A Systematic Literature Review of Technological Developments and Challenges for Inland Waterways Freight Transport in Intermodal Supply Chain Management

[a-d] *Liverpool Logistic Offshore and Marine Research Institute (LOOM) of Liverpool John Moores University, United Kingdom.* [e] *Faculty of Transport and Traffic Engineering, University of Belgrade.*

S.Gbako@2019.ljmu.ac.uk, D.Paraskevadakis@ljmu.ac.uk, J.Ren@ljmu.ac.uk, J.Wang@ljmu.ac.uk, Zoran.radmilovic1944@gmail.com

Abstract

Purpose: Inland shipping has been extensively recognised as a sustainable, efficient, and good alternative to rail and road modes of transportation. In recent years, various authorities and academic researchers have advocated shifting from road to other sustainable modes like Inland Waterway Transport (IWT) or rail transport. Academic work on modernisation and technological innovations to enhance the effectiveness and efficiency of waterborne transportation is becoming apparent as a growing body of literature caused by the need to achieve a sustainable transport system. Thus, it became apparent to explore the research trends on IWT.

Design/methodology/approach: A systematic and structured literature review study was employed in this paper to identify the challenges and concepts in modernising inland waterways for freight transportation. The review analysed 94 articles published in 54 journals from six well-known databases between 2010 and 2022.

Findings: The key findings of this review are that despite various challenges confronting the sector, there have been successful cases of technological advancement in the industry. The main interest among scholars is improving technical and economic performance, digitalisation, and safety and environmental issues. The review revealed that most of the literature is fragmented despite growing interest from practitioners and academic scholars. Academic research to address the strategic objectives, including strengthening competitiveness (shipbuilding, hydrodynamics, incorporating artificial intelligence into the decision-making process, adopting blockchain technology to ensure transparency and security in the transactions, new technologies for fleets adaptation to climate change, more effective handling, maintenance and rehabilitation technologies), matching growth and changing trade patterns (intermodal solutions and new logistics approaches) are major causes of concerns.

Originality: By employing the approach of reviewing previously available literature on inland waterway transport review papers, this review complements the existing body of literature in the field of inland waterway transport by providing in a single paper a consolidation of recent state-of-the-art research on technological developments and challenges for inland waterways freight transport in the intermodal supply chain that can act as a single resource to keep researchers up to date with the most recent advancements in research in the domain of inland waterway freight transport. Additionally, our review identified gaps in the literature that may inspire new research themes in the field of IWT.

Keywords: Inland waterways transport (IWT), inland navigation, technological innovation, river freight, literature review

1. Introduction

Waterborne transport has played an essential role in transport corridors, gateway ports, hinterland, and industries. The carriage of goods through these inland waterways is considered a good transport alternative and environmentally friendly way of moving freight. Compared to

alternative forms of transportation, inland waterway transport (IWT) exhibits notable attributes such as substantial transport capacity, low energy use and environmental impact.

Nevertheless, despite the inland waterways' substantial benefits for freight transportation, they have remained a minor used mode within the logistic chain, predominantly prevalent in developing nations. This discrepancy can be attributed to various factors, including inadequate infrastructure, insufficient investment, inadequate regulatory measures, and a lack of cooperation between national and sub-national authorities, which hinder the effective operation of IWT (Praveen and Jegan, 2015; Solomon et al., 2020; Rogerson et al., 2020; Trivedi *et al.,* 2021; Hassan and Xuefeng, 2022; Hunt *et al.,* 2022). However, studies have indicated that the sector remains one of the transport modes with lots of unused capacity for increased exploitation (Hofbauer and Putz, 2020; Totakura *et al.,* 2020; Barrow *et al.,* 2022). In recent years, inland waterways for freight transportation have continued to receive growing attention due to issues associated with the environment, transport safety and unsustainable and congested road networks. The ever-increasing acknowledgement of the external outcome of transport has necessitated the direction of a more sustainable transport mode. As a result, academic studies and political interest are growing towards a low environmental impact mode for freight transportation such as IWT, rail and Short-Sea Shipping (SSS) (Razah et al., 2020; Comi and Polimeni, 2020; Wang *et al.,* 2020; Grosso *et al.,* 2021).

Reviewing the current transportation policy of some developed countries has been characterised by a trend of increasing interest in the use of other transport modes to overcome these road-related negative externalities (Mihić *et al.,* 2012; Erceg, 2018; Bu and Nachtmann, 2021; Plotnikova, 2022). Significant efforts are growing to modernise and green the inland waterways sector and strengthen its competitiveness as a sustainable transport system worldwide. Consequently, IWT will play a significant role in an environmentally friendly green supply chain by using energy sources that are environmentally sustainable and serving as a base for complex transport along with autonomous inland vessels.

Since fitting significantly to a large extent on the political agenda of many developed countries as an efficient and climate-friendly alternative transport mode, academic research on shifting freight from road to waterborne transport has attracted considerable attention from academic researchers. Previous literature research studies have highlighted significant issues and challenges in the modal shift of freight to waterways (Roso et al., 2020; Schoneich *et al.,* 2022). Research studies have focused on the sustainability of the transport system (Lier and Macharis, 2014; Havinga, 2020; Barrow *et al.,* 2022), transport safety (Meers and Macharis, 2015; Mircetic *et al.,* 2017), cost-effectiveness (Wiegmans and Konings, 2015; Mostert and Limbourg, 2016; Osama et al., 2017), Infrastructural issues (Wiegmans and Van-Duin, 2017), performance

measurement (Farazi *et al.,* 2021), climate change (Hunt *et al.,* 2022), intermodal opportunities for city logistics (Nemato *et al.,* 2006; Janjevic and Ndiaye, 2014; Trojanowski and Iwan, 2014; Wojewodzka and Rolbeiecki, 2019).

The IWT industry has recently experienced notable change due to technological advancements. The sector is undergoing a revolution that has the potential to significantly improve efficiency, sustainability, and safety due to improvements in multiple areas, including automation, electrification, alternative fuels, digitalisation and new vessel and logistic concepts. By streamlining logistics processes, cutting carbon emissions, and enhancing navigational capabilities, these advancements have opened the doors for a new age in IWT. The industry is poised to take even more advantage of innovative developments. Compared to the earlier reviewed literature, the main objective of this work is to add value by conducting a systematic review of current relevant literature focusing on the modal shift to IWT, challenges and technological innovation to enhance the transport efficiency of the sector in general. The study aims to thoroughly review research strands and topics to develop research efforts in this field over time. Therefore, the current systematic literature review considered the following research questions: (1) What are the main IWT issues and challenges the academic researcher acknowledges in the literature? (2) What technological innovations were recently developed to improve transport efficiency? Consequently, this paper contributes by complementing the existing body of literature in the field of inland navigation by providing detailed information on inland waterway freight transport research, thus improving our understanding of the existing level of knowledge. The research study followed a systematic literature review and information pattern retrieved, as suggested by Raza *et al.* (2020).

The remainder of this paper is organised as follows. The following sections present the methodology used to carry out this study - followed by section 3 includes vital features of the identified papers researched and reviewed in the previous sections. Section 4 of the paper summarises findings and future research directions.

2. Methodology

A systematic literature research study was employed to identify and analyse papers covering current technological developments and challenges for inland waterways transport and logistics published between 2010 and 2022. A systematic review is defined as a critical synthesis of research proof that aims to systematically identify, select, and synthesise all research published on a specific topic or question (Bruce and Mollison, 2004). This research seeks to identify various challenges and summarise the recent technological innovation for developing IWT as an excellent

alternative to road transport. A formal, rigorous methodological approach is followed in the systematic review to reach the proposed goal.

The research followed the scientific process of academic literature searches and information retrieved assessment suggested by Tranfield *et al.* (2003), Okoli (2015), Winchester and Salji (2016) and Kraus *et al*. (2020). The research used four major phases: planning, searching, screening and extraction. As shown in Fig 1, the flowchart of the systematic research approach details the review process in detail.

2.1. Research planning phase

At the beginning of this review, the intended goals and purpose of the research paper were formulated. A detailed discussion with other reviewers was established at the early phase of the study, and research questions (RQs) were created to guide the paper.

RQ 1. What are the main IWT issues and challenges the academic researcher acknowledges in the literature?

RQs 2. What are the technological innovations recently developed to improve transport efficiency?

Creating a research question is significant for any research work (Pilbeam *et al.,* 2012). The first research question in this review deals with the essential issues and challenges acknowledged by academic literature. The question seeks to understand the developmental issues and challenges that hinder the enhancement of IWT as an excellent alternative transport mode. The second question identifies recent academic research on technological innovations in inland waterway transport and logistics. After establishing the research questions, the current research works relevant to the topic of interest and potential importance to answering the specific research question were reviewed. The search for peer-reviewed literature connected with IWT was conducted systematically, and this was done by identifying various databases and strings (Smiths et al., 2011). As depicted in Fig. 1, the systematic review followed an iterative process presented by Davarzani *et al*. (2016).

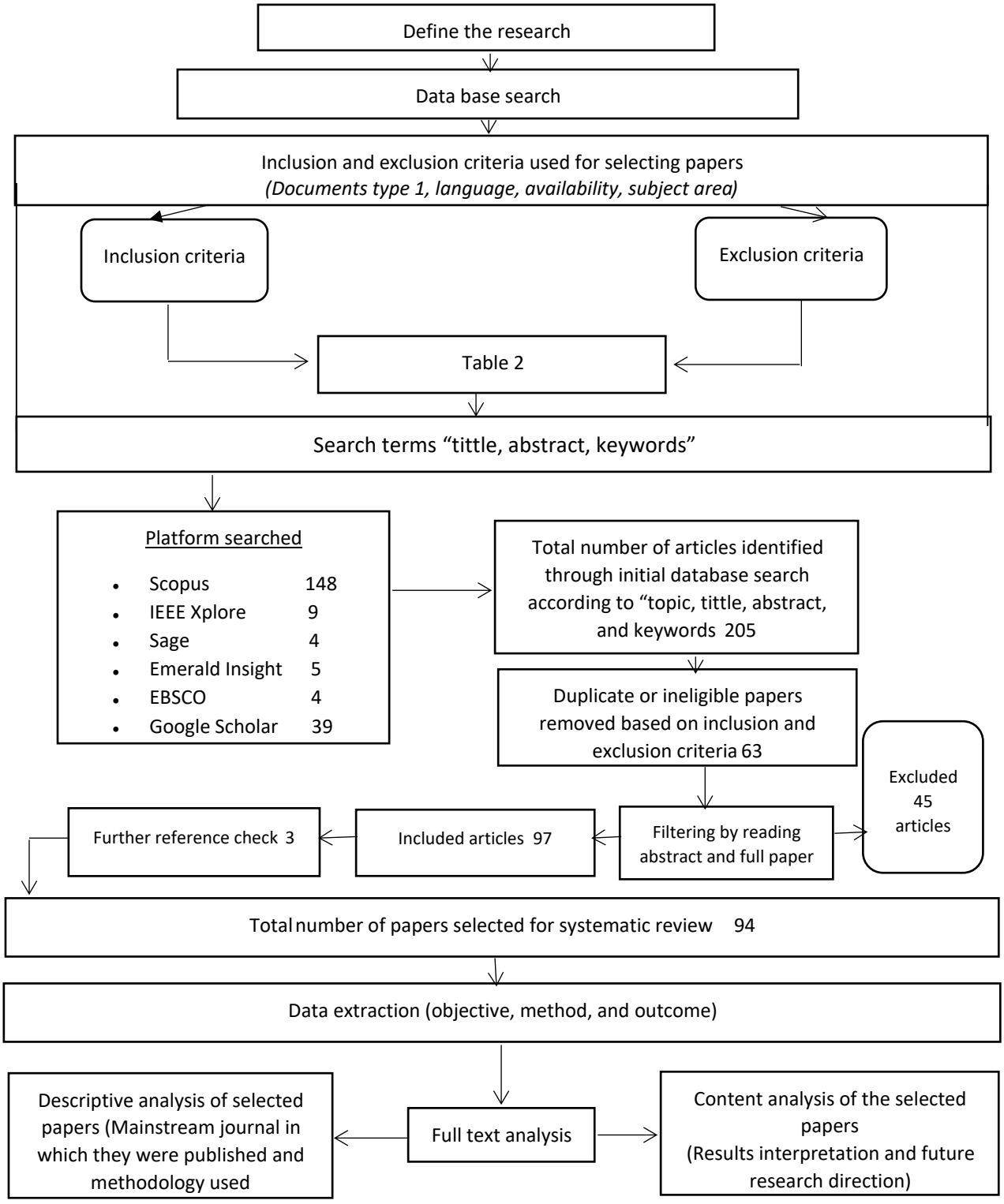


Fig 1. Main steps the systematic review followed.

