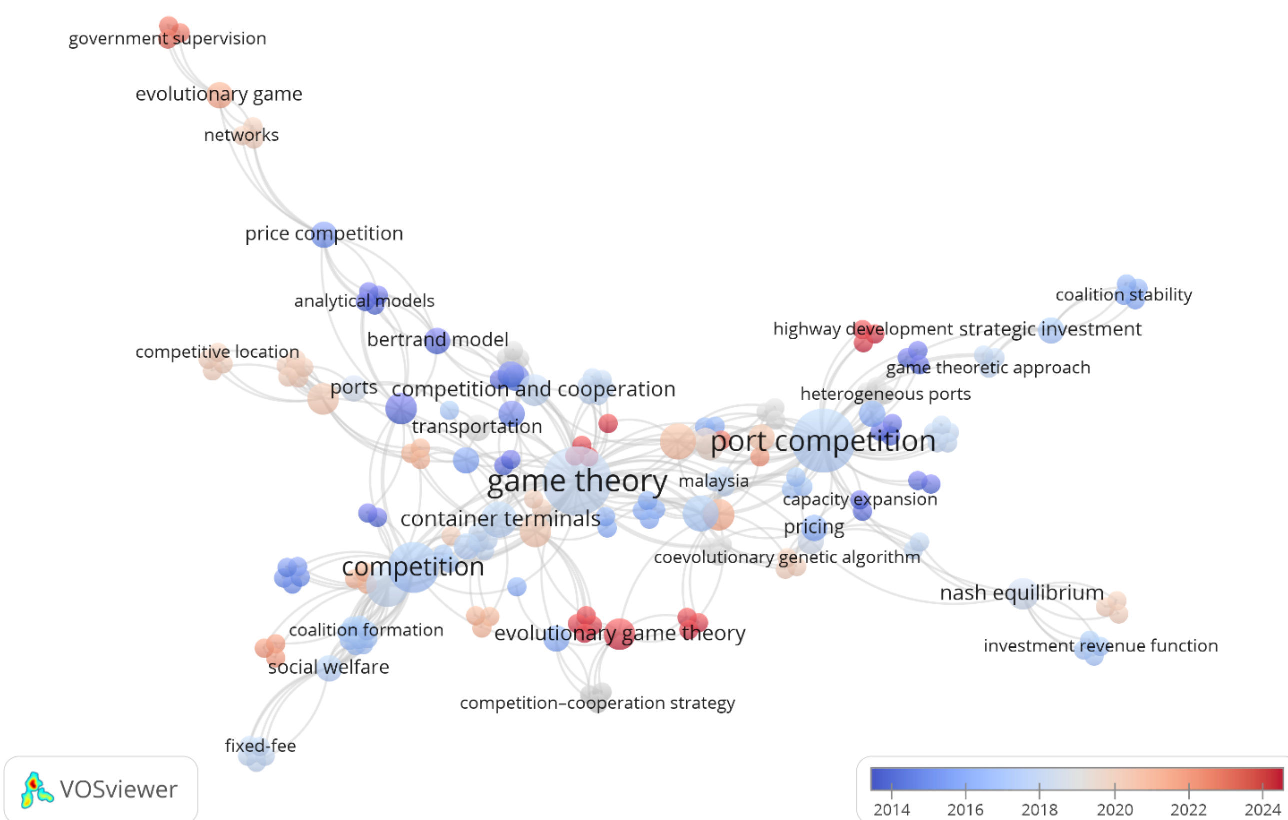

Figure 6 Occurrences of keywords by year (VOSviewer [73], items: 188, clusters: 9, links: 626, total link strength: 657)

The size of a circle is proportional to the number of occurrences; red circles represent the most recent occurrences.

