

Choi, Young-Seo; Yeo, Gi-Tae

Article

An analysis of research trends of inland waterway utilizing social network analysis

Asian Journal of Shipping and Logistics (AJSL)

Provided in Cooperation with:

Korean Association of Shipping and Logistics, Seoul

Suggested Citation: Choi, Young-Seo; Yeo, Gi-Tae (2023) : An analysis of research trends of inland waterway utilizing social network analysis, Asian Journal of Shipping and Logistics (AJSL), ISSN 2352-4871, Elsevier, Amsterdam, Vol. 39, Iss. 2, pp. 52-59,
<https://doi.org/10.1016/j.ajsl.2023.02.002>

This Version is available at:

<https://hdl.handle.net/10419/329713>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<https://creativecommons.org/licenses/by-nc-nd/4.0/>



An analysis of research trends of inland waterway utilizing social network analysis

Young-Seo Choi, Gi-Tae Yeo *

Graduate School of Logistics, Incheon National University, Incheon 22012, South Korea

ARTICLE INFO

Article history:

Received 23 November 2022

Accepted 5 February 2023

Keywords:

Inland waterway

Research Trend

Social Network Analysis (SNA)

Europe

China

USA

ABSTRACT

This study aimed to analyze the research trends of inland waterways in the field of logistics by compiling previous studies that contain keywords related to inland waterways. To investigate the research trend, this study used a keyword network among the SNA methodology and deduced results using the concepts of centrality, including degree centrality, betweenness centrality, closeness centrality, and eigenvector centrality. According to the results of the comprehensive analysis by each region based on the eigenvector centrality outcome, Europe had a core keyword of modal shift, which refers to the conversion to eco-friendly vehicles due to the exhaust problem of land carriage, as well as the continuously implemented government policy. The results of China showed that the country's task to solve was on studies aimed at reducing traffic jams in inland waterways using AIS data. In the case of the US, the problems of ship delay remain unsolved owing to old locking facilities and equipment. This study provided academic implications that clarify the state-of-the-art in this research topic in three regions that have advanced inland waterways.

© 2023 The Authors. Production and hosting by Elsevier B.V. on behalf of The Korean Association of Shipping and Logistics, Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

An inland waterway refers to a large stream in which water transportation has developed rivers, canals, lakes, etc., where sailing is possible (Mako & Galierikovk, 2021). An inland waterway is navigable when it can load a ship weighing 50 tons or more. Inland waterway transportation is a competent mode of transportation because it is safer and more cost-effective than land transportation.

In the past, inland waterways were a major mode of transportation of goods. They are being neglected due to alternative transportation methods, such as roads and railways, as investment and business promotion of inland waterway transportation networks have waned. Despite the possibility of being an efficient alternative to road transportation in terms of cost and environment, some nations do not use inland waterways.

Inland waterways in Europe, the United States, and China are well-developed and established as significant networks for the transport and logistics of goods. In Europe, investment support and infrastructure improvements for inland waterways are sustained through the EU network for complex transport and the development of environmentally friendly modes of transportation. Currently,

significant efforts are underway worldwide to use inland waterways as sustainable complex transport systems. Consequently, inland waterways will play a central role in an environmentally friendly green supply chain by using environmentally friendly energy and serving as a base for complex transport along with autonomous vessels. Therefore, exploring the possibility that inland waterways are expected to be significant, and identifying trends in inland waterway research are necessary for the development of inland waterways.

This study aims to examine the research trend of inland waterways in each region. Research in inland waterways in the field of logistics is collected, followed by a centrality assessment using a keyword network analysis. Degree centrality, betweenness centrality, and closeness centrality are derived. The properties of each region will be comprehensively compared based on the eigenvector centrality results. This research may provide a viewpoint for the further development of inland waterways and directionality for relevant research by studying the overall current state and characteristics of research trends for inland waterways in each region in the field of logistics.

This paper is organized as follows. The second section presents a review of previous research on inland waterways that is distinct from this research. The third section includes a description of the Keyword Network, among social network analysis (SNA), which is the method of this research. In the fourth section, the results of

* Corresponding author.

E-mail addresses: youngseochoi@inu.ac.kr (Y.-S. Choi), ktyeo@inu.ac.kr (G.-T. Yeo).

degree, betweenness, and closeness centralities are derived for each region, and the results of the comprehensive analysis are specified through eigenvector centrality. Finally, the fifth section presents the analysis of the results of this research.

2. Literature review

Asborno and Hernandez (2021) used a stochastic approach with data from the automatic identification system (AIS) and the quantity of transported goods in the harbor of the Arkansas River from 2016 to verify a new estimation model. A modeling scenario, including 39,366 determinants, was demonstrated using IBM ILOG CPLEX Optimization Studio version 12.10. The verification results showed a low error rate of 0.25% between the prediction model and the actual data on the quantity of goods. The authors contended that their study verified the application of the model in other inland waterway simulation scenarios and that the flow of goods for each item was estimable.

Solomon et al. (2021) surveyed 25 experts to derive methods for activating the inland waterway system of Volta Lake in Ghana. The respondents commented on the administration, market, goods, and technology for the activation of inland waterway transport (IWT) of Volta Lake. The institutionalization of IWT, moderate regulation, periodic maintenance, improvement of goods, and development of infrastructure, as well as promotion of integrated transport planning, were included as factors of activation for each sector. The factors derived through the surveys were essential to the development and improvement of Ghana's IWT, and the authors claimed that government support was required.