Source: Redesigned by authors, using search keywords. Procedure adapted from Tranfield *et al.* (2003). Okoli (2015), Davarzani *et al.* (2016) Raza *et al.* (2020) and Chowdhury *et al.* (2021).

This paper used this method to design, structure and find the most relevant paper dealing with the topic of interest in different areas and aspects using various keywords in the literature search. A robust research paradigm for selecting and dismissing research papers is characterised. The study used different parameters to ensure correctness and suitable reactions to the research questions to reduce bias and cover an extensive information range while upholding the research's objectivity and validity (Asgher *et al.,* 2020). Several keyword searches were used in this paper selection based on the proposed topic and the asked questions. The following keywords were included in the initial search strings: "inland navigation", inland shipping", "innovation", "modernisation", "barriers" "logistical concepts", "river logistics", "technological developments", "cooperation", "collaboration mechanisms". The iterative keyword formation pattern procedure, as suggested by Davarzani *et al.* (2016), was restricted to AND and OR. This logic is used since the review considered separate derivatives for matching words; for example, "modern" is obtained from "modernisation".

Furthermore, this paper used Boolean operators' logic to elaborate search: "AND" to link two vital keywords and "OR" to permit synonyms (Gu and Lago, 2009). In the systematic review, various keywords are used for choosing papers, and other logical operators like AND OR are utilised to make the inquiry more precise. Table 1 shows how the independent research was conducted using titles, abstracts, and keywords and presents the search strings used for the individual database.

2.2. Searching

Locating, retrieving and sourcing relevant literature in a systematic literature study is challenging yet crucial to the successful outcome of the review. The materials used to perform the review offer the information from which findings, conclusions, and recommendations are derived (Smith *et al.,* 2011). After completing the research planning phase, the reviewing phase proceeded. This phase was another critical step as it locates relevant studies on the topic of interest and potential importance in answering the specific research question (Agatz *et al.,* 2008). A range of electronic database searches that are relevant to the subject matter under consideration were used in this review. The purpose was to reduce bias and serve an extensive information range while upholding the research's objectivity and validity. As already stated, choosing a search engine in a systematic review is a core step. In this case, an online database used for relevant literature searches was initially carried out using a Scopus database (Springer, Elsevier and Wiley). Scopus is one of the best databases for worldwide literature searches. Academic scholars have extensively used it in performing systematic reviews on various subjects (Geraldi et al., 2011; Reim *et al.,* 2015).

Nonetheless, additional iterative search measures were taken to minimise any missing piece of literature. This additional process was carried out by reviewing further and improving the quality and value of the process. Hence, an extensive search for literature through more databases was also conducted (Petticrew and Roberts, 2008). Web of Science, Research Gate, IEEEX Xplore Digital Library, Emerald Insight and Google Scholar formed part of the other electronic data-based platform search. According to Tennant and Ross-Hellaue (2020), certain primary studies may encounter publication rejections from reviewers, significantly if the result presented deviates from the intended standards. Peer-reviewed journal papers, as recommended by Jacalyn et al. (2014), offer credible material with the highest level of relevance because they undergo a rigorous review by a team of specialised professionals before being published in a journal. In addition to books, journal articles are sources of current information (Moher et al., 2009). The search for peer-reviewed papers was comprehensively conducted between September 2021 and December 2022. The search scope was limited to papers published between 2010 and 2022.

Table 1. Databases searching with a different tittle, abstract and keywords for relevant paper

Search Database	Searched Metadata	Search Strings
Scopus	Title, Abstract, Keywords	TITLE-ABS-KEY (IWT OR IWW) OR (inland navigation or inland shipping) OR (River freight OR River transportation) OR (IWT modernisation OR IWT state-of-the-art) OR (Modal shift OR Mode shift) AND (barriers OR Obstacles) AND (Cooperation OR collaboration) AND (Logistics OR Organisation) AND (Technology or Technological)
EBSCO	Title, Abstract, Keywords	("All metadata": IWW OR IWT) AND (navigation OR Shipping) AND (Digitalisation OR Advance technology) AND (Logistics OR Planning) AND (Freight OR goods)
Google Scholar	Title, Keywords	TITLE-KEY (Title: IWT OR Key: IWT) OR (IWW OR Key: IWW) OR (Title: Technology or Key: Technology) OR (Title: Innovation OR Key: Innovation) AND (Title: Navigation OR Key: Navigation) OR (Title: Smart -rivers) AND (Title: Digitalisation OR Key: Digitalisation) OR (Title: Cooperation OR Key: Cooperation) OR (Tittle: Barrier or Key: Barrier)

IEEE	Title, Abstract, Keywords	("All metadata": IWW OR IWT) AND (Transportation OR Shipment) AND (Impact OR Influence) AND (Barge OR Vessel) AND (Logistic OR Planning OR Organisation)
Emerald Insight	Title, Abstract	((TIT: IWW OR TIT: IWT) OR ((ABS: IWW OR ABS: IWT)) AND ((TIT: Modernisation OR TIT: State-of-the-art)) AND ((ABS: Modal shift OR ABS: Mode shift) OR ((TIT: transportation OR TIT: Shipment))
Sage	Title, Abstract, Keywords	TIT-ABS-KEY (IWT OR IWW) AND (Shipping OR Navigation) AND (Logistic OR Planning) AND (Barriers OR Obstacle) AND (Impact OR affect OR influence)

Source: Authors' work

2.3. Screening

After the search results, all literature studies relevant to this review were carefully reviewed before filtering through the inclusion and exclusion criteria. Fig 1. shows the results obtained from titles, abstracts, and initial keywords searched through individual electronic databases. Based on the search results, a total of 205 papers were found suitable during the initial search. For an in-depth analysis of this review paper, the inclusion and exclusion criteria used for selecting papers appropriate to or closely related to the topic are presented in Table 2 below.

2.3.1. Inclusion and exclusion criteria

The inclusion and exclusion criteria are clearly stated based on the study's scope and quality (Gu and Lago, 2009). The inclusion criteria for this study were articles published in high-quality scientific journals.

Table 2. Set of inclusion and exclusion criteria used for selecting relevant papers for in-depth analysis for this paper

Inclusion Criteria	- Publication in peer-reviewed journal - Research published in academic journals - All papers in English - Access to the full text

	- Paper covering or that describes various barriers, technological development for IWW freight transport and logistics. - Studies published since 2010 and 2022 (both years inclusive)
Exclusion Criteria	- Non-English research papers - Book chapter, editorial books review, comments, conference proceeding dissertation, government documents, working papers, white papers, grey literatures such as blog - Research not covering IWT technological development and freight logistics challenges - Studies published before 2010

Source: Authors work

The review exclusively considered peer-reviewed journal articles that were written and fully accessed in the English language. The review did not consider in its analysis grey literature, conference papers, official government documents, doctoral and master's dissertations, textbooks, and notes. The main rationale behind targeting the database was their substantial amount of peer-reviewed literature.

Additionally, a comprehensive examination of the sources referenced in this resulting article was conducted using a systematic review. After the initial search result of 205 papers during the search. The publications' abstracts were thoroughly reviewed to verify whether they addressed IWT-related topics, including issues and challenges, technological innovation to enhance the use of this transport mode, logistic optimisation and identifying research gaps.

2.4. Data extraction and reporting

The review follows the quality assessment recommendation Kitchenham and Charters (2007) suggested. A systematic data extraction step was applied after identifying all the relevant research papers available for this review. The study obtained essential information from the individual research papers in this step. The assessment procedure was carried out on all papers identified before extracting their data. The relevance of these selected papers to the study objectives was thoroughly evaluated, considering potential biases and the validity of the data,

before expanding the quality assessment on all relevant papers identified. An initial trial check was conducted to check their effectiveness. In general, the review used descriptive analysis as a reporting procedure.

3. Descriptive Overview of the Literature Studies

This section provides a summary of the material obtained from the identified scholarly literature papers, as well as the research questions. Additionally, a significant body of information on optimising logistics in inland waterway transportation was also identified and synthesised.

3.1. Descriptive analysis

The papers that were subjected to the descriptive analysis were examined based on four primary characteristics:

- The journal in which they were published.
- The distribution of research papers over time.
- The geographical scope or location.
- The methodology employed.

The assessment encompasses key dimensions that address the challenges and issues faced in the IWT freight transport industry, as well as technological innovation, including cooperation and collaboration mechanisms to enhance the efficiency of the transport system.

3.1.1. Distribution by journal of publication

The number of studies published each year in different scientific journals is shown in Table 3 below. Ninety-four papers relevant to the study's objectives were identified between 2010 and 2022. The number of academic papers published in various scientific journals validates the interdisciplinarity of practical issues and challenges as well as technological innovations to enhance the effectiveness and efficiency of transportation modes. The Journal of Ocean Engineering, Transportation Research Part D ranks at the top with five published papers, each among all the journals that address the area of interest. Seventeen papers were published in eleven journals of transportation. The Journal of Transport Geography, Journal of the Maritime University of Szczecin and the Journal of Physics are second, with three papers each. Energies, European Journal of Operational Research, Water, Benchmarking Journal, Maritime by Holland,

and Polish Maritime Research, with two publications, closely follow this. The remaining journals have one publication each. Table 3 presents the number of papers in dominant academic journals.

Table 3 Number of papers in dominant journals

Journal	Number of articles
Transportation	
Journal of Transport Geography	3
European Transport Review	1
Research in Transportation Business and Management	1
Transport Problems	1
IEEE Transact on Transportation Electrification	1
Case Studies on Transport Policy	1
Transportation Research Part D	5
Journal of Sustainable Development of Transport and Logistics	1
Transportation Safety and Environment	1
Transportation Research Part E	1
Transport Policy	1
Maritime	
Scientific Journals of the Maritime University of Szczecin	3
Polish Maritime Research	2
Maritime by Holland	2
Maritime Economics and Logistics	1
Journal of ETA Maritime Science	1
Environment	
Environmental Change	1
Global Environmental Change	1
Environmental Science and Pollution Research	1
Regional Environmental Change	1
Science	
International Journal for Scientific Research and Development	1
Safety Science	1
Applied Science	1
Supply Chain	
Operations and Supply Chain Management	1

International Journal of Supply Chain Forum	1
Engineering	
Ocean Engineering	5
Journal of Computing in Civil Engineering	1
International Journal of Advanced Research in Engineering and Technology	1
Advanced Engineering Informatics	1
Engineering Economist	1
Cleaner Engineering and Technology	1
Research	
European Journal of Operational Research	2
European Research Studies Journal	1
International Journal of Logistics Research and Application	1
Journal of Danubian Studies and Research	1
Miscellaneous	
Journal of Physics	3
Energies	2
Water	2
Benchmarking: An International Journal	2
FME Transaction	1
Nase More	1
Journal of Cleaner Production	1
International Journal of Distribution Sensor Networks	1
Mukt Shabd Journal	1
Actual Problems of Economics	1
L'Espace géographique	1
Decision Support Systems	1
Geomorphology	1
Tehnički vjesnik	1
Atmosphere	1
Journal of Intelligent System	1
Climate Risk Management	1
Natural Hazards	1
Sustainability	1
Total	**74**

Source: Authors' work

3.1.2. Publications over time

In recent years, shifting freight from roadways to other sustainable alternative modes of transport, like IWT, has continued to receive attention. The ever-increasing acknowledgement of the external outcome of transport has necessitated the direction of a more sustainable transport mode (Macharis et al., 2011; Yuan et al., 2020). As a result, academic studies are growing towards using waterborne transport for freight. An emerging field in this area of study is technological innovation to improve the efficiency of the transport system. The year-wise distribution of papers from 2010 to 2022 (both years inclusive) is shown in Fig 2. It was observed that most of the papers were published in the last six years between 2016 and 2022. The observation figures show that research interest in this topic is growing.