When restricting keywords to those with at least two occurrences, VOSviewer identified 33 distinct keywords and grouped them into three clusters, represented by different colors in Figure 7. The largest cluster (red) contains the most common keywords (game theory, Bertrand game, Stackelberg game, etc.), while the second-largest (green) contains keywords such as competition, cooperation, evolutionary game, social welfare, etc. The smallest cluster (blue) contains keywords such as port competition, strategic investment, Nash equilibrium, and related terms.

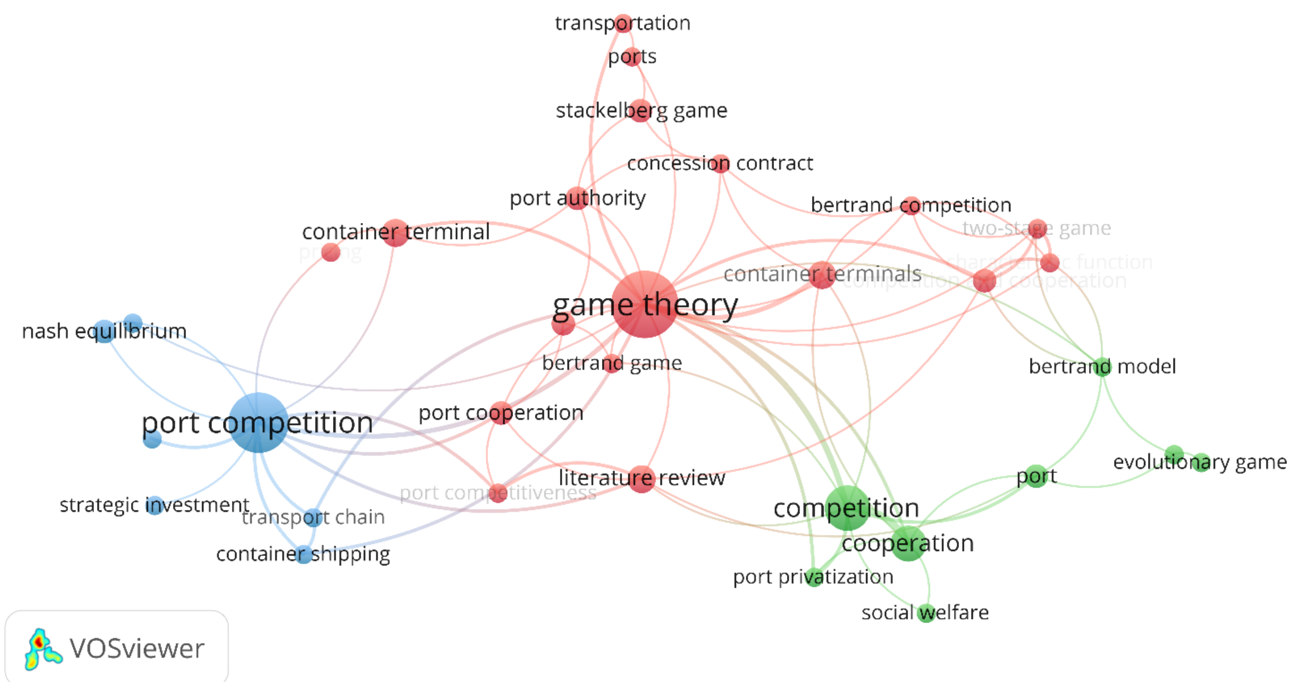

Figure 7 Keyword clusters (VOSviewer [73], items: 33, clusters: 3, links: 76, total link strength: 107)

Using the online tool Litmaps [74], we created a network map of the reviewed papers. Litmaps uses multiple databases (Semantic Scholar, Crossref, and OpenAlex) to extract references and citations for each article, enabling us to create a collaborative network that provides a deeper insight into the relationships and links among articles. Articles are categorized by port interactions and presented so that articles towards the right are more recent, those towards the top have a higher citation rate, and the larger the circle, the more citations the article has. Figure 8 displays a map of the analyzed articles, labelled by port interactions.