Bu and Nachtmann (2021) reviewed and analyzed 135 studies with a focus on Barge (COB) among research related to complex transportation containers between April 2000 and April 2021. Their results showed that the number of publications has been increasing over the past 10 years, and the increase was particularly significant during the past five years. Additionally, 26% of the total research was published in the Netherlands and 53% in northwestern Europe, indicating that it was the center of COB transportation. In terms of research methodologies, 23% were verified through simulations, followed by 19% through case studies. The authors stated that their study supported a positive change in COB transportation research.

Jiang et al. (2021) verified a model to investigate oil spills in inland waterways. They used the oil spill map of the Yangtze River in China as input into the verification model to analyze the relationship between the thickness and area of the oil layer over time using parametric programming. The results showed that oil had spread along the direction of the current or the horizontal direction owing to convection in the inland waterway. Additionally, the impact of wind on the oil spill trajectory was found to be high when the current speed was low, and the wind speed was high. The authors stated that their research could be used as a reference to predict the transport and dispersion of oil spills in inland waterways.

Sihn et al. (2015) developed and verified the inland vessel NEWS (FP7 project), which is an innovative container ship to tackle the decline in transport volume on inland waterways in central Europe. Their results showed that resource efficiency could be increased by a maximum of 30% with the LNG-gas-electricity propulsion system, and the design of a new ship body could reduce fuel consumption by up to 10%. Additionally, they found that significant reductions in the external costs and costs of climate change could be obtained. The effect that could be obtained from this project was the reduction of greenhouse gases and other pollutants and an increase in inland waterway transport volume. Therefore, the expectations of the project and the study objective were to enable the sustainable transport of goods.

Jiang et al. (2018) collected data from the IWT of the Yangtze River and Pearl River in China between 2002 and 2014 and compared

the management methods using the Vensim PLE software. Their results showed that the management of the Yangtze River is superior to that of the Pearl River. Various investment structures by the central government were shown to affect the development of inland waterways in both rivers. Thus, the authors contended that the rate of investment by the central government increased and systematic efforts for development are necessary.

The majority of previous research covered case studies and modeling studies; numerous studies were published in regions where inland waterways were well utilized, with many of those being recent studies. However, no review has been published on the research trends in inland waterways. In particular, a regional analysis that may reflect regional characteristics worldwide is lacking. Therefore, this study extracts keywords for inland waterway research in three overseas regions (Europe, the United States, and China) for network analysis. Degree, betweenness, closeness, and eigenvector centralities were derived to ascertain regional research trends.

3. Research methodology

This study utilizes a keyword network, which is an SNA method that analyzes the keywords of previous research published. The keyword network methodology was first presented by Freeman (1978) and consists of nodes with designated keywords and links that represent the interactions of the nodes (Kong et al., 2019). The results comprehensively present the relationship between the nodes and the degree of importance of the nodes within the network (Jeon et al., 2016).

The current study used a keyword network to ascertain the overseas research trend of inland waterways in the field of logistics by performing a centrality analysis of research on inland waterways. The relationships between the nodes were visualized using Ucinet to identify the relationships between the keywords. Therefore, this study used degree centrality, betweenness centrality, closeness centrality, and eigenvector centrality among the concepts of keyword network centrality. The characteristics of each region for inland waterway research and keywords with a high impact were determined using the derived results.

This research gathered academic papers from international academic databases by searching with the keyword "inland waterways." The search period was from August 2nd to September 15th, 2021. Academic papers were collected from seven databases: Science Direct, Scopus, Springer e-journals, and Web of Science. The first paper on the topic was published in 2001, followed by a variety of other publications.

First, the studies were classified by region. Studies from countries with few publications and those irrelevant to logistics were excluded. Three regions—Europe, the United States, and China—were selected because inland waterways were well developed, and studies were abundant. The keywords were cleansed using the following process: standardization of plural to singular and standardization of abbreviations. Fig. 1.

4. Empirical analysis

4.1. Europe analysis results

A total of 143 publications relevant to logistics within inland waterways in Europe were found, and the graph in Fig. 2 shows the number of publications by year. Starting from 2014, the numbers have been increasing, peaking in 2018 and 2020 at 16 units. The results of centrality analysis were derived for 695 keywords after keyword cleansing.

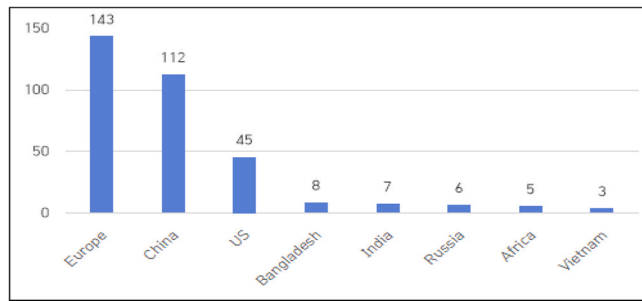


Fig. 1. Number of studies published in each region.

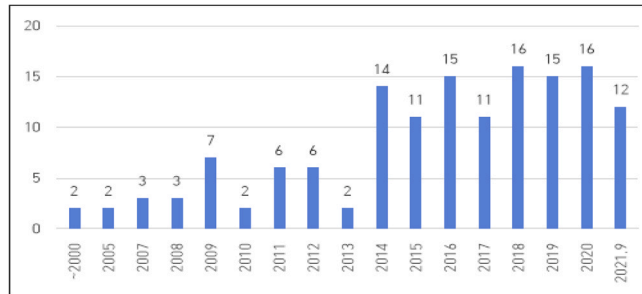


Fig. 2. Number of publications per year in Europe.