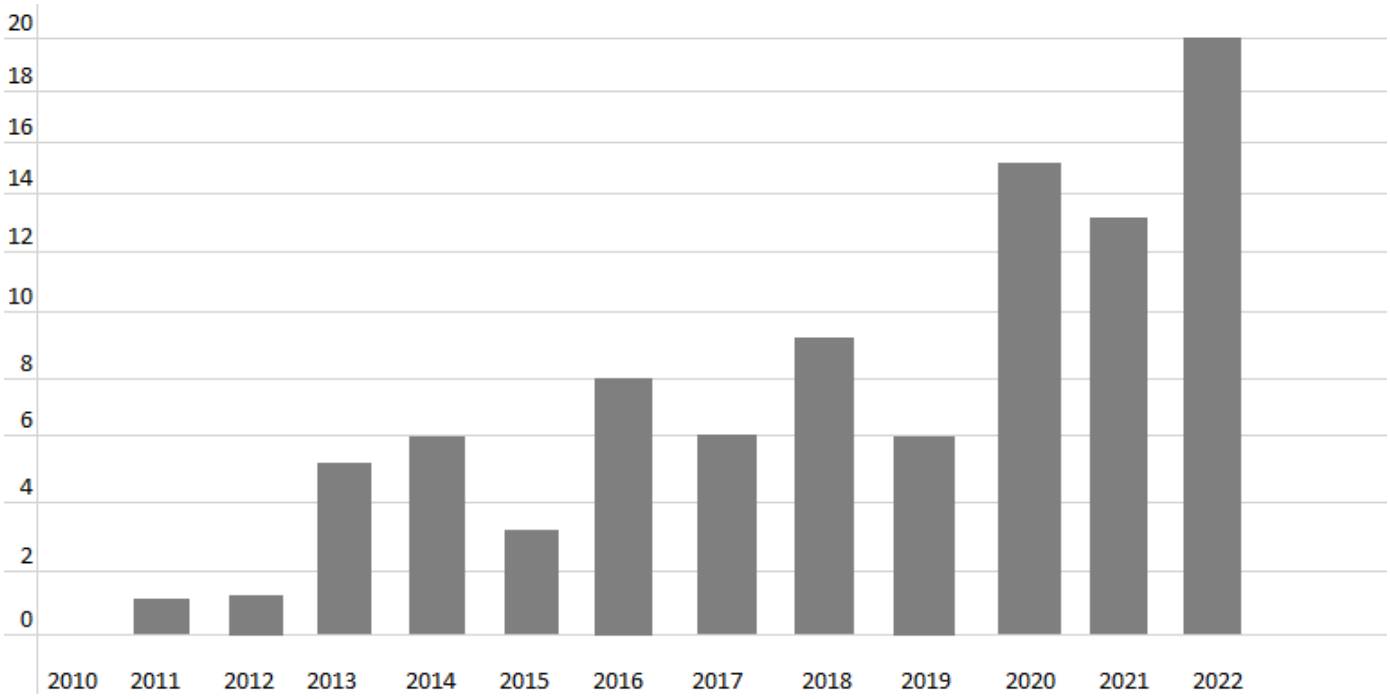


Fig 2: Distribution of publication over time 2010 to 2022

Source: Authors' own elaboration from six database

3.1.3 Geographical distribution of identified papers

The identified papers were geographically distributed and analysed in this section according to the regional scope. It was observed that significant proportions of research studies were conducted in Europe (63), followed by China (23 papers). Similarly, the United States accounted for eleven papers. Only a few papers have addressed challenges, barriers, and technological innovations to enhance the transport efficiency of the sector in the context of other countries, including India (7 papers), (Bangladesh (2 papers), Indonesia (4 papers), Brazil (2 papers) Saudi Arabia, Vietnam, Canada, Ghana and Egypt (1 paper respectively). Fig 3 shows the geographical location of the author's affiliated institutions.

The European and Chinese authors accounted for a more significant part of the reviewed papers. Emerging interest by academic researchers in this region is due to the prosperity of maritime trade in connection with inland shipping. One of the policy objectives of the Chinese government on transportation includes creating favourable conditions for further development of the inland shipping sector. While also contributing to achieving the set goal of China's dual carbon goals by lowering carbon emissions generated by the transportation industry. Academic researchers' interest in low-carbon engines for inland waterway transport technologies that adapt to Chinese-specific national conditions is emerging (Yuan, et al., 2020; Zhu et al., 2021).

Also, European authors accounted for a significant part of the reviewed papers. According to Caris et al. (2014), the emerging interest by academic scholars is due to strategic investment support at both local and national levels to integrate the use of IWT in its domestic logistic chain.

Additionally, the importance and effectiveness of IWT as a sustainable alternative transport have also been conducted in the USA with various technologies to enhance freight transportation efficiency further (James et al., 2013). Table 4 presents the share of academic studies in different geographical locations connected with the topic of interest.

3.1.4. Distribution by the research methodology

Various academic researchers adopted different research methodologies in their papers, as shown in Fig 3. From Table 4, the methods mainly used are mixed methods, with about fifty-eight papers summarising their work. The authors combined models, case studies, surveys, or empirical research with other quantitative and qualitative methods from the identified papers to establish a balanced methodology. Model testing follows suit, with about fifteen authors presenting their work with different models. The authors of nine papers employed a literature review to explore the technological innovations qualitatively; similarly, case studies and empirical methods were performed in six and four papers, respectively. As shown in Table 4, the

last decades have witnessed a growing number of academic publications in these areas, indicating that research in inland waterways freight transportation problems is growing.

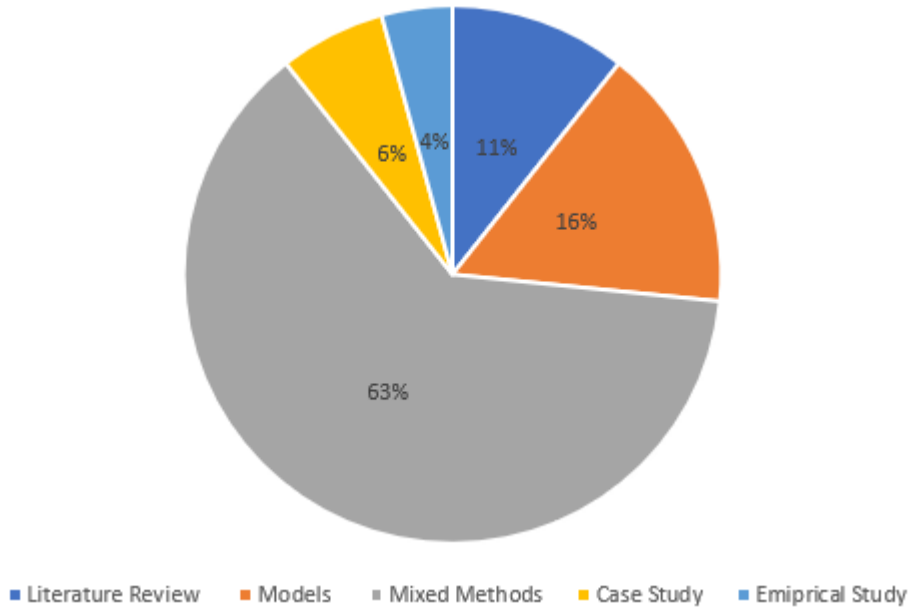


Fig 3: Distribution by the research methodology 2010 to 2022

Source: Authors' own elaboration from six database

Table 4. Authors, year of publication, methods, and geographic location of authors

Author(s)	Years	Methodology	Geographical Location of Authors*
		Literature review	
Mihic, *et al.*	2011	Literature review	Serbia (Europe)
Li, *et al.*	2014	Literature review	Belgium (Europe)
Jonkeren *et al.*	2014	Literature review	Netherland
Liu *et al.*	2015	Literature review	Netherland
Abramowicz-Gerigk and Burciu	2018	Literature review	Poland (Europe)
Vilarinhoa *et al.*	2019	Literature review	United States and Brazil
Abramowicz-Gerigk and Burciu	2020	Literature review	Poland (Europe)

Wang *et al.*	2020	Literature review	United Kingdom and China
Shankur *et al.*	2021	Literature review	India and United Kingdom
Abbas *et al.*	2022	Literature review	Germany
		Models	
Randeniya and Hilliar	2013	Statistical model	United States
Simić and Radojčić.	2013	Mathematical model	Belgrade (Europe)
Mohaimenuzzaman, *et al.*	2016	Internet of Things (IoT) models	Bangladesh and Saudi Arabia
Bucci *et al.*	2016	Computer-Aided Synthesis Model (CASM)	Italy (Europe)
Abramowicz-Gerigk, *et al.*	2017	CFD Stimulation model	Poland (Europe)
Łebkowski.	2018	Stimulation model	Poland (Europe)
James *et al.*	2019	Automatic River Information Service model (ARISM)	India
Liu *et al.*	2020	Mathematical model	China
Yuan *et al.*	2020	Artificial neutral network model	China, United Kingdom and United State
Zhu *et al.*	2021	Mixed Integer Programming	China
Lei *et al.*	2021	Neutral network model	China
Kalajdzic *et al.*	2022	Mathematical model	Serbia
Xiao *et al.*	2022	Mathematical model	China
Asnorno *et al.*	2022	Stimulation modelling	United State
Verberght *et al.*	2022	ECM Empirical model	Belgium, Egypt, Germany
		Mixed Methods	
Douma *et al*	2012		Netherlands

		Literature review and simulation gaming	
Xing *et al.*	2013	Mathematical model, Empirical study, case study	China
Dobbins and Langsdon	2013	Case study and GIS customised software	United States
Buitelaar	2013	Literature review and case Study	Netherlands (Europe)
Caris, *et al.*	2014	Literature review, system wide model and business models	Belgium (Europe)
Lendjel and Fischman	2014	Literature review and case study	France (Europe)
Grubišić et al.	2014	Mathematical model, Linear programming tool and optimisation model	Croatia
Jonkeren *et al.*	2014	Literature review and case study	Italy and Netherlands
Praveen and Jegan	2015	Case study and empirical studies	India
Grushevska and Notteboom	2016	Literature review and case study	Belgium and China
Zhang *et al*	2016	Case study and mixed-integral model	China and United Kingdom
Kuklicke and Demeritt	2016	Policy documents and interviews	United Kingdom and Germany
Boniar, *et al.*	2016	Survey and case study	Ukraine (EU)
Kujawski and Stępień	2017	Empirical and computational model	Poland (Europe)
Liu *et al.*	2017	Empirical methods literature review	Netherlands and China

Zheng and Kim	2017	Autoregressive integrated moving average (ARIMA) model, literature review, and schedule planning model	Canada
Meers *et al.*	2017	Literature review, choice-based conjoint (CBC) experiment, case study	Belgium
Kotowska, *et al.*	2018	Case study and literature review	Poland (Europe)
Pfoser, *et al.*	2018	Literature review, case study and empirical study	Australia
Zhen *et al.*	2018	literature review, mixed-integer programming model	China, and Australia
Jiang *et al.*	2018	Case study, literature review and system dynamics (SD) model	China
Chen *et al.*	2018	Lp-norm model, Matching Pursuit Fletcher Reeves (MPFR) and Least-squares Cubic Spline Curves Approximation (LCSCA) technique	China, and United States
Gospikirisha and Deo	2018	Case study and shoreline evolution model	India
Lalla-Ruiz et al.	2018	Literature review, case study and mathematical model	Germany and India
Liu *et al.*	2019	Case study, Indices, direct observation	China

Verberght and Hassel.	2019	Literature review, Social Cost/Benefit Analysis (SCBA) and System of Innovation Approach (SIA)	Belgium (Europe)
Markolfa *et al.*	2019	Literature review and empirical study	United States
Christodoulou *et al.*	2020	LisFlood hydrological models, numerical models, general circulation model and regional climate models	Spain and Italy
Peeters, *et al.*	2020(a)	Literature review and empirical study.	Belgium (Europe)
Peeters *et al.*	2020 (b)	Literature review, modelling and empirical studies	Belgium (Europe)
Pradana, *et al.*	2020	Literature review and AHP	Indonesia
Meersman *et al.*	2020	Case study and VT business models (BMs)	Belgium (Europe)
Roso *et al.*	2020	Case study, literature review and interviews	Sweden (Europe)
Williamssona and Rogersonb.	2020	Business model, literature review, case study and survey	Sweden (Europe)
Rogerson, *et al.*	2020	Case study and interviews	Sweden (Europe)
Trivedi *et al.*	2021	DEMATEL-ISM and case study	India
Aroke *et al.*	2021	Literature review, case study, empirical study, survey and simulation model	United State

Hasan, *et al.*	2021	Literature review, case study empirical, study and inventory theory model	Bangladesh
Zhu *et al.*	2021	Mixed integral programming model and empirical model	China
Jiang *et al.*	2021	Empirical method, case study, AIS-based emission model	China
Fan *et al.*	2021	Case study and empirical study	China and Croatia
Bak and Zalewski	2021	Literature review, case study and probabilistic model	Poland
Mahmoudzaheh *et al.*	2021	Literature review, case study and mixed integer model	United States
Defryn *et al.*	2021	Literature review and mathematical model	Netherlands and Germany
Zhang *et al.*	2022 (a)	Mathematical modelling, stimulation and case study	China
Zhang *et al.*	2022 (b)	Artificial Neutral Network (ANN), statistical model and case study	China and Sweden
Totakura *et al.*	2022	Fuzzy analytical hierarchy process, case study and multi criteria decision making method	India and Oman
Specht *et al.*	2022	Interview, empirical survey and literature review	Germany