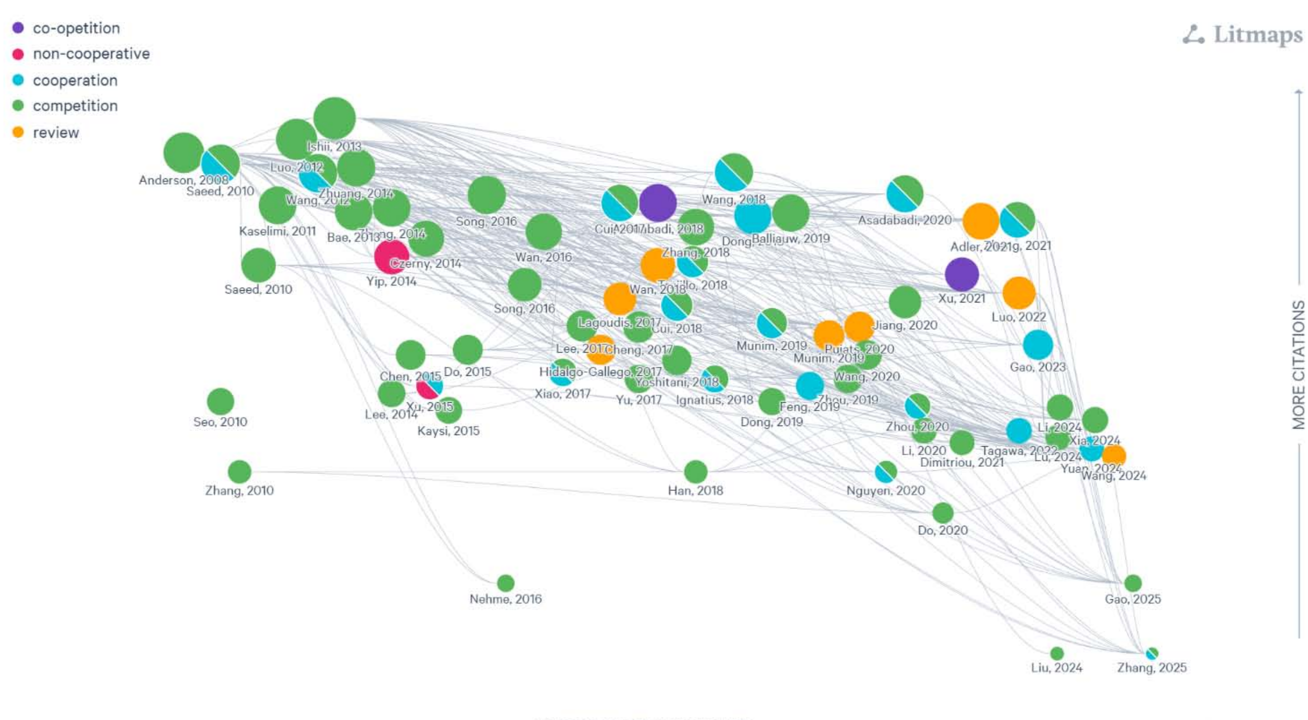

Figure 8 Network map of analysed articles by type of port interactions (map made with [74])

Sixty-one publications present models involving port interactions. Competition among ports is the most prevalent model in publications on port interactions. It is present in 36 articles (59%) and is accompanied by cooperation in an additional 14 articles (23%). Six more publications (10%) address cooperation alone.

The majority of research papers (76%) focus on inter-port interactions. In comparison, intra-port interactions account for 16%, and the simultaneous examination of both intra- and inter-port interactions accounts for the remaining 8% of studies. The distribution among types of port connections is shown in Figure 9.