4.1.1. Degree centrality

As shown in Table 1, the Degree Centrality of European papers showed that the keyword with the highest Degree Centrality was “inland waterway” at a value of 0.194, followed by “IWT” (0.137), “inland navigation” (0.075), and “Danube” (0.061).

Research on IWT began in 2011, as shown in Table 1 followed by numerous studies, including the impact of climate change on the competence of the Rhine River (Jonkeren et al., 2011), the impact of climate change on IWT (Hendrickx & Breemers, 2012), the impact of extreme climate and climate change on IWT (Schweighofer, 2014), and the economic impact of climate change on IWT in Europe (Jonkeren et al., 2014).

Further IWT research studied the modeling conditions that affect the cost competency (Wiegman & Konings, 2015), inland waterway gas fuel vessels, Computer-aided synthesis modelling (CASM).

Table 1
Degree centrality analysis results for the top 20 keywords in papers from Europe.

Rank	Keywords	Degree
1	Inland Waterway	0.194
2	IWT(Inland Waterway Transport)	0.137
3	Inland Navigation	0.075
4	Danube	0.061
5	Intermodal Transport	0.059
6	Freight Transport	0.057
7	External Costs	0.055
8	Modal Shift	0.053
9	Sustainability	0.051
10	Transport	0.051
11	Waterway	0.051
12	Sustainable Transport	0.042
13	Climate Change	0.040
14	Emission	0.036
15	Inland	0.036
16	Port	0.036
17	Container Transport	0.034
18	Europe	0.034
19	Inland Shipping	0.034
20	Shipping	0.028

-based electrification of European tankers (Bucci et al., 2016), sailing time, and cost modeling for IWT (Hekkenberg et al., 2017), classification of external costs of IWT, and analysis of determination methods (Hofbauer & Putz, 2020). Those studies showed that the use of modeling expanded from 2015 onwards, presumably to increase the competency of inland waterways by implementing differentiated research methodologies. Fig. 3.

4.1.2. Betweenness centrality

The analysis results for betweenness centrality are shown in Table 2. Similar to the results of degree centrality, the keywords with the highest values were derived in the following order: “inland waterways” (0.289), “IWT” (0.234), and “external costs” (0.072). The values for “Danube” (0.066) and “inland navigation” (0.063) declined in comparison with those from degree centrality. This was attributed to the property of betweenness centrality, in which a low value was exhibited because the mediating role between papers was low despite numerous connected nodes from a single node and the degree centrality was high.

4.1.3. Closeness centrality

Closeness centrality analysis results (see Table 3) showed that “inland waterways” (0.259) showed the highest value, followed by “IWT” (0.251). The keyword “modal shift,” which recorded the 8th and 12th highest values in degree centrality and betweenness centrality, respectively, ranked third highest in closeness centrality. The keyword “emission” (0.239) was among the high-ranking keywords at the fourth highest Closeness Centrality. This was attributed to the closeness centrality being determined by considering all nodes that are directly and indirectly connected.

4.2. China analysis results

A total of 112 papers were found on inland waterway logistics in China. Fig. 4 illustrates the number of publications by year. Research relevant to logistics, including the keyword “inland waterway,” appeared in 2001; the number of publications in this field increased from 2014, and the number of published papers increased to 15 or above in 2019. The number of publications was the highest until September 2021, at 21 units. Centrality was derived for the 515 keywords after keyword cleansing.

The highest Degree Centrality among publications from China was shown, from “inland waterway” (0.235), followed by “IWT” (0.086), “Yangtze river” (0.064), “AIS” (0.049), and “maritime safety” (0.044), as summarized in Table 4.

As for research on inland waterways in China, studies on the site selection of inland waterway service areas (IWSA) (Peng et al., 2011; Bi et al., 2013) and the development of Chinese inland waterway road noise prediction models (Dai et al., 2014, 2015) have been conducted. Recent studies have included navigation risk assessment of inland waterway transportation systems (Zhang et al., 2016; Gan et al., 2019), prediction of traffic volume within inland waterways (Xie & Liu, 2018; Liao et al., 2019), locking device problems and management of inland waterway vessels (Deng et al., 2021; Ji et al., 2021), and inland waterway ship detection and tracking modeling (Di et al., 2020; Jie et al., 2021; He et al., 2021). The changes in the research focus relevant to inland waterways by year are distinguishable through the uncovered research topics along with the trends in recent research. Numerous studies have attempted to model inland waterways.

4.3. United States analysis results

A total of 45 papers were found on inland waterway logistics in the United States, and the number of publications by year is shown in Fig. 5. In the United States, publications in this field were first