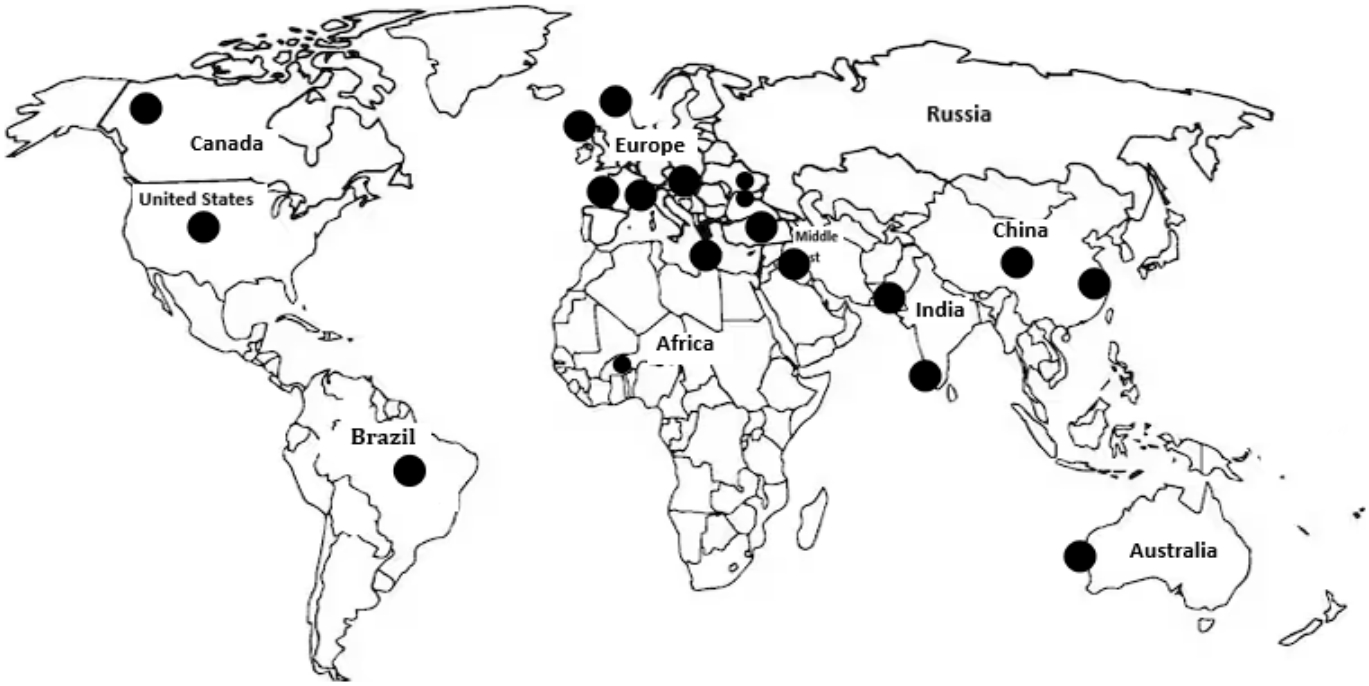
Johnson *et al.*	2022	Bayesian and agent-based model, data-driven analysis approach and economic interdependent model	United States
Schoneich *et al.*	2022	Case study and probabilistic model	Poland
Liu *et al.*	2022	Case study and evaluation model	China
Segovia *et al.*	2022	Switching max-plus linear (SMPL) model, modelling nonlinear discrete event system (DES) and mixed - integer linear programming model (MILP)	Netherland and Germany
Krausel *et al.*	2022	Stimulation model, and empirical study	Denmark, Germany and Norway
Gao *et al.*	2022	Energy consumption model and mathematical model	China
Vinke *et al.*	2022	Literature review and OpenCLSim simulation model	Netherlands
Welch *et al.*	2022	Literature review, case study and multiregional input-output (MRIO) model	United States
Ngugen *et al.*	2022	Case study and SPD-GIZ emission calculation model.	Vietnam and United Kingdom
Essel *et al.*	2022	Survey, empirical studies, case study and partial least square structural equation modelling.	China and Ghana

Hunt *et al.*	2022	Case study, literature review and empirical study	Austria, United States, Brazil, and Germany
		Case study	
Schweighofer	2014	Case study	Austria
Ionescu	2016	Case study	Romania (Europe)
Durajczyk *et al.*	2020	Case study	Poland (Europe)
Vanelslander and Hassel	2020	Case study	Europe
Kumar and Subhashini	2020	Case study	India
Kaup *et al.*	2021	Case study	Poland
		Empirical study	
Kujawski	2015	Empirical study	Poland (Europe)
Bouckaert	2016	Empirical study	Germany (EU)
Gao, *et al.*	2017	Empirical study	China and France
Pencheva *et al.*	2019	Empirical study	Bulgaria (Europe)

Geographical distribution of identified literature*

Source: Authors' work

Fig 4: The geographical location of the author's affiliated institutions



Serbia, Poland, USA, Brazil, Belgrade, China, India, UK, Italy, Bangladesh, Bulgaria, Saudi Arabia, Belgium, Indonesia, France, Egypt, Netherlands, Sweden, Ukraine, Bulgaria, Germany, Croatia, Romania, Austria, Denmark, Norway, Canada, Spain, and Vietnam

Source: Authors' work

4. Analysis and results

This section used a systematic review method to analyse the research structure of all identified papers relevant to the two research questions. The findings from the relevant research papers about the two research questions asked are summarised in this section.

4.1. What are the main IWT issues and challenges acknowledged by academic researchers in literature?

The inland waterway transport is sustainable, considering energy consumption, gas emissions and traffic congestion. Nevertheless, various challenges and issues remain. Research on modal shifts points out issues and challenges connected to several areas of the transport system. Table 5 presents various issues and challenges identified by researchers.

Table 5. Challenges and issues

• Availability of research
• Government support and investment
• Seasonal variation and climate change
• Workforce/skill shortage gap
• Competitiveness with other modes of transport
• Integration of operational planning systems
• Service quality
• Regulatory and administrative complexities

Source: Authors' work

4.1.1. Availability of research

One of the crucial challenges observed in the analysed papers is the limited academic literature concerning the sustainable development of inland waterways for freight transportation (Caris et al., 2014; Vilorainho et al., 2019). However, studies have indicated that this mode of transport's potential is not fully exploited as there is much room for academic pieces of literature to be carried out more comprehensively and profoundly (Caris et al., 2014; Sys et al., 2020). As the geographical prerequisite for inland navigation differs at continental and country levels due to navigational channels, some research work models cannot be replicated in some areas. According to Wisnicki (2016), this is another important reason why a limited number of academic papers exist in the field.

4.1.2. Government support and investment

The fundamental requirement for implementing multimodal transport is the presence of infrastructure that effectively links various economic regions. The concept of availability encompasses more than just the presence and enough infrastructure capacity, such as rivers and railways; it also includes quality considerations. Despite substantial spare capacity, the efficiency and competitiveness of waterborne transport are hindered by inadequate infrastructure quality at crucial segments of the network. Literature has highlighted the importance of government support and linked investment to guarantee the sustainability and competitiveness of this form of transport. According to Meers et al. (2017), transport policies and investments are overly concentrated on road and rail transport in Europe and the Baltic Sea region. The advantage of

inland shipping concerning societal external costs has yet to receive enough attention. The total effectiveness of inland shipping is constrained by missing links and bottlenecks. As a result, certain regions exist where this mode of transport can only engage in limited competition with the prevailing rail and road transport options. This has been corroborated by Praveen and Jegan (2017), who highlighted that IWT has suffered severe setbacks due to government under-investment in the sector compared to road and rail transport. There is significant uncertainty regarding the planning and allocating financial resources to mitigate bottlenecks. This phenomenon hinders customers' desire to transition to alternative modes of transportation like inland shipping, as they seek logistical operations that are both energy-efficient and reliable while also considering factors such as pricing, transit times, and other relevant variables.

Kotowska et al. (2019) demonstrated in their studies how the quality of infrastructure directly impacts the selection of transport modes. In order to facilitate the implementation of intermodal services, it is crucial to ensure the high quality of rail and waterway services, as well as the quality of the intermodal transfer alternatives and the connections to clients, such as the local railway networks within the port vicinity.

In addition, Niedzielskia et al. (2021) stressed that ensuring the proper maintenance and availability of infrastructure per market demand while maintaining competitive pricing is essential. Varghese and Shallen (2021) examine the difficulties that arise from the ageing process and the insufficiency of the infrastructure in the domain of IWT in South Asia. The barriers to efficient and reliable IWT were highlighted in their work as old canal systems, crumbling locks and dams, and restricted navigation depth. Scholars acknowledge the limitation of locks and dams in IWT. The study by Defryna et al. (2021) emphasises that insufficient infrastructure to support contemporary vessels, the restricted capacity of locks, and inadequate navigational clearance contribute to the formation of bottlenecks, impeding the efficient movement of traffic and resulting in delays and increasing costs.

Although China has the most commercial usage of IWT, persistent infrastructure challenges still exist (Gao, 2017). Wang and Li (2012) point out that a strategic objective in Chinese transport policies is to promote inland waterways for freight transport by substantially upgrading and investing in its infrastructures. According to Beyer, (2018) investment in IWT represents six per cent of the Chinese transport infrastructure investment. However, literature studies indicate that IWT in China has remained underdeveloped compared to other modes due to infrastructure deficiencies, government/private investment, and institutional weaknesses (Grushevska and Notheboom, 2016; Aritue et al., 2016).

In Europe, policymakers are more concerned about stimulating IWT as part of the modern intermodal logistic chain because of its sustainability, considering gas emission, energy consumption and traffic congestion (Mihić et al., 2011). According to Sys et al. (2020), strategies

outlined by the EU identified the elimination of infrastructure bottlenecks as a fundamental requisite for developing inland navigation in Europe. Infrastructural investment funds in the member states and regions are primarily assisted and accomplished through cohesion instruments of regional development funds. In this region, IWT has mainly been financed by the institution concerned with reducing road transport's carbon footprint. Another support is financing EU (funding and financing) programmes such as Horizon 2020, connecting European facilities (CEF) and EU structural and investment funds (Beyer, 2018).

However, despite the funding and support infrastructural investment in this sector, statistics reported on freight transported via this mode do not reflect many advancements (Caris et al., 2014). Inadequate fund allocation to a member state for IWT infrastructure and maintenance was observed to be insufficient for the volume of infrastructure and maintenance demanded, leading to an extensive backlog in the sector. Removing substantial bottlenecks and allocating resources towards establishing the missing links would result in socio-economic advantages and enhance intermodal transportation. This would be achieved by expanding the market's geographical reach, hence increasing its modal share.

In general, scholarly literature highlights the importance of tracking infrastructure barriers in IWT to provide effective and sustainable operations. This emphasises the necessity of allowing resources towards investment, maintenance, and upgrades to guarantee this particular mode's sustainability and competitiveness.

4.1.3 Seasonal variation and climate change

Climate change is always regarded as a global issue (Abbas et al., 2022). Climate change and extreme weather conditions' effects on transportation have continued to gain significant attention in recent years by scholars (Markolfa *et al.,* 2019; Wang *et al.,* 2020; Aroke *et al.,* 2021; Hunt *et al.,* 2022). It is widely acknowledged that transport networks generally perform worse in adverse and severe weather conditions. The inland waterway transportation industry has felt the impact of climate. The primary climate factors that affect inland waterway transportation include air and water temperature fluctuations, as well as seasonal variations or extremes in precipitation. As the climate warms up, risks of all kinds are increased, from coastal erosion brought on by rising sea levels to more regular extreme weather events like heatwaves, droughts or floods (Hunt *et al.,* 2022). Several academic literatures have assessed the impact of climate change on the functionality of the inland waterway transportation system, including Jonkeren *et al.* (2014), Kuklickea and Demeritt (2016), Liu *et al.* (2019), and Schoneich *et al.* (2022).

According to this research, a broad consensus is that shallow water level significantly affects inland waterway transportation.

Zheng and Kim (2017) presented a model that shows how inland waterway transport can be seriously impaired due to droughts by lowering waterway levels to either fully impassable or to a level that forces operators to reduce vessel load. Vinke *et al.* (2022) proposed a novel method of cascading the effects of sustained low water on inland navigation and the system-level performance of the waterborne supply chain mitigation strategies in climate risk assessments. While forecasting the impacts of climate change on inland waterways, Christodoulou et al. (2020) consider location-specific variables by concentrating their analysis on particular Rhine and Danube areas, where a significant portion of the overall freight transport activity by inland waterways in the European Union (EU) occurs. The results from their work show that droughts can seriously impair inland waterway transport services by lowering water levels to fully impassable levels or, more frequently, to levels where operators are compelled to lower the load factors of the vessels. In addition to water levels, Schweighhofer (2014) demonstrated how ice accumulation can also interfere with inland waterway transport operations, especially in slow-moving rivers.