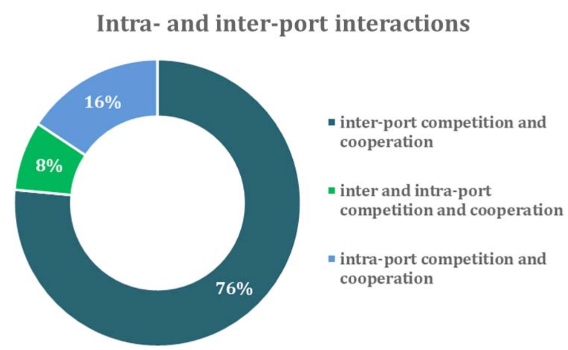

Figure 9 Intra- and inter-port interactions

Among the analysed articles, almost 45% developed new theoretical models, 32% applied new theoretical models to a case study, and about 11.5% were case studies using existing theoretical models. The remaining 11.5% are review articles. The distribution of publications per research approach (Theoretical model or Case study) is shown in Figure 10.

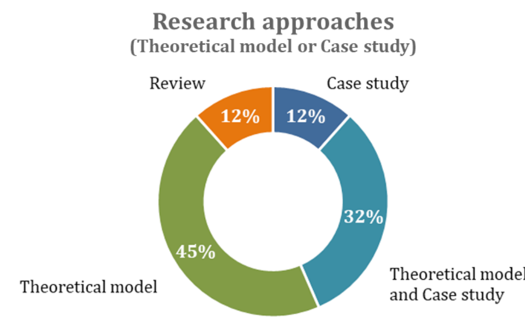

Figure 10 Distribution of articles per research approach (Theoretical model or Case study)

Publications conducted case studies on ports worldwide, covering 88 ports across 35 countries. Most ports are from Asia (52, i.e., 59%), followed by Europe (23, i.e., 26%). Ports from other parts of the world (North and South America, Africa, Australia, and Oceania) cover 13 ports (15% of all ports). Most publications covered ports in China (25), followed by Vietnam (13) and Malaysia (6). Ports from around the world are presented on a world map in Figure 11.