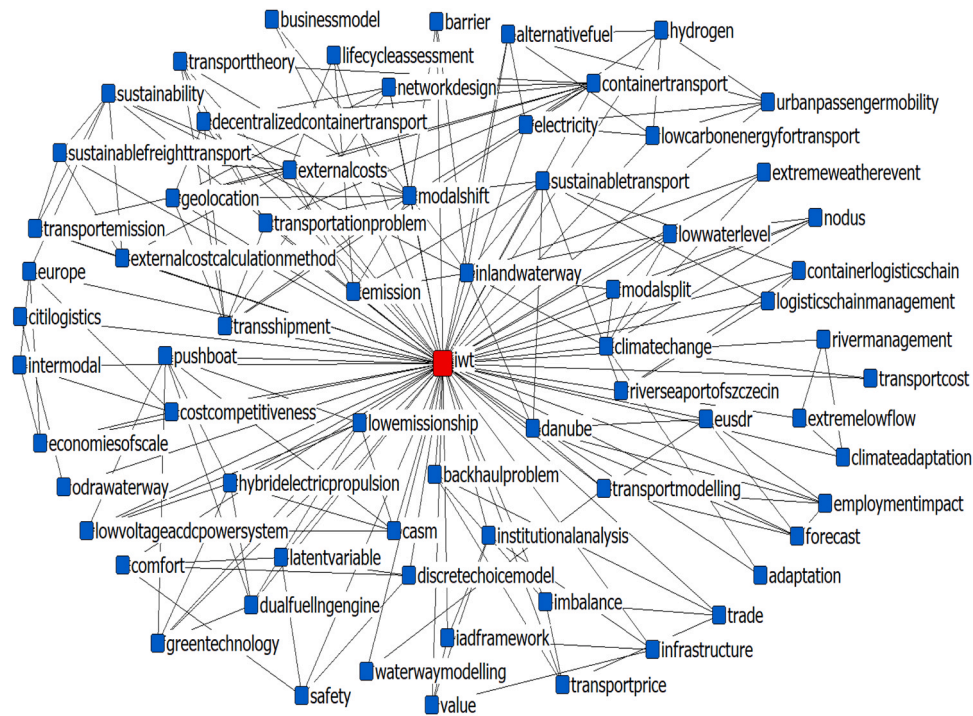


Fig. 3. IWT keyword ego network.

Table 2
Analysis results of the Top 20 Betweenness Centralities in Europe.

Rank	Keywords	Betweenness centrality
1	Inland Waterway	0.289
2	IWT	0.234
3	External Costs	0.072
4	Danube	0.066
5	Inland Navigation	0.063
6	Safety	0.062
7	Transport	0.062
8	Intermodal Transport	0.057
9	Sustainability	0.054
10	Inland Waterway Ship	0.050
11	Port	0.049
12	Modal Shift	0.039
13	Waterway	0.038
14	Climate Change	0.036
15	Freight Transport	0.035
16	Sustainable Transport	0.035
17	Shallow Water	0.032
18	Inland	0.029
19	Transport Cost	0.029
20	Europe	0.028

Table 3
Analysis results of the Top 20 Closeness Centrality in Europe.

Rank	Keywords	Closeness centrality
1	Inland Waterway	0.259
2	IWT	0.251
3	Modal Shift	0.241
4	Emission	0.239
5	Sustainability	0.239
6	Sustainable Transport	0.237
7	External Costs	0.235
8	Intermodal Transport	0.234
9	Danube	0.233
10	Inland Navigation	0.232
11	Transport	0.231
12	Climate Change	0.229
13	Container Transport	0.229
14	Freight Transport	0.229
15	Low Water Level	0.227
16	Modal Split	0.227
17	Port	0.227
18	Alternative Fuel	0.226
19	Barrier	0.226
20	Extreme Weather Event	0.226

published in 2002, and the number of publications increased in 2018. The record was highest in 2020, with 10 publications. The centrality results were derived for 255 keywords after keyword cleansing.

Degree centrality analysis results showed that inland waterways (0.295) ranked the highest, followed by “maritime transportation” (0.109), “inland waterway ports” (0.077), and “GIS” (0.071) (see Table 5).

4.4. Combined analysis results

The eigenvector centrality was derived to ascertain the characteristics of inland waterways and research for each region. The eigenvector centrality was determined not only by detecting the degree of node connectivity near one node but also by detecting

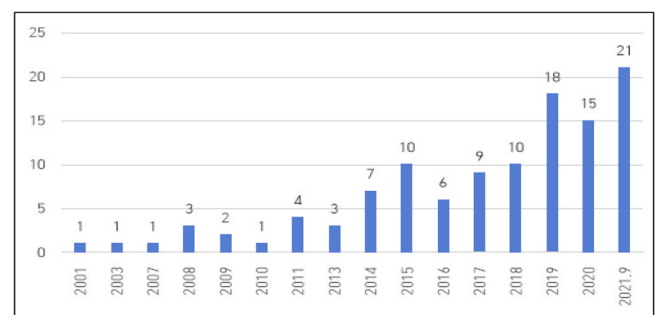


Fig. 4. Number of publications by year in China.

Table 4
Analysis results for China.

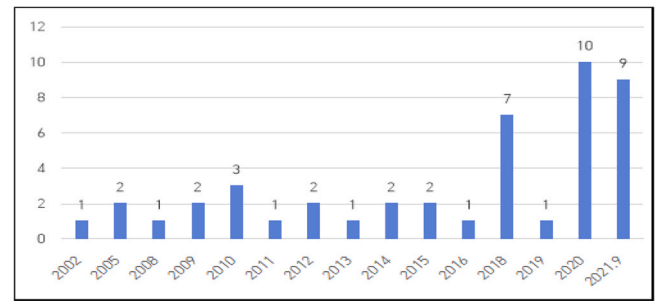
Rank	Keywords (Degree centrality)	Keywords (Betweenness centrality)	Keywords (Closeness centrality)
1	Inland Waterway (0.235)	Inland Waterway (0.288)	Inland Waterway (0.183)
2	IWT (0.086)	IWT (0.147)	Maritime Safety (0.179)
3	Yangtze River (0.064)	Maritime Safety (0.099)	AIS Data (0.178)
4	AIS (0.049)	AIS (0.081)	Maritime Risk (0.173)
5	Maritime Safety (0.044)	AIS Data (0.061)	Waterway Service Area (0.173)
6	China (0.042)	3D Modeling (0.052)	IWT (0.172)
7	AHP (0.035)	Yangtze River (0.050)	Evidential Reasoning (0.171)
8	AIS Data (0.035)	Digital Waterway (0.041)	Fuzzy set (0.171)
9	DBSCAN (0.032)	Waterway Service Area (0.032)	Abnormal Data (0.169)
10	Waterway Transportation (0.032)	Maritime Risk (0.030)	Assessment (0.169)
11	Bayesian Network (0.030)	Mixed integer linear Programming (0.027)	Data Repair (0.169)
12	Maritime Risk (0.030)	Waterway Transportation (0.027)	Data Restoration (0.169)
13	Digital Waterway (0.025)	DBSCAN (0.024)	Least squares support vector machine (0.169)
14	Inland River (0.025)	Inland River (0.024)	Recurrent Neural Network (0.169)
15	Lowest Navigable Water level (0.025)	AHP (0.023)	Distance (0.168)
16	Assessment (0.022)	Assessment (0.018)	Site Selection (0.168)
17	Inland River Shipping (0.022)	Lowest Navigable Water level (0.018)	Black Spot Water (0.167)
18	Lock Scheduling (0.022)	Bayesian Network (0.016)	DBSCAN (0.167)
19	Trajectory Clustering (0.022)	Inland River Shipping (0.015)	3D Modeling (0.166)
20	Mixed integer linear Programming (0.020)	Lock Scheduling (0.015)	Collision Risk (0.166)