Zhang *et al.* (2022b) proposed a model based on an Artificial Neutral Network (ANN) and a statistical model to explore the likelihood of a specific operating condition for an inland vessel on ice. Other studies have pointed out the regional economic impact of coastal and river flood-induced disruption of an inland waterway transportation system (Gospikirisha and Deo, 2018; Johnson *et al.* 2022). Kuklicke and Demeritt, (2016) explained how high flows due to severe weather and climate change can cause culverts, among other land-based infrastructure, to overtop and flood. Additionally, they can heighten the likelihood of a collapse or breach, worsen bank erosion or score and the related deposition, and compromise users.

Welch *et al.* (2022) further demonstrated that at exceptionally high-water levels, high river flow velocities and powerful eddies can impede or stop navigation. The necessity to employ tugboats to support the inland vessels on the berth, the price of additional berthing time, and the cost of the pilots; standby time may result in higher expenditures for freight operating firms. Where there are prolonged delays before the flow of traffic returns to normal, more costs will be incurred as a result. Nevertheless, floods are regarded as having less severe effects on inland waterway transport than droughts due to their comparatively shorter duration (Christodoulou *et al.,* 2020). Although inland waterway transport is considered a relatively reliable mode of freight transportation, it can be more sensitive to climate change than road or rail transport since the safe passage of inland vessels significantly depends on the water level.

4.1.3 Workforce/skill shortage gap

The analysis of the relevant academic papers reveals that the sector has continued to suffer from the skilled labour force despite growing interest from academic scholars. Praveen and Jegan (2015) stress the concern for capacity building. Ionescu (2016) mentioned a fragmented labour force and confronted with a growing shortage of qualified staff. Pfoser *et al.* (2018) pointed out that a global problem associated with the inland waterway freight transport industry is that highly qualified and motivated staff for port activities is a problem that often results in immense waiting times. Praveen and Jegan (2015) evidenced that the sector demands a vast, trained workforce for vessel operations as employees need more qualifications and training. The authors concluded by stressing the need for personnel training and valorisation.

4.1.4 Competitiveness with other modes of transport

Inland waterway transportation is gaining more attention for its potential to offer a practical and competitive alternative to road and rail transportation. However, due to the several difficulties the sector faces, various key challenges affect its competitiveness with other modes. Several academic studies have addressed various factors influencing the competitiveness of inland waterway transport. In terms of infrastructure, academic scholars have identified inadequate infrastructure as a significant barrier to inland navigation (Totakura et al., 2022).

Schoeneich *et al.* (2022) identified fairway depth as a primary competitive factor for inland waterway transport since it determines a vessel's potential freight volume. Their work demonstrated how inland cargo vessel carrying capacity is determined by fairway. The study of Bak and Zalewski (2021) corroborated this by showing how draught loaded can significantly influence the cost-effectiveness of freight transportation via inland waterways.

Inadequate air draught is another bottleneck often mentioned by scholars. Kaup *et al.* (2022) focused on waterway parameters as a safety component for inland navigation. Their study reveals that the vessel size and the number of container layers they can transport simultaneously depend on the clearance under bridges and the width of the channels. Thus, the ability of inland vessels to pass simultaneously depends on bridge clearance and the highest navigable water level (highest fixed point). Defryna *et al.* (2021) studied the influence of increased lock capacity on inland waterway freight transportation. Results from their work show that due to vessel size, locks might delay travel times, or in extreme cases where a single chamber lock is closed for maintenance, the entire river's navigation could be halted.

Other studies also analysed the impact of river bottlenecks and missing links as a major competitive factor of inland navigation (Zhang *et al.,* 2016; Liu *et al.,* 2022). In addition to prolonged journey times, primarily caused by the network's relatively low density, transport-related problems have also been identified as a significant drawback for freight transportation via waterways. This transport-related problem includes barge scheduling problems involving the interaction of inland barge operators with terminal operators, dispatchers and ports/terminals. The study of Douma *et al.* (2012), Zhen *et al.* (2018) and Segovia *et al.* (2022) focused on barge scheduling problems, including barge handling, rotation and dispatch. Berth allocation problems were presented by Grubišić *et al.* (2014). Other associated problems, including port and terminal efficiency and quay crane scheduling problems, were presented by Grubišić *et al.* (2014), Lalla-Ruiz (2018) and Roso *et al.* (2020). In addition, regular infrastructure maintenance problems are also often mentioned as critical to ensuring competitive inland waterway transport; however, until recently, this topic had received less research. Mahmoudzaheh *et al.* (2021) have comprehensively reviewed these topics by showing how the inland waterway transport systems' efficiency and safety depend on these maintenances as well as its impact on the competitiveness of the transport.

4.1.5 Integration with other transport modes

Efficient infrastructure is considered a fundamental prerequisite for waterborne transport to operate successfully. The sector can only play its full role if the infrastructure is adequately maintained and better connected with other modes of transportation (road and rail), including filling missing links, clearing critical bottlenecks and inland port development. In the current network, there are still significant bottlenecks and missing links. On a European scale, the European NAIADES II programme is actively working to promote the use of IWT on regional, national and local levels (Mihic *et al*., 2011; Mihic *et al.*, 2012). One of the significant interventions includes “improving infrastructure quality and fostering the integration of IWT into the logistics chain” (Caris *et al.,* 2014).

However, significant challenges still exist regarding the issue of standards that need to be met for this investment to take place. The requirement includes meeting the recommended guideline proposed by the EU and the European transport and logistics services (Niedzielskia et al., 2021). According to Kotowska *et al*. (2018) studies, the development of waterborne transportation is gaining importance in Poland. However, a significant challenge exists regarding integrating the transport system into the modern intermodal chain. Due to the country’s inability to meet some of the European navigation parameters, the polish government has difficulty receiving financial

support to facilitate investment in this sector. Niedzielskia *et al*. (2021) corroborated this, affirming that quality waterway infrastructural facilities linked with other modes as a trimodal transport system are a basic necessity for IWT integration in Poland.

In China, infrastructure deficiencies, investment and institutional weakness, including persistent coordination challenges across organisations at all levels, are the combination of factors that have hindered the development of IWT in the country (Li *et al.,* 2014). Although connectivity between roadways, railways and waterways and the high sea exists in China, the Chinese government, through its transport policies, has continued to promote the use of waterways for freight transport by making more rivers accessible and better intermodal connectivity (Jiang *et al.,* 2018). The government highlighted the improvement of domestic connectivity and regional integration of the transport network. Still, concerning investments Praveen and Jegan (2015) affirms that, like other transport modes by the economic slowdown, the Indian IWT sector has continued to be confronted by specific difficulties, including lack of integration and fragmentation of infrastructures. Recently, institutional funding supported this investment through the Asian development bank (Kumar and Subhashini, 2020).

4.1.6. Regulatory and administrative complexities

Inland waterway transportation frequently crosses international borders and, in some circumstances, involves many corridors. Uniformity across the countries in many operational aspects is crucial since navigable inland waterways are often border-crossing or multi-corridor transport. The lack of an adequate regulatory framework is often a barrier for the sector because there are always variances between countries, resulting in administrative and operational delays. Research on the modal shift to inland waterway transport has identified various regulatory and administrative issues, such as piloting regulations in the Swedish context (Rogerson *et al.,* 2020) and administrative problems in the Indian setting (Praveen and Jegan, 2015). According to Grushevska and Notteboom (2016), the regulatory practices for inland waterway transportation in Ukraine substantially influence the intermodal competitiveness of waterborne transport. This is primarily due to the imposition of excessive additional costs associated with pilotage, bridge, locks and one-time permits, which results in higher transportation expenses on the Dnepr River compared to rail and/or road transportation.

Pfoser *et al.* (2018) highlighted that adherence to legislative requirements imposes a significant administrative burden on barge operators while also incurring substantial costs for regulatory authorities tasked with verifying compliance. According to their study, these challenges arise due to the multifaceted nature of legislation, encompassing various aspects, as well as the

complexities associated with cross-border operations involving multiple jurisdictions. Kotowska *et al.* (2018) also noted that the legal obligations and required documentation involved in crossing different international boundaries for waterborne transportation are of utmost importance, which often entails a complex and challenging administrative procedure.

4.1.7. Service quality

Although IWT has been increasingly integrated into the transport network and modern logistic chains in recent years, particularly the case in Western Europe, studies have revealed that IWT will continue to gain from the increasing transport market share in Europe in the coming years (Mihic *et al.,* 2011). Besides cost, which has been identified as a crucial consideration for shippers when choosing a transport provider, time, reliability, and transport quality have also been identified as vital, including on-time delivery. Reliability by meeting up with delivery time has been recognised as a critical challenge for inland waterway transport (Kotowska *et al.,* 2018). Other factors that influence the competitiveness of inland waterway transport by making it less competitive than road mode of transport, as identified by academic studies, include time (transit, loading and unloading) (Meers *et al.,* 2017; Kotowska *et al.,* 2018), issues with waitings in port due to staff work schedules have also been identified as a major challenge for transport users (Pfoser *et al.,* 2018). However, for the transport sector to gain from increasing transport demand, it must enhance the quality of its services to cope with the future demand and improve its competitiveness (Caris *et al.,* 2014; Meers *et al,* 2017).

4.2 What are the technological innovation currently developed to improve the efficiency and performance of IWT?

To ascertain the primary research question on technological innovation currently developed to improve the performance and efficiency of IWT in various studies, the papers that were final assessment were categorised into three major categories, which are as follows: (I) Modernisation and greening the fleet (II) information and communication technology (ICT) (III) digitalisation (automation and robotic technologies). These domains were classified to categorise the many works obtained through the systematic literature review (SLR), which shares similar criteria.
Based on detailed analyses of the identified papers published in this field between 2010 and 2022, it was observed that the research interest in innovative technologies to improve the efficiency of IWT is emerging. As the research interest continues to grow, there has also been an increase in the number of publications by academic scholars in recent years, as substantial attention has been

given to achieving sustainability in transport. Research has been increasingly focused on innovative technologies relating to greening and modernising fleets, alternative fuels, new river logistics concepts, digitalisation, automation, robotics, the creation of green corridors, environmental issues, security and safety. The conclusive connection between innovative technology, economic, environmental issues and security has recently been featured in academic papers with findings from extensive academic studies on IWT (Mohaimenuzzaman et al., 2016; Gao et al., 2017; James et al., 2019). Specifically, innovative technology and modern concepts in waterborne transportation have improved navigation safety, service quality, operational efficiency, and modal shift in some regions.

From the existing literature, the researchers' views and findings differ. For example, in the relevant paper identified from a geographical perspective, most papers on technological innovation to improve the efficiency of IWT came from China, and many others came from Europe and the United States. In contrast, research from Croatia, Indonesia, Brazil, Saudi Arabia, and Ukraine has fewer published papers. The global trend in modernising IWT makes it attractive and competitive among other modes. Significant advances have been made in this field of study, which is notable mainly in China and Europe. Mihić et al. (2012) conducted a detailed analysis of the European policy and its strategies to promote inland navigation. The study findings indicate that IWT has continued to receive growing attention as an excellent sustainable alternative transport. Technological development to enhance transport efficiency as a sustainable alternative transport is emerging as a body of literature. Research has continued to focus on improving the performance of the transport system.

4.2.1. Modernisation and greening the fleet

The grouped and selected articles in the greening of the fleet domain show a more significant interest in solving issues associated with reducing emissions from the waterway fleets. The contemporary necessity to address environmental sustainability and decrease carbon emissions has made modernising and greening inland waterway fleets a critical concern within the transportation industry. Specifically, four innovation areas were identified: Alternative fuels with pollution-reduction technologies, energy and fuel consumption, impacting the carbon footprint, emission reduction of air pollutants, and lowering pollution through purer exhaust.

As inland navigation has been considered an inherently energy-efficient mode of transport, work by Simić and Radojičić (2013) looked into new vessel designs and the energy efficiency of self-propelled inland cargo vessels. Their work analysed the development of a concept for the future structure of the smaller canal fleets to optimise the performance of inland waterway transport in international competition. Liua et al. (2015) and Ond and Bedos (2022) were more concerned

about inland vessels' manoeuvrability using modern transport technology. They reviewed the recent evaluation and future prediction techniques to enhance vessels' manoeuvrability.