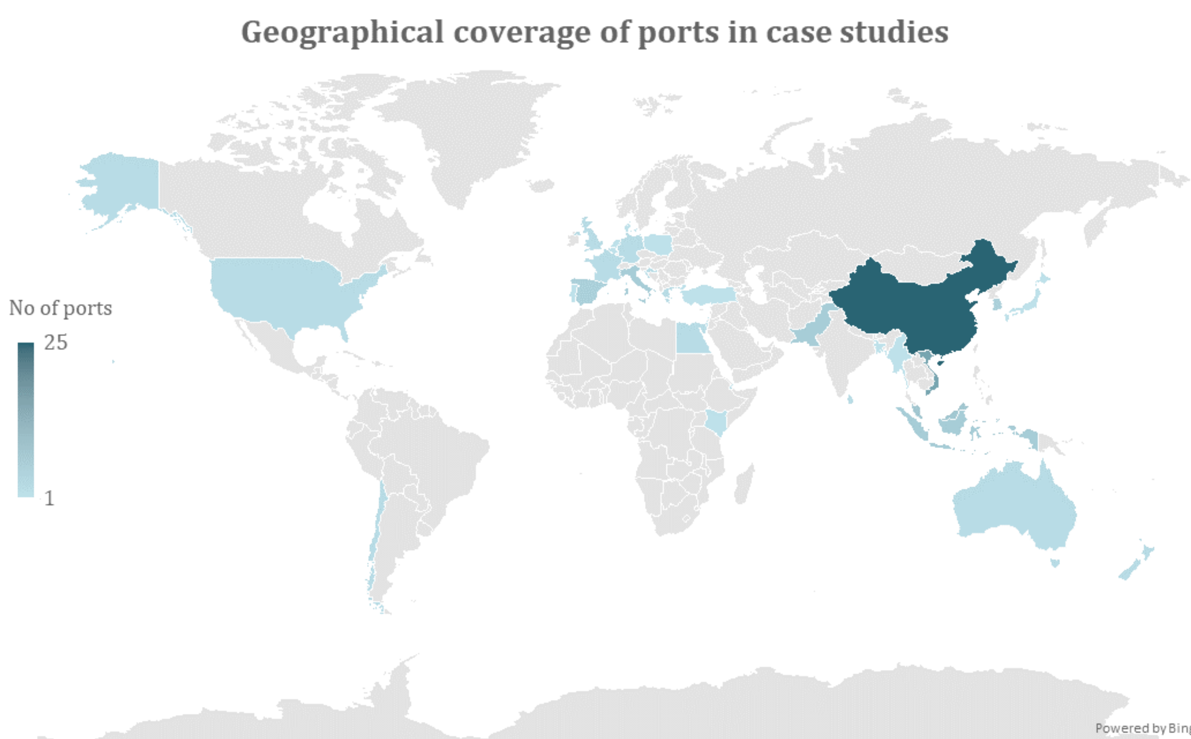

Figure 11 Geographical coverage of ports worldwide

The most commonly used game is the Bertrand game (price competition between players, simultaneous decision-making), and it appears in 16 articles (28%). The Cournot game, which determines each player's quantity and involves simultaneous decision-making, is used in 8 articles (14%). The Nash equilibrium game (a non-cooperative game in which players act independently) is presented in 7 publications (12%). The Stackelberg model, which involves sequential decision-making, appears in 6 articles (10%). Evolutionary game is used in 4 publications (7%). Other games participate to a lesser extent individually, but together they make up about 29% of all articles. Figure 12 presents the distribution among applied game theory models.

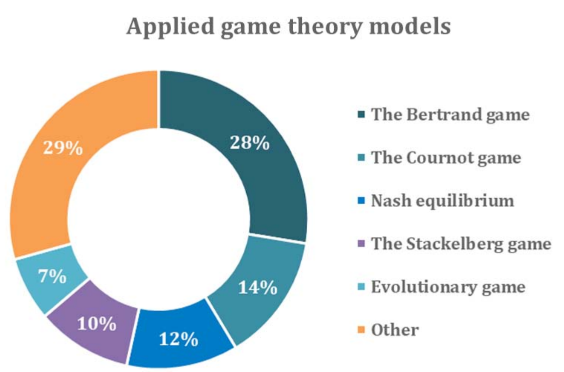

Figure 12 Applied game theory models

5 Discussion

The port system is highly complex, characterized by frequent conflicts and dynamic interactions among multiple stakeholders. This research highlights the analytical significance of game-theoretic methodologies in clarifying such behaviors and the resulting competitive or cooperative outcomes. Bibliometric evidence shows that about one-third of research contributions in this field are published in two leading journals: Maritime Policy & Management (14 articles) and Transportation Research Part E: Logistics and Transportation Review (8 articles) – reinforcing their central role in shaping scholarly discourse and establishing them as principal publication platforms within the field. Case-based evidence also reveals a strong geographical bias: 67% of empirical studies focus on Asian ports, while European cases account for 14% and those from other regions for the remaining 19%, suggesting an uneven distribution of research attention across global port systems.

The decrease in publication activity after 2018 suggests a possible shift in the focus of research in the field. This decline could signal a shift in research focus from conventional topics such as port pricing, investment, and throughput-based competition to emerging or alternative fields, including carbon emission reduction, green technology adoption, and the formation of strategic alliances among ports, shippers, and other logistics participants within the supply chain, both vertically and horizontally.

In the remainder of this section, we address the research questions.

RQ1) What types of game-theoretic models are most commonly employed?

Among all game-theoretic approaches, the Bertrand model is the most prevalent (28%), followed by the Cournot game (14%) and the Nash equilibrium (12%), accounting for more than half of the research articles. Other games individually contribute to a much lesser extent. Competition among ports dominates publications on port interactions (59%), followed by a combination of both competition and cooperation (23%). Thirty-nine percent of the reviewed studies employ Bertrand and Nash equilibrium frameworks to model competitive interactions among ports. Cooperation alone covers only 10% of research articles. In approximately 19 percent of the articles, evolutionary and alternative game-theoretic approaches are utilized to examine cooperative behavior. Most research papers (76%) focus on inter-port interactions, 16% on intra-port interactions, and 8% on both.