Betweenness Centrality analysis results were similar to that of Degree Centrality as “inland waterway” (0.288) and “IWT” (0.147) ranked the first and second highest, followed by “maritime safety” (0.099), “AIS” (0.081), and “AIS Data” (0.061). Closeness Centrality analysis results were similar, as the first two ranks were occupied by “inland waterway” (0.183) and “maritime safety” (0.179), and they were followed by “AIS data” (0.178), “maritime risk” (0.173), “waterway service area” (0.173), and “IWT” (0.172).

nodes that are intensely connected to substantial nodes. Therefore, eigenvector centrality is useful for ascertaining the characteristics of inland waterways in Europe, China, and the United States through region-specific keywords, which were the objectives of this study. This paper describes the characteristics and objectives of inland waterways based on the first- to fifth-ranking results of eigenvector centrality.

4.4.1. Europe

Europe is a peninsula of 44 densely adjacent nations, and 27 nations have opened borders to form the European Union (EU). The

**Fig. 5.** Number of publications per year in the United States.**Table 5**
Analysis results for the United States.

Rank	Keywords (Degree centrality)	Keywords (Betweenness centrality)	Keywords (Closeness centrality)
1	Inland Waterway (0.295)	Inland Waterway (0.226)	Inland Waterway (0.243)
2	Maritime Transportation (0.109)	Maritime Transportation (0.086)	Maritime Transportation (0.228)
3	Inland Waterway Port (0.077)	IWT (0.039)	Economic Impact (0.225)
4	GIS (0.071)	GIS (0.034)	Agent-based Modeling (0.222)
5	Freight Transportation (0.066)	Transportation (0.033)	Discrete-event Simulation (0.222)
6	IWT (0.066)	Freight Transportation (0.028)	GIS (0.222)
7	Cargo Prioritization (0.055)	Oil Spill (0.022)	Input-output Modeling (0.222)
8	Disruption Response (0.055)	Resilience (0.022)	System Dynamics (0.222)
9	Economic Impact (0.055)	Simulation (0.017)	Cargo Prioritization (0.221)
10	Simulation (0.049)	Economic Impact (0.013)	Disruption Response (0.221)
11	Transportation (0.049)	Inland Waterway Port (0.003)	Freight Transportation (0.220)
12	Oil Spill (0.044)	Cargo Prioritization (0.002)	Linear Regression (0.220)
13	Port Optimization (0.044)	Disruption Response (0.002)	Lock Maintenance (0.220)
14	Sample Average Approximation (0.044)	Absorptive Capacity (0.000)	Maintenance Dredging (0.220)
15	Water level Fluctuation (0.044)	Agent-based Modeling (0.000)	Oil Spill (0.220)
16	Cracking (0.038)	Agent-based Simulation (0.000)	Optimization (0.220)
17	Fatigue Life (0.038)	Analytical Model (0.000)	Transportation (0.220)
18	Marine Terminal (0.038)	Analytic Hierarchy Process (0.000)	Emergency Response (0.219)
19	Reliability (0.038)	Anomaly Detection (0.000)	TCE (0.219)
20	Steel pile (0.038)	Asset Management (0.000)	Analytic Hierarchy Process (0.218)

Betweenness Centrality results were similar to those of Degree Centrality as the first two ranks were occupied by “inland waterway” (0.226), “maritime transportation” (0.086), followed by “IWT” (0.039), “GIS” (0.034), and “Transportation” (0.033). Similarly, the highest closeness centrality was ranked by inland waterways (0.243), followed by “maritime transportation” (0.228), and “economic impact” (0.025).

Table 6

Analysis results of the top five eigenvector centralities in Europe.

Rank	Keywords	Eigenvector centrality
1	Inland Waterway	0.484
2	IWT	0.270
3	Inland Navigation	0.193
4	Modal Shift	0.186
5	Freight Transport	0.181

second-ranking keyword of Europe's Eigenvector Centrality was "IWT," which is one major method of transportation (see Table 6). Inland waterways within Europe connect more than 100 cities and account for 37,000 km or more.