In China (the Yangtze River), Liua et al. (2017) developed a manoeuvring model using vessel stimulation and an empirical method characterised by a considerable water depth other than European waterways. Buitelaar's (2013) survey investigated the innovations linked to green shipping, new engine concepts and optimisation for efficient and green propulsion. In an era where sustainable transportation is growing, Essel et al. (2022) investigated green marine practices used by maritime authorities in Ghana to ensure sustainable development in the maritime industry.

The significance of alternative fuel in IWT is its capacity to mitigate the environmental consequences and sustainability issues linked to conventional fuel sources. Adopting alternative fuels in the sector can yield several advantages, including mitigating Greenhouse Gas emission (GHGs), improving energy efficiency, reducing operational expenses, and promoting sustainability. Researchers worldwide have examined many alternative fuel options in the inland shipping industry; specifically, Fan et al., 2021 presented a shift from carbon-based fuels such as hydrogen and ammonia. The imperative to achieve decarbonisation in the transport sector necessitates implementing measures to promote the adoption of environmentally friendly practices within the inland waterway fleet. Historically, inland waterway vessels have predominantly utilised fossil fuels, contributing to GHG release and air pollution exacerbation. Various other alternative fuels, including Liquefied natural gas (LNG)/ Compressed Natural Gas (CNG), Gas-To-Liquid (GTL), Biofuel (such as HVO and biodiesel), methanol, ethanol, and hydrogen, have been explored as potential substitutes for conventional fossil fuels (Kalajdzic et al., 2022).

The Chinese inland navigation industry has been under critical pressure to reduce its emissions. Different researchers have presented academic work on technologies and fuels on a pathway to zero-emission level on a regional level (Yuan et al., 2020; Lei et al., 2021; Fan et al., 2021; Kalajdzic et al., 2022; Ngugen et al., 2022). Across China and Europe, inland shipping organisations and institutions favoured the use of LNG and methanol, which are low-carbon fuels, as alternative fuels (Lendjel and Fischman, 2014; Hidouchea et al, 2016; Abramowicz-Gerigk et al., 2017; Gao et al., 2017; Zhang et al., 2022). Technologies and fuels to replace old marine diesel engines with clean and renewable energy as a measure for carbon reduction and economic growth are being exploited extensively by researchers (Simić and Radojčić, 2013; Bouckaert, 2016; Bucci et al., 2016; Łebkowski, 2018; Pencheva, et al., 2019).

Bucci et al.'s (2016) study illustrated that the electrification of a vessel’s propulsion by using a hybrid or entirely battery-based propulsion system, or fuel cells is a variable option to reduce energy consumption in fleets. These technologies can potentially facilitate the emission-free

operation of the inland fleet, contributing to climate change mitigation and enhancing local air quality. The advantages of modernising and implementing environmentally friendly practices within the inland waterway fleets are apparent. However, they stated that a limiting factor of such an alternative is the high cost. This was also corroborated in the study of Jiang et al. (2021). Jiang et al. (2021) highlighted various obstacles that must be overcome to attain these objectives successfully. In their study, factors necessitating consideration include infrastructure development in alternative fuel technologies, policy and regulatory initiatives, and collaborative effort among various stakeholders are expected to shape the business's prospects by fostering the use of these technologies and facilitating knowledge exchange.

Besides China and Europe, which have been relatively successful in greening their fleets, the experience from emerging countries like Croatia has been very intensive (Xing et al., 2013; Per ˇci´c et al., 2021; Fan et al., 2021).

4.2.2. Application of information and communication technology (ICT)

The uptake of sustainable transport technologies in inland shipping is essential for integrating the transport systemic into the domestic logistics chain. A seamless integration entails improving the transport system's service quality, including tracking and tracing, flexibility and reliability. The use of an automatic identification system was used by James *et al.* (2019) in the United States; in their study, they tried to achieve reliable trip information for inland vessels using the automatic identification system. James *et al.* (2019) looked into cooperation and improved information exchange between relevant authorities and shippers in the same vein. They developed a model based on automated river information services to handle complex information systems in India's inland navigation sector. In the suggested model, "data are gathered from several services providers and users and processing it to provide information to multiple agencies depending on the traffic situation".

Many other researchers have stressed the need for comprehensive information communication technology in waterborne transport to enhance competitiveness. Implementing an ICT system will efficiently transmit information/data between the inland navigation stakeholders (Niedzielski *et al.,* 2021). Duminda *et al.* (2013) developed a nonlinear model for barge tracking location on the Ohio River. Their findings show a reliable prediction for the tracking of inland barges. Other researchers presented different means of tracking a vessel's location. Kujawski (2015) used a closed-circuit television, while Kujawski and Stępień (2017) used a non-metric stationary camera to ascertain barge location.

In Europe, the academic researcher has continued to analyse the possibility of using the river information service (RIS) to enhance the efficiency of the transport system. (Durajczyk, 2020; Niedzielskiet *et al.,* 2021). In urban logistics, Durajczyk and Drop (2021) examined the possibility of RIS to improve waterborne transport for urban and interurban cargo shipments in Poland. Their finding reveals that adopting RIS can significantly improve urban and interurban inland shipping. Other researchers are exploring the future of RIS beyond navigability into transport logistics (James *et al.,* 2019).

Although the RIS supports and enhances the safety and usability of waterborne transport, there is still an increasing need for how best to use RIS through designing a decision support system (Mihic *et al.,* 2011). The use of modern information systems and digitalisation of transport services has been increasing in some European countries as noticeable efforts have been achieved (Mihic *et al.,* 2011; Mihić *et al.,* 2012).

4.2.2.1 Digitalisation of inland waterway transport and logistics optimisation

In recent years, the digitalisation of IWT and logistics has emerged as a significant catalyst, fundamentally altering the global transportation of goods. The escalating dependence on technology and the rapid expansion of data has rendered digitalisation essential in optimising transport and logistic operational effectiveness, boosting safety and security measures and improving overall efficiency and productivity within the transportation industry while facilitating streamlined administration of supply chains. Digitalisation has driven changes in many industries, has remained an essential technological trend globally, and has impacted the transport sector. Digitalisation trends must be followed for IWT to compete with other modes in the logistics chain. The optimisation of inland navigation by employing these means should integrate the transport into the domestic logistic chain and shift cargo flow to waterways. The utilisation and integration of digital IT tools have contributed significantly to cost reduction (energy-efficient navigation in combination with route planning and optimal cargo load, auto-piloting) and quality service improvement (tracking and tracing vessels' information system on route and cargo). Researchers have acknowledged that the significance of digitalisation within the IWT cannot be overemphasised. The growing dependence on technology and rapid expansion have made digitalisation essential in enhancing transportation and logistics operations.

Shankur et al. (2021) investigated the application of Internet of Things (IoT) technology within the digitalisation framework in the domain of IWT. The research conducted by the authors highlights the significance of integrating devices, sensors and software systems in IoT applications within this particular industry. This integration facilitates data collection and

sharing, enabling improved monitoring and control of the diverse processes. The researchers concluded that these applications can potentially enhance operational efficiency, maintenance practices and decision-making processes. Incorporating ICT to optimise operations, enhance safety and improve efficiency within the transport sector was another aspect focused on by academic scholars. According to Schilka and Seemann (2012), the RIS systems are "information technology designed to optimise traffic and transport processes in inland navigation". The system assists in streamlining the exchange of information between relevant authorities and shippers. Research directions in improving the transport performance of waterborne freight through a seamless flow of information have resulted in the fast development of RIS. Academic research has broadly acknowledged that the extended use of RIS can enhance the competitiveness of IWT (Durajczyk, 2020; Niedzielski et al., 2021; Asborno et al., 2022; Xioa et al., 2022).

Academic research has broadly recognised that the extended use of RIS can enhance the competitiveness of IWT (Durajczyk, 2020; Niedzielski et al., 2021; Asborno et al., 2022; Xioa et al., 2022).

A significant aspect of digitalisation through RIS services is its capacity to offer precise and up-to-date data concerning the vessel location, speed and the state of the cargo onboard. Advanced tracking systems and sensors on inland vessels allow real-time monitoring of fleets' movement. This cognitive ability facilitates more precise estimation of arrival and departure, reducing delays, enhancing the safety of the transport system by facilitating immediate and effective response to emergencies or accidents and improving overall operational effectiveness.

In Europe, the digitalisation of IWT is mainly a European task that the member states jointly progress within various EU projects. However, RIS supports IWT by optimising traffic and transport processes in inland navigation. The European Commission is keen on making the sector modern, innovative, and attractive for freight transport. Thus, the commission launched DINA to investigate the potential for digitalising inland waterway transport. Digitalisation and automation further integrate IWT into the seamless modern industrial logistic chain. Academic scholars are already looking into intelligent IWT (Mohaimenuzzaman et al., 2016; Zhu et al., 2021; Shankur et al., 2021), automated and unmanned vessels (Verberght and Van Hassel, 2019; Meersman et al., 2020; Krause et al., 2022).

Peeters et al. (2020) believe that automation of inland infrastructures and fleets can enhance the competitiveness of the transport mode; hence, they launched an investigation into the feasibility of current and future unmanned inland vessels. Thus, their research concludes that automation and robotics technology can significantly improve the effectiveness and security of IWT operations. These technologies facilitate the execution of freight handling, navigation, and inspection tasks with limited human involvement.

5. Implications for practice and theory

5.1. Managerial implications

Inland shipping is critical to the global economy, especially facilitating trade and environmental sustainability. Promoting alternative transport systems like inland waterways transport has recently received more attention from academic researchers because of its potential to address concerns related to CO_2 emissions and alleviate traffic congestion. The managerial implications of this mode of transportation are complex, necessitating a thorough understanding of industry dynamics. One of the fundamental requirements for integrating inland waterway transport into the modern industrial logistic chain is the presence of infrastructure that facilitates connectivity between different economic regions, availability not only in existence and sufficient capacity alone but also in standards and quality. Infrastructure planning and management is one significant managerial implication in inland waterway transport.

Management must know the infrastructure requirements and challenges to waterborne transport to facilitate seamless operational processes (Schoeneich et al., 2022). For example, the maintenance and enhancement of locks, dams and navigation channels are among the infrastructural requirements for the waterways that managers must regularly review. Regular monitoring and analysis are necessary to identify potential bottlenecks or the necessity for expansion to meet the growing traffic.

Furthermore, the optimisation of vessel capacity utilisation is of utmost importance in order to minimise expenses (Fan, 2021). It is imperative for managers to conduct comprehensive analyses of demand trends and formulate strategies to align supply with demand. This may involve coordinating vessel schedules and implementing information systems to monitor cargo movement efficiently. Environmental sustainability is another critical aspect for managers in inland waterways transport. With the growing attention given to sustainability during the last decades, environmental sustainability holds significant importance for managers regarding freight transportation via waterways (Sys et al., 2021; Barros et al., 2022). In light of the current global emphasis on carbon emission reduction, it is crucial for managers to use environmentally sustainable practices and technologies. This includes the use of engines with low emissions, propulsion systems that are fuel-efficient, and the implementation of waste management strategies to mitigate pollution.

In order to adequately respond to the dynamic nature of waterborne transportation, managers must remain well-informed on emerging technologies and regulatory modifications (Grosso et al., 2021). The sector is undergoing significant transformation due to automation and digitisation. For example, the emerging trends in the IWT industry include the development of autonomous

barges, digitalisation and intelligent shipping systems, which have the potential to improve operational efficiency and safety significantly. It is imperative for managers to diligently oversee these technological innovations and evaluate their viability and prospective integration within their operational framework.

5.2. Theoretical contributions

The current work additionally provides significant theoretical advances. While significant research has been conducted on enhancing the transport and operational efficiency of IWT, there is still limited exploration and understanding of modern concepts, innovative technologies, and novel measures to facilitate the sector's adaptation to innovative advancements and enhance its competitiveness.

The primary theoretical contribution of this study involves the comprehensive identification of issues and challenges that impede the growth and development of inland waterway transportation. Furthermore, the study also explores and establishes the main trends in current technology innovation studies as well as to understand if these technologies' progress enhances the effectiveness and efficiency of the transport sector.

Applying a systematic review approach to identify challenges and technological trends/strategies being studied to solve these problems by ensuring its long-term sustainability and competitiveness are also an essential contribution and can support other similar works. The study also complements the existing body of literature in the field of inland navigation by increasing the level of awareness about recent and ongoing technological innovation and possible approaches for optimising inland waterway transport and inland vessels/barges

6. Conclusion and implications for future research

This paper presents a systematic literature review of the technological developments and challenges for inland waterways freight transport in the intermodal supply chain. With this, we identified key themes and issues that impede the growth and development of inland waterway transportation in the logistic chain and explored the technological innovation trends developed to help enhance the effectiveness and efficiency of the IWT sector.