The results indicate that current research in port management primarily concentrates on competitive game-theoretic models. There is a notable gap in the exploration of cooperative strategies, and the limited use of advanced or hybrid models suggests an opportunity for further research to capture the complexity of evolving port dynamics.

RQ2) How is the research geographically distributed across different regions?

An analysis of the selected papers shows that case studies collectively examine 88 ports across 35 countries. Of these, Asian ports represent the largest share (59%), followed by European ports at 23%. Ports located in North and South America, Africa, Australia, and Oceania account for only 13 cases in total, or approximately 15% of all ports studied. This distribution indicates a marked regional imbalance, with research disproportionately concentrated on Asian and European ports, while ports in the rest of the world receive comparatively limited attention from researchers.

RQ3) What gaps and limitations exist in current game-theoretic modeling of port management?

While the literature has extensively explored competitive dynamics among ports using models such as Bertrand, Cournot, and Nash equilibrium, there is a noticeable lack of studies focusing on cooperation and collaborative strategies between ports and related stakeholders. Also, there is a significant deficiency of research employing more complex or hybrid modeling methodologies, such as evolutionary games or dynamic models, that could more effectively capture the evolving dynamics of port competition and cooperation.

The regional distribution of research reveals a distinct predominance of studies focused on Asian and European ports. In contrast, analysis of ports in the Americas, Africa, and Oceania is noticeably less present.

6 Conclusion

To identify relevant studies, we conducted a comprehensive search across three major academic databases: WoS, Scopus, and Google Scholar. A total of 69 international peer-reviewed journal articles concerning cooperation, competition, and capacity investment decisions between TOs and PAs were systematically reviewed, including studies that employ game-theoretic models to capture competitive and cooperative dynamics under varying governance and management structures. A systematic bibliometric analysis was then carried out to synthesize the state of the literature and evaluate current trends in the application of game theory in this research domain.

The most significant limitation of this study is its focus on English-language publications and the limited database searches performed. While Scopus offers a systematic method that balances the broad scope of Google Scholar with the selectivity of Web of Science, it does not adequately incorporate regional databases. This limitation can affect the comprehensiveness of the literature review [75]. To address this gap, researchers should consider integrating regional databases into their systematic reviews, as these sources can provide valuable insights into local practices and policies that may not be represented in mainstream databases.

The analytical synthesis of the reviewed literature emphasizes both the strengths and limitations of existing modelling approaches. Bertrand and Nash equilibrium formulations emerge as the most effective mechanisms for capturing and analyzing core competitive dynamics within port markets. Conversely, in the realm of port cooperation, various game approaches exhibit comparable levels of modeling effectiveness.

The following recommendations outline potential avenues for future research.

Shipping alliances are deploying larger vessels to gain economies of scale, prompting ports to expand capacity and improve hinterland links to stay competitive. These alliances influence pricing, traffic flows, and investment decisions, reshaping port competition. Future research should examine how alliances affect competitive dynamics, how ports form strategic partnerships, and how collaboration with logistics providers can create value and strengthen port competitiveness in a changing market.

Game theory offers valuable frameworks for optimizing carbon-emission reduction strategies in port operations by analyzing the interactions among various stakeholders, including TOs, shipping companies, and PAs. The future application of game-theoretic models can help identify optimal investment strategies and cooperative behaviors that lead to significant reductions in emissions.

Finally, future research should include case studies of specific regions to understand how local factors, such as geography, labor availability, and economic development initiatives, affect port competition. Addressing the geographic imbalance in studies, comparative research spanning a broader range of geographic regions may yield profound insights into the diversity of port management techniques and the relevance of game-theoretic models across different contexts.

These findings highlight the need for broader methodological approaches and more inclusive geographic coverage to extend our understanding of global port management practices.

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