As environmental awareness of exhaust gas during road or railway transport grew, research relevant to the fifth-ranking Eigenvector Centrality "freight transport" (0.181) increased. Therefore, a change to transportation methods that are more environmentally friendly than transportation via roads on land is essential. The European market is seeking to connect conventional and environmentally friendly methods of transportation or transition to environmentally friendly transportation. Consequently, the significance of the fourth-ranking "modal shift" (0.186), which refers to a transition of carbon-intensive road transport to coastal shipping, is growing. Therefore, the government has been supporting environmentally friendly policies by actively participating in continued support and infrastructure improvements. The European Union has invested in and operated environmentally friendly inland waterway infrastructure through the Marco Polo program implemented from 2003 to 2013 in two distinct phases, and the Trans-European Transport Network (TEN-T) infrastructure project worth more than 320 million (CCNR, 2020). Modal shift is expected to significantly reduce social costs through air quality improvement, noise reduction, infrastructure maintenance cost reduction, traffic accidents, congestion improvement, etc. The importance of the third-ranking "inland navigation" (0.193) was shown to grow to establish and develop inland waterway infrastructure through rivers that are environmentally efficient and cost-efficient through the above policies. Inland navigation transportation is energy efficient and suitable for achieving a low-carbon economy. Additionally, transportation and services are convenient in regions with a high population density, as noise levels are low.

4.4.2. China

In China, with the world's longest inland waterways stretching above 128,000 km, a total of 774.25 million tons of goods were transported through inland waterways in 2019 (Report on Sustainable Transport in China, 2021). Transportation via inland waterways enables the delivery of bulk freights that are large in volume and at a lower cost compared to land transport. Therefore, inland waterways in China serve as a critical transportation method, taking up the second greatest quantity of goods after road transport.

According to a statistical analysis of marine accidents in the People's Republic of China (KMI China Report, 2019), a report on inland waterway vessel accidents showed that collisions were most frequent between 2000 and 2016, followed by sinking and damage by contact (Wang et al., 2020). This was relevant to the keyword "maritime risk" (0.092), which ranked fifth in eigenvector centrality, while congestion in inland waterways was the primary cause among a variety of maritime risk factors (see Table 7). Traffic density inevitably increases in congested inland waterways, and sailing efficiency decreases near dams and lock gates. This leads to restricted transportation capacity and accidents such as delays, stranding, and shipwrecks, and significant delays are incurred during container terminal transport due to inland waterway transportation constraints (Yan et al., 2017). They

Table 7

Analysis results of the top five eigenvector centralities in China.

Rank	Keywords	Eigenvector centrality
1	Inland Waterway	0.662
2	AIS Data	0.114
3	Maritime Safety	0.112
4	Service Area	0.096
5	Maritime Risk	0.092

found that the second risk factor was China's geography. In the south, the conditions are stable, as ice does not freeze, but the river in the north freezes during winter and impacts inland waterway transport in the corresponding area. Additionally, congestion or suspension of inland waterway systems has been reported to occur because of natural constraints such as strong winds, dry seasons, dense fog, and flooding (REWWay, 2021). The probability of the occurrence of accidents is not high, but the loss of lives, environmental pollution, and economic loss continue to threaten safe navigation in inland waterways (Cai et al., 2021).

Therefore, considering the third-ranking keyword "maritime safety" (0.112), the second-ranking "AIS Data" (0.114) was utilized to determine the accurate location and density of vessels in advance to prevent traffic congestion. Additionally, an AIS and big data are used to reduce vessel collisions by assessing the maritime transportation capacity under the current speed limit (Cai et al., 2021). The fourth-ranking keyword, "service area" (0.096), refers to crucial navigational aid facilities for inland waterways. Inland waterway service area (IWSA) planning and design are critical for identifying the maximum number of simultaneously acceptable vessels, and congestion and collision may be prevented through the IWSA design (Liao et al., 2019). Maritime traffic safety and risk analysis for reducing the frequency of accidents in inland waterways are comprehensive and complex, requiring recent data for quantitative and qualitative analyses, along with improvements through the views of experts.

4.4.3. The United States

The inland waterway system in the United States is more than 40,000 km long, transports significant goods, and plays a significant role in international trade and the economy (Port Performance Freight Statistics in 2019: Annual Report to Congress 2020). Critical goods, such as agricultural produce, energy products, construction materials, and industrial chemicals, are transported through inland waterways in the United States. In 2019, 514.9 million tons of goods, accounting for approximately 14% of the total goods transported, were transported through inland waterways in the United States. The US Army Corps of Engineers (USACE) predicted that this amount will increase to 942 million tons by 2045 (USACE, 2021). Therefore, "maritime transportation" (0.180) ranked second, as it was the core of the supply chain in the United States. "Freight transportation" (0.145) ranking fifth, refers to the use of inland waterways for the transport of goods, which plays a significant role in improving congested traffic of road transport for the environment as well as the economy (see Table 8).

Table 8

Analysis results for the top five eigenvector centralities in the United States.

Rank	Keywords	Eigenvector centrality
1	Inland Waterway	0.568
2	Maritime Transportation	0.180
3	Cargo Prioritization	0.166
4	Disruption Response	0.166
5	Freight Transportation	0.145

The inland waterway system in the United States comprises routes, ports, lock gates and dams, locks and facilities, terminals, and vessels. The vessels that are mainly used are barges, which are created to navigate rivers of various depths through locks and dam systems (Delgado-Hidalgo & Nachtmann, 2021). However, delays occurring in locking facilities and devices have not improved. This issue is detrimental to the operation of navigation-based facilities and causes economic loss and system closures. The closure of systems owing to problems in the waterway leads to the cessation of barges that require measures. Therefore, research relevant to the fourth-ranking keyword “disruption response” (0.166) has been conducted. The cargo that falls under the category of the third-ranking keyword “cargo prioritization” (0.166) must be prioritized for loading and unloading for transportation on the road until its final destination. A resolution was found to be necessary for terminal allocation and prioritization of loading and unloading at accessible terminals (Delgado-Hidalgo et al., 2020).