We started our systematic literature review by establishing two research questions: (1) What are the main IWT issues and challenges the academic researchers acknowledge in the literature? (2) What technological innovations are recently developed to improve transport efficiency? To answer these questions, we reviewed articles published by academic researchers between 2010 and 2022 (both years inclusive) in six digital libraries named Scopus, IEEE Xplore, Sage, Emerald

Insight, EBSCO and Google Scholar from which we extracted the studies. Subsequently, a rigorous filtering process was conducted utilising inclusion and exclusion criteria in order to identify the relevant studies that would best address our research questions.

Our findings elucidate that the benefits and development of IWT, with a focus on its contribution towards achieving sustainability, have been discussed extensively in the scientific literature in recent times. Researchers have also identified and analysed several key issues and challenges impacting competitiveness in the sector, including seasonal variation and climate change, workforce/skill shortage gap, competitiveness with other modes of transport, integration of operational planning systems, service quality, government support and investment, regulatory and administrative complexities.

Regarding the technological innovations to enhance the effectiveness and efficiency of waterborne transportation, our results show that the significance of technological innovation in IWT is recognised, especially concerning the competitiveness and efficiency of the sector. Changes in the transport system are primarily influenced by supply factors (i.e., infrastructure and innovations), demand conditions (i.e., changes in flow), as well as regulations. Academic research work is becoming apparent as a growing body of literature. We identified some innovations that contribute to tackling the existing challenges of IWT and making the sector more sustainable: digitalisation (ICT, RIS, automation, robotics technology and IoT) and greening the fleets innovation research (alternative fuels with pollution-reduction technology, energy/fuel consumption uses on the carbon footprint, air pollutant emission reduction, lowering emissions of air pollutants and using cleaner, new engine concepts and optimisation for efficient and green propulsion).

In the uptake of logistic optimisation of IWT, reviewing the existing literature shows that cargo owners and logistics operators do not always acknowledge IWT as a crucial component of the logistics chain. Studies show that the IWT can offer a wide variety of freight forwarding solutions if used optimally. Research indicates that the increased utilisation and integration of digital and ICT tools can reduce costs by implementing energy-efficient navigation techniques, optimising cargo load and route planning and implementing auto-piloting systems. Additionally, service improvement can be realised through the implementation of track and tracing mechanisms, as well as the development of information systems for both the route and cargo.

Many academic publications deal with developing inland shipping as a sustainable transport mode that can be integrated into the modern supply chain. Numerous articles describe the benefit of implementing RIS services in the inland shipping industry. However, scientific and academic addresses still require insight into how the currently available information services meet industry needs. Also, the possibilities to provide practical suggestions and recommendations are limited to regions or countries. Most articles reviewed in this study describe the benefits of

implementing RIS services on a theoretical rather than practical basis. Through a combination of qualitative and quantitative research methods, academic research still needs to be made available to fill this gap in the practicability of using RIS to meet industry needs beyond the regional or country level.

The primary aim of this study was not to thoroughly analyse each technology employed in addressing challenges related to IWT. This study is regarded as an initial research work towards conducting comprehensive analyses that aim to comprehend the technological innovation developed to enhance the use of inland navigation, especially in intermodal transport.

Future works should take a broader approach, collecting articles from a more scientific resource. Future systematic literature reviews in each domain identified in the study should be conducted to thoroughly analyse each technological innovation development to solve problems and strengthen competitiveness in the IWT domain. Since innovation and modernisation in IWT are being enabled and accelerated by research and development. Therefore, future research should consider incorporating artificial intelligence into the decision-making process, adopting blockchain technology to ensure transparency and security in the transactions, and integrating sustainability and environmental factors, which will significantly influence the course of digitalisation in IWT. By adopting and incorporating these emerging patterns, the sector has the potential to significantly improve its operational effectiveness, safety measures and overall commitment to sustainability.

Funding

The authors of this work received no financial funding in the form of any grants from funding agencies, the public or commercial or non-profit organisations. The research was purely independent.

Conflicts of Interest

Authors declare no conflict of interest.

Reference

Abbas, K., Qasim., M.Z., Song, H., Murshed, M., Mahood, H., and Younis (2022) A review of the global climate change impacts, adaptation, and sustainable mitigation measures, *Environmental Science and Pollution Research*, Vol. 29, pp. 42539 - 42559

Abramowicz-Gerigk, T., Burciu, Z., and Jachowski, J. (2017), an innovative steering system for a river push barge operated in environmentally sensitive areas, *Polish Maritime Research,* Vol. 24 No. 4, pp. 27-34.

Agatz, N. A. H., Fleischmann, M., and Van Nunen, J. A. E. E. (2008), E-fulfilment and multi-channel distribution – a review, *European Journal of Operational Researc*h, 187(2), pp. 339–356.

Aroke, O.M., Esmawili, B., and Kim., S.C., (2021) Impact of climate change on transportation infrastructure: Comparing perception difference between the US public and the department of transportation (DOT) professionals, *Sustainability,* Vol. 13 No. 21, pp. 1 -19

Asborno, M. I., Sarah, H., Kenneth, N.M., Manzi, Y. (2022) Inland waterway network mapping of AIS data for freight transportation planning*, Journal of Navigation*, Vol. 75, No. 2. Pp. 251-272

Asgher, H.M., Hassim,Y.M.B.M., Ghazali, R., and Saleem, M.A. (2020), A Systematic Literature Review- SLR On Recent Advances and Variants of Grey Wolf Optimization, *International Journal Of Scientific and Technology Research,* Vol. 9 No. 6, pp. 512-518.

Asia Development Bank (2016) Promoting Inland Waterway Transport in the People's Republic of China.

Baird, A. J. (2007), 'The economics of Motorways of the Sea', *Maritime Policy and Management,* Vol. 34, pp.287 – 310.

Bak, A. and Zalewski, P. (2021) Determination of the waterway parameters as a component of safety management system, *Applied Science*, Vol. 11 No.10, pp. 1-20

Barrow, B.R.C, Carvalho, E.B. and Antonio, C.P.B.J. (2022) Inland waterway transport and the 2030 agenda: Taxonomy of sustainability issues, *Cleaner Engineering and Technology,* Vol. 8, pp.1-13
Boniar S.M. Korniiko Y.R. and Valiavska, N.O. (2016), Impediments to the development of Ukrainian Inland waterways, *Actual Problems of Economics*, Vol. 177 No. 3, pp.246 – 252.

Bouckaert, B. (2016), First hybrid powered dry-cargo ship for Inland Waterways, *Maritime by Holland,* Vol. 65 No. 1, pp. 60 – 63.

Bruce, J. and Mollison, J. (2004), Evidence-based reproductive health: Reviewing the literature: adopting a systematic approach, *Journal of Family Planning and Reproductive Health Care,* Vol. 30 No. 1, pp. 13–16.

Bu, F and Nachtmann, H (2021) Literature review and comparative analysis of inland waterways transport. "Container on Barge", *Maritime Economics and Logistics*, Vol. 25, pp.140-173

Bu, F. and Nachtmann, H. (2021), Literature review and comparative analysis of inland waterways transport: "Container on Barge", *Maritime Economics and Logistics.* Doi: https://doi.org/10.1057/s41278-021-00195-6

Bucci, V., Marinò, A. and Bosich, D. (2016), Inland waterway gas-fueled vessels: casm-based electrification of a pushboat for the European network, *IEEE Transactions on Transportation Electrification,* Vol. 2 No. 4, pp.607-617.

Buitelaar, H. (2013), Redesigning barge transport: Innovations linked for clever green inland shipping, *Maritime by Holland,* Vol. 62 No. 2, pp. 58-60.

Caris, A., Limbourg, S., Macharis, C., Lier, T.V. and Mario, C. (2014), Integration of inland waterways transport in the intermodal supply chain: a taxonomy of research challenges, *Journal of Transport Geography,* Vol. 41 No. 3, pp.126-136.

Chen, Z., Xue, J., Wu, C., Qin, L.Q., Liu, L., and Cheng, X. (2018), Classification of vessel motion pattern in inland waterways based on automatic identification system, *Ocean Engineering*, Vol. 161, pp. 69-76.

Chowdhury, P., Paul, S.K., Kaisar, S. and Moktadir, M.A. (2021), COVID-19 pandemic related supply chain studies: A systematic review, *Transportation Research Part E: Logistics and Transportation Review,* Vol. 148 No. 102271, pp.1-26.

Christodoulo, A., Christidis, P. Bisselink, B. (2020) Forecasting the impacts of climate change on inland waterways, *Transportation Research Part D: Transport and Environment,* Vol. 82, pp 1-9

Comi, A. and Polimeni, A. (2020) Assessing the potential of short sea shipping and the benefits in terms of external costs: Application to the Mediterranean Basin, *Sustainability,* Vol. 12, pp. 1-17

Cuong, D.C., Nguyen, T.T.,Duoug, V.T., Tran, D.N.,Chinh, T.M., Le, N.G. and Tran. D.T. (2020) Smartphone-based sensing for intelligent inland waterway transportation, *International Journal of Interactive Mobile Technologies*, Vol 4 No. 18, pp.195-203

Davarzani, H., Fahimnia, B., Bell, M., and Sarkis, J. (2016), Greening ports and maritime logistics: A review. *Transportation Research Part D: Transport and Environment*, Vol. 48, pp. 473–487.

Defryna, C., Golaka, J.A.P., Grigorieva, A., and Timmermans, V. (2021) Inland waterway efficiency through skipper collaboration and joint speed optimization, *European Journal of Operational Research,* Vol. 292, pp. 276 – 285

Dobbins, J.P. and Langsdon, L.C. (2013), Use of data from automatic identification systems to generate inland waterway, Transportation Research Record: *Journal of the Transportation Research Board,* Vol. 2330, pp. 73–79.

Douma, A.M., Hillegresberg, J.V., and Schuur, P.C. (2012) Design and evaluation of a simulation game to introduce a Multi-Agent system for barge handling in a seaport. *Decision Support Systems*, Vol. 53, pp. 465 - 472

Durajczyk, P. (2020), The analysis of the possibility to improve the efficiency of container transport via the Oder waterway with the use of the RIS system, *"Naše More",* Vol. 67 No. 3, pp. 199-208.

Durajczyk, P. and Drops, N. (2021), possibilities of using inland navigation to improve efficiency of urban and interurban freight transport with the use of the River Information Services (RIS) system—case study, *Energies,* Vol. 14 No.7086, pp. 1 -16.

Erceg (2018) Legal framework of European inland waterways and Croatian legislation on inland waterways navigation – problems of non-harmonized rules, *European Scientific Journal,* Vol. 11, pp, 1-21

Essel, D., JiN, Z., Bowers, J.O., Abdul-salam, R. (2022) Green maritime practices in an emerging economy towards the achievement of sustainable development: a Ghanaian context, *Benchmarking: An International Journal*, Doi: https://doi.org/10.1108/BIJ-10-2021-0629

European Federation of Inland Ports (2015) *Platform for Multimodality and Logistics in Inland Ports.* Position Paper

Fan, A., Wang, J., He, Y., Percic, M., Vladimir, N and Yang, L. (2021) Decarbonising inland ship power system: Alternative solution and assessment method*, Energy,* Vol. 226. No. 120266. pp. 1-16

Fan, A., Xiong, Y., Yang Liu, Zhang, H. and He, Y. (2023) Carbon footprint model and low-carbon pathway of inland shipping based on micro-macro analysis, *Energy,* Vol. 263. No. 126150. pp. 1-16

Gao, D., Zhang, W., Shen, A. and Wang, Y. (2017), Parameter design and energy control of the power train in a hybrid electric boat, *Energies,* Vol. 10 No. 1028, pp. 1-12.

Garcia-Menendez, L., and Feo-Valero, M. (2009), "European Common Transport Policy and Short-Sea Shipping: Empirical Evidence Based on Modal Choice Models." Transport Reviews: *A Transnational Transdisciplinary Journal,* Vol. 29 No. 2, pp. 239–259.

Geraldi, J., Maylor, H. and Williams, T. (2011), Now, let's make it really complex (complicated): A systematic review of the complexities of projects, *International Journal of Operations and Production Management,* Vol. 31 No. 9, pp. 966-990.

Gopikrishna, B. and Deo, M.C.(2018) Changes in the shoreline at Paradip Port, India in response to climate change, *Geomorphology,* Vol. 303, pp 243 – 255

Govindan, K., Soleimani, H. (2016), A review of reverse logistics and closed-loop supply chains: a Journal of Cleaner Production*, Journal of Cleaner Production*, Vol. 142 No. 1, pp. 371-384.