A total of 193 lock gates and 239 locks of the inland waterway system were established in the 1930s by the USACE, and 50 years or more have passed for more than 50% of the construction. Thus, modernization or large-scale restoration is necessary for this system. However, active support from the government is required because the budget is limited for waterway maintenance projects.

5. Conclusions

This study employed SNA methodology to derive region-specific degree centrality, betweenness centrality, closeness centrality, and eigenvector centrality of keywords relevant to inland waterways in the field of logistics. The top five keywords with the highest eigenvector centrality were compared to analyze the characteristics of the inland waterways in each region. The analysis results are summarized below.

First, the significance of transport through inland waterways has been increasing in Europe to reduce exhaust gas from road freight transport. Thus, policy support for the transition to an environmentally friendly method of transport and sustained association with this method is in steady progress. Therefore, numerous studies have been published on inland navigation through modal shifts.

China has the world's longest inland waterway, but accident reports from inland waterways state that vessel collisions are most frequent and incessantly threaten maritime safety. Therefore, the goal is to decrease collisions through the design of the IWSA. For this purpose, previous studies have conducted simulations to reduce density and accurately locate vessels using AIS data.

Major maritime transportation in the United States occurs in inland waterways, among which the weight of agricultural production is significantly high. However, the problem of delay during cargo transport due to a halt in the system stemming from the aged lock gate facility and lock maintained by the USACE has not been resolved. Therefore, disruption-response modeling has progressed, mainly comprising simulation research for cargo prioritization.

The implications of this study are as follows. The eigenvector centrality analysis results for Europe, the United States, and China showed that the top five highest-ranking keywords were the different, except for “inland waterway.” Utilizing these findings would facilitate comprehension of the characteristics, issues, and resolutions of inland waterways in each region.

This study included region-specific analysis, but lacks time-specific trends in research as an overall analysis from the point in time of the first inland waterway publication to the year 2021. Therefore, more significant findings can be obtained by analyzing studies from each area over distinct periods.

Conflicts of interest statement

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Acknowledgments

This research was supported by the 4th Educational Training Program for the Shipping, Port and Logistics from the Ministry of Oceans and Fisheries of South Korea.

References

- Asborno, M. I., & Hernandez, S. (2021). Assigning a commodity dimension to AIS data: Disaggregated freight flow on an inland waterway network. *Research in Transportation Business & Management* Article 100683.
- Bi, H., Lu, J., & Cai, Q. (2013). Location method of inland waterway service areas based on comprehensive assessment. In *ICTE 2013: Safety, Speediness, Intelligence, Low-Carbon, Innovation*, 1060–1066.
- Bu, F., & Nachtmann, H. (2021). Literature review and comparative analysis of inland waterways transport: Container on Barge. *Maritime Economics & Logistics*, 1–34.
- Bucci, V., Marin, A., Bosich, D., & Sulligoi, G. (2016). Inland waterway gas-fueled vessels: CSM-based electrification of a pushboat for the European network. *IEEE Transactions on Transportation Electrification*, 2(4), 607–617.
- Cai, M., Zhang, J., Zhang, D., Yuan, X., & Soares, C. G. (2021). Collision risk analysis on ferry ships in Jiangsu Section of the Yangtze River based on AIS data. *Reliability Engineering & System Safety*, 215, Article 107901.
- Dai, B. L., He, Y. L., Mu, F. H., Xu, N., & Wu, Z. (2014). Development of a traffic noise prediction model on inland waterway of China using the FHWA. *Science of the Total Environment*, 482, 480–485.
- Dai, B. L., Sheng, N., He, Y. L., Mu, F. H., Xu, J. M., & Zhu, A. F. (2019). Development of an inland waterway traffic noise prediction model considering water surface adsorption and embankment shielding influences. *International Journal of Environmental Science and Technology*, 16(10), 5927–5936.
- Dai, B. L., Sheng, N., He, Y. L., Xu, J. M., & Zhu, A. F. (2016). An inland waterway traffic noise prediction model for environmental assessment in China. *International Journal of Environmental Science and Technology*, 13(5), 1235–1244.
- Dai, B., He, Y., Xu, J., Xu, N., Wu, Z., & Deng, Y. (2015). Applying the RLS 90 to develop an inland waterway traffic noise prediction model in China that considers water surface influence. *Journal of Low Frequency Noise, Vibration and Active Control*, 34(1), 73–85.
- Delgado-Hidalgo, L., & Nachtmann, H. (2021). A heuristic approach to managing inland waterway disruption. *Engineering Management Journal*, 33(1), 2–14.
- Delgado-Hidalgo, L., Rainwater, C., & Nachtmann, H. (2020). A computational comparison of cargo prioritization and terminal allocation problem models. *Computers & Industrial Engineering*, 144, Article 106450.
- Deng, Y., Sheng, D., & Liu, B. (2021). Managing ship lock congestion in an inland waterway: A bottleneck model with a service time window. *Transport Policy*, 112, 142–161.
- Di, X., Zhang, J., Li, B., & Xu, Z. (2020). Research on the Method and Application of Intelligent Information Service Demand Identification of Inland Waterway. *2020 IEEE 5th International Conference on Intelligent Transportation Engineering (ICITE)*, 345–350.
- Freeman, L. C. (1978). Centrality in social networks conceptual clarification. *Social Networks*, 1(3), 215–239.
- Gan, W., Huang, M., Li, Y., & Yang, Z. (2019). Risk assessment for cruise ship navigation safety of inland waterway based on evidential reasoning. *2019 5th International Conference on Transportation Information and Safety (ICTIS)*, 1122–1126.
- He, W., Liu, X., Chu, X., Wang, Z., Fracz, P., & Li, Z. (2021). A novel fitting model for practical AIS abnormal data repair in Inland River. *Elektronika ir Elektrotechnika*, 27(1), 60–70.
- Hekkenberg, R. G., Van Dorsser, C., & Schweighofer, J. (2017). Modelling sailing time and cost for inland waterway transport. *European Journal of Transport and Infrastructure Research*, 17, 4.
- Hendrickx, C., & Breemers, T. (2012). The effect of climate change on inland waterway transport. *Procedia-Social and Behavioral Sciences*, 48, 1837–1847.
- Hofbauer, F., & Putz, L. M. (2020). External costs in inland waterway transport: An analysis of external cost categories and calculation methods. *Sustainability*, 12(14), 5874.

- Jeon, J. W., Wang, Y., & Yeo, G. T. (2016). SNA approach for analyzing the research trend of international port competition. *The Asian Journal of Shipping and Logistics*, 32(3), 165–172.
- Ji, B., Zhang, D., Samson, S. Y., & Fang, X. (2021). An exact approach to the generalized serial-lock scheduling problem from a flexible job-shop scheduling perspective. *Computers & Operations Research*, 127, Article 105164.
- Jiang, Y., Lu, J., Cai, Y., & Zeng, Q. (2018). Analysis of the impacts of different modes of governance on inland waterway transport development on the Pearl River: The Yangtze River Mode vs. the Pearl River Mode. *Journal of Transport Geography*, 71, 235–252.
- Jiang, P., Tong, S., Wang, Y., & Xu, G. (2021). Modelling the oil spill transport in inland waterways based on experimental study. *Environmental Pollution*, 284, Article 117473.
- Jie, Y., Leonidas, L., Mumtaz, F., & Ali, M. (2021). Ship detection and tracking in inland waterways using improved YOLOv3 and deep SORT. *Symmetry*, 13(2), 308.
- Jonkeren, O., Jourquin, B., & Rietveld, P. (2011). Modal-split effects of climate change: The effect of low water levels on the competitive position of inland waterway transport in the river Rhine area. *Transportation Research Part A: Policy and Practice*, 45(10), 1007–1019.
- Jonkeren, O., Rietveld, P., van Ommeren, J., & Te Linde, A. (2014). Climate change and economic consequences for inland waterway transport in Europe. *Regional Environmental Change*, 14(3), 953–965.
- Kong, X., Shi, Y., Yu, S., Liu, J., & Xia, F. (2019). Academic social networks: Modeling, analysis, mining and applications. *Journal of Network and Computer Applications*, 132, 86–103.
- Liao, P., Hou, M., Chu, M., & Zhang, W. (2019). Simulation of vessel traffic flow in inland waterway based on cellular automata. In *CICTP 2019*, 1–10.
- Mako, P., & Galierikov, A. (2021). Inland navigation on the Danube and the Rhine waterways. *Transportation Research Procedia*, 55, 10–17.
- Peng, J., Lu, J., & Zhu, S. (2011). Analysis on site selection and distance of an inland waterway service area. *ICCTP 2011: Towards Sustainable Transportation Systems*, 3887–3893.
- Schweighofer, J. (2014). The impact of extreme weather and climate change on inland waterway transport. *Natural Hazards*, 72(1), 23–40.
- Sihn, W., Pascher, H., Ott, K., Stein, S., Schumacher, A., & Mascolo, G. (2015). A green and economic future of inland waterway shipping. *Procedia CIRP*, 29, 317–322.
- Solomon, B., Otoo, E., Boateng, A., & Koomson, D. A. (2021). Inland waterway transportation (IWT) in Ghana: A case study of Volta Lake transport. *International Journal of Transportation Science and Technology*, 10(1), 20–33.
- Wang, S., Yin, J., & Khan, R. U. (2020). The multi-state maritime transportation system risk assessment and safety analysis. *Sustainability*, 12(14), 5728.
- Wiegmans, B., & Konings, R. (2015). Intermodal inland waterway transport: Modelling conditions influencing its cost competitiveness. *The Asian Journal of Shipping and Logistics*, 31(2), 273–294.
- Xie, Z., & Liu, Q. (2018). LSTM networks for vessel traffic flow prediction in inland waterway. *2018 IEEE International Conference on Big Data and Smart Computing (BigComp)*, 418–425.
- Yan, X. P., Wan, C. P., Zhang, D., & Yang, Z. L. (2017). Safety management of waterway congestions under dynamic risk conditions: A case study of the Yangtze River. *Applied Soft Computing*, 59, 115–128.
- Zhang, D., Yan, X., Zhang, J., Yang, Z., & Wang, J. (2016). Use of fuzzy rule-based evidential reasoning approach in the navigational risk assessment of inland waterway transportation systems. *Safety Science*, 82, 352–360.

Further reading

- CCNR, <https://www.ccr-zkr.org/>.
- Eurostat, <https://ec.europa.eu/eurostat>.
- KMI China Report, 2019.
- Port Performance Freight Statistics in 2019: Annual Report to Congress 2020.
- Report on Sustainable Transport in China, 2021.
- REWWay, <https://www.rewway.at/en/>.
- US Army Corps of Engineers, <https://www.usace.army.mil/>.