Grosso, M., Santo, F.L.M., Gkoumas, K., Epniak, M. and Pekar, F. (2021) The role of research and innovation in Europe for the decarbonisation of waterborne transport, *Sustainability,* Vol. 13, pp.1-15

Grubišić, N., Hess, S. and Hess, M. (2014) A solution of berth allocation problem in inland waterway ports, *Tehnički vjesnik*, Vol. 5, pp. 1135-1141

Grushevska, K. and Notteboom, T. (2016) the development of river-based intermodal transport: The case of Ukraine, Journal of International Logistics and Trade, Vol. 14 No. 2, pp. 182-199

Grushevska, K. and Notteboom, T. (2016), The Development of River-based Intermodal Transport: The Case of Ukraine, *Journal of International Logistics and Trade*, Vol. 4 No. 3, pp.182-199.

Gu, Q., Lago, P. (2009), Exploring service-oriented system engineering challenges: a systematic literature review, *SOCA,* Vol. 3 No. 3, pp. 171–188.

Hasan, K.R., Zhang, W. and Shi, W. (2021), Barriers to intermodal freight diversion: a total logistics cost approach, *Maritime Economics and Logistics*, Vol. 23, pp.569–586.

Hassan, M.M. and Xuefeng, W (2022) The challenges and prospects of inland waterway transportation system of Bangladesh, *International Journal of Engineering and Management Research,* Vol. 12 No. 1, pp. 1-12

Havinga, H. (2020) Towards sustainable river management of the Dutch Rhine River, *Water,* Vol. 12 No. 6, pp.1-28

Hofbauer, F and Putz, L.M. (2020) External costs in inland waterway transport: An analysis of external cost categories and calculation methods, Sustainability, Vol. 12, pp, 1-18

Hunt, J.D., Pokhrel, Y., Chaudhari, S., Mesquita, A.L.A., Nascimento, A., Filho, W.L., Biato, M.L., Schneider, P.S. and Lopes, M.A. (2022) Challenges and opportunities for a South America Waterway System, *Cleaner Engineering and Technology,* Vol. 11 No.100575, pp. 1-14

INE (2018) *Working Together for More and Better Waterway Transport.* Annual Report. Available at: https://gallery.mailchimp.com/40c5b590ad62400cee25ee987/files/6f870722-7f01-4bb2-a67d-4dab8255bad9/INE_AR_2018_final.pdf

[Accessed: 20 August 2023]

Ionescu, R.V. (2016), Inland Waterways' Importance for the European Economy. Case Study: Romanian Inland Waterways Transport, *Journal of Danubian Studies and Research*, Vol. 6 No. 2, pp. 207 – 219.

Jacalyn, K., Sadaeghieh, T. and Adeli, K. (2014), Peer review in scientific publications: benefits, critiques, and a survival guide, *The Journal of International Federation of Clinical Chemistry and Laboratory Medicine,* Vol. 25. No. 3, pp. 1 – 17

James, K.J., Shenoy. V.V., Bhasi, M. and Nandakumar, C.G. (2019), automated ICT systems in inland waterways by developing a multi flow river information services system, *International Journal of Advanced Research in Engineering and Technology,* Vol. 10 No. 2, pp. 389-402.

Jiang, H., Peng, D., Wang, Y., and Fu, M. (2021) Comparison of inland ship emission results from a real-world test and an AIS-based model, *Atmosphere,* Vol.12. No.1611, pp. 1-13

Jianga, Y., Lua, J., Caic, Y. and Qingcheng, Z. (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*, Vol. 71, pp. 235 -252.

Johnson. P.M., Baroud, H., Philip, C., and Abkowitz (2022) An integrated approach to evaluating inland waterway disruption using economic interdependence, agent-based, and Bayesian models*, Engineering Economist*, Vol. 68 No. 1, pp. 2 – 19

Jonkeren, O., Rietveld, P. Ommeren, J.V. and Linde, A. (2014) Climate change and economic consequences for inland waterway transport in Europe, Regional Environmental Change, Vol.14, pp. 953 – 965

Kalajdzic, M., Vasilev, M. and Momcilovic, N. (2022) Evaluating an inland waterway cargo vessel's energy efficiency indices, *Polish Maritime Research,* Vol. 2. No. 114, pp. 27-34

Kaup, M., and Lozowicka, D. and Slaczka, W. (2021) Dimensions of inland ships in relation to the parameters of waterways: The case of Poland, *European Research Studies Journal*, Vol. 25 No.1, pp. 917-939

Kitchenham, B. and Charters, S. (2007), Guidelines for Performing Systematic Literature Reviews in Software Engineering, *Engineering*, Vol. 2, pp. 1051.

Kotowska, I., Mańkowska, M. and Plucinski, M.(a) (2018) Inland shipping to serve the hinterland: The challenges for seaport authorities, *Sustainability,* Vol. 10, pp. 1-13

Kotowska, Mańkowska and Pluciński, (2018), Planning the development of inland shipping in the seaport hinterland transport: A case study of the Oder River in Poland, *Scientific Journals of the Maritime University of Szczecin, Vol.* 58. No. 130, pp. 84–92

Kraus, S. Breier, M. and Dasí-Rodríguez, S. (2020), The art of crafting a systematic literature review in entrepreneurship research, *International Entrepreneurship and Management Journal,* Vol. 16, pp. 1023–1042.

Krause, S., Wurzler, L. Morkrid, O.E., Fjortoft, K., Psaraftis, H.N. Vilanova, Coelho, N.F, Tatenhove, J.V., Raakjaer, J., Kloch, K., Billeso and Kristiansen, J.N. (2022) Development of an advanced, efficient and green intermodal system with autonomous inland and short sea shipping -AEGIS, *Journal of Physics*, Vol. 2311. No. 012031. pp. 1-24

Kujawsk, A., Lemke, J. and Dudek. T. (2018), Concept of using unmanned aerial vehicle (UAV) in the analysis of traffic parameters on Oder Waterway, *Transportation Research Procedia,* Vol. 39, pp. 231–241.

Kujawski, A. (2015), Inland waterway vessels tracking using closed circuit television, *Scientific Journals of the Maritime University of Szczecin*, Vol. 44 No. 116, pp. 135–140.

Kujawski, A. and Stępień, G. (2017), A method of determining inland vessel position using a single stationary, non-metric camera, *Scientific Journals of the Maritime University of Szczecin*, Vol. 52 No. 124, pp.103–111.

Kuklickea, C. and Demeritt (2016) Adaptive and risk-based approaches to climate change and the management of uncertainty and institution risk: The case of future flooding in England, *Global Environmental Change*, Vol. 37, pp. 56-68

Kumar, N. and Subhashini, T. (2020), Precedence and Challenges of Inland Waterways Transportation in India, *Mukt Shabd Journal,* Vol. 9 No. 8, pp. 2017 – 2079.

Lalla-Ruiz, E., Shi, X., and Voß, S. (2018) The waterway ship scheduling problem, *Transportation Research Part D,* Vol 60, pp. 191 – 209

Łebkowski, A. (2018) Reduction of fuel consumption and pollution emissions in inland water transport by application of hybrid powertrain, *Energies,* Vol. 11, No. 1981, pp.1-16.

Lei, L., Wen, Z. and Peng, Z. (2021) Prediction of main engine speed and fuel consumption of inland ships-based o deep learning, *Journal of Physics*, Vol. 2025. No. 012012, pp. 1-13

Lendjel. E. and Fischman, M. (2014), Innovations in barge transport for supplying French urban dense areas: A Transaction Costs Approach, *International Journal of Supply Chain Forum*, Vol. 15 No. 4, pp.16-27.

Li, J.Y., Notteboom, T.E., and Jacobs, W. (2014), China in transition: institutional change at work in inland waterway transport on the Yangtze River, *Journal of Transport Geography*, 40, pp.17 -28.

Lier, T.V. and Macharis, C. (2014), Assessing the environmental impact of inland waterway transport using a life-cycle assessment approach: The case of Flanders, *Research in Transportation Business and Management,* Vol. 12 pp. 29 – 40

Lisaj, A. (2019) Implementation of e-navigation strategies for RIS centres supporting inland navigation, *International Journal of Marine Navigation and Safety of Sea Transportation,* Vol. 13 No. 1, pp. 145-149

Liu, J., Hekkenberg, R., Rotteveel, E., Hopman, H. (2015), Literature review on evaluation and prediction methods of inland vessel manoeuvrability, *Ocean Engineering*, Vol. 106 pp. 458 – 471.

Liu, J., Hekkenberg, R., Rotteveel, E., Quadvliegc, F., Hopman, H. and Zhaoda, B. (2017), An integrated empirical manoeuvring model for inland vessels, *Ocean Engineering*, Vol. 137 pp. 287 – 308.

Liu, J., Yan, X., Liu, C., Fan., A and Ma, F. (2023) Developments and applications of green and intelligent inland vessels in China*, Journal of Marine Science and Engineering*, Vol, 11. No 318. pp. 1-12

Liu, L., Wen, Y., Liang, Y., Zhang, F., and Yang. (2019) Extreme weather impacts on inland waterway transport of Yangtze River, *Atmosphere,* Vol. 10 No.3, pp. 1-26

Liu, R., Qin, F., Li, L., and Bo, Y. (2020), The Best-Worst Ant System for the Lock Chamber Arrangement Problem, *Journal of Physics,* Vol. 1631 No. 1012112, pp. 1-7.

Lui., J., Jiang, X., Huang, W., He, Y., and Yang, Z. (2022) A novel approach for navigational safety evaluations of inland waterway ships under uncertain environment, Transportation Safety and Environment, Vol. 4, pp. 1-11

Macharis, C., Caris, A., Jourquin, B. and Pekin, E. (2011), A decision support framework for intermodal transport policy, *European Transport Research Review*, Vol. 3 No. 1, pp. 167-178.

Mahmoudzaheh, A., Khodakarami, M., Ma, C., Kenneth, N.M., Wang, X.B., and Zhang, Y. (2021) Waterway maintenance budget allocation in a multimodal network, *Transportation Research Part E.,* Vol. 146, pp. 1-13

Markolfa, S.A., Hoehnea, C. Frasera, A., Mikhail, V., Chestera, B. and Underwoodc, B.C. (2019) Transportation resilience to climate change and extreme weather events – Beyond risk and robustness, *Transport Policy,* Vol. 74, pp. 174-186

Medda, F. and Trujillo, L. (2010), Short-sea shipping: an analysis of its determinants, *Maritime Policy and Management,* Vol. 37 No. 3, pp. 285-303.

Meers, D., Macharis, C., Vermeiren, T. and Van Lier, T. (2017), 'Modal choice preferences in short distance hinterland container transport', *Research in Transportation Business and Management,* Vol. 23, pp.46-53.

Meersman, H., Moschouli, E., NanwayBoukani, L., Sys, C., Hassel, E.V., Vanelslander, T. and Voorde, E.V.D (2020), Evaluating the performance of the vessel train concept, *European Transport Research Review,* Vol. 12 No. 23, pp.1-11.

Meline, T. (2006), Selecting studies for systematic review: inclusion and exclusion criteria, *Contemporary Issues in Communication Science and Disorders*, Vol. 33, pp. 21–27.

Mihić, S. Mihajlovic, M. and Škiljaica, I. (2012), European policy for the promotion of inland waterway transport: A case study of the Danube River, *African Journal of Business Management,* Vol. 6 No. 7, pp. 2498-2507.

Mihic, S., Golusinb, M. and Mihajlovicc, M. (2011), Policy and promotion of sustainable inland waterway transport in Europe –Danube River, *Renewable and Sustainable Energy Reviews*, Vol. 15, pp.1801–1809.

Mohaimenuzzaman, M., Rahman, M.M., Alhussein, M., Muhammed, G., Mamum, K.A. (2016) Enhancing safety in water transport system based on Internet of Things for developing countries, *International Journal of Distributed Sensor Networks*, Vol. 3, pp.1-12

Mohaimenuzzaman, M.D., Rahman, S.M.M., Alhussein, M., Muhammad, M., and Al Mamun, K.A. (2016), Enhancing Safety in Water Transport System Based on Internet of Things for Developing Countries, *International Journal of Distributed Sensor Networks*, Vol. 2834616, pp.1-10.

Moher, D. Liberati, A., Tetzlaff, L., and Altman, D.G. (2009), preference reporting items for systematic reviews and Meta-analysis: the PRISMA statement. *Plos Medicine.* Vol. 6. No. 7, pp. 1 - 6

Mostert, M. Limbourg, S. (2016) External cost as competitiveness factors for freight transport – A state of the art, Transport, *Transport Review,* Vol 36, pp.692-712

Okoli, C. (2015), A guide to conducting a standalone systematic literature review. *Communications of the Association for Information Systems*, Vol. 31 No.37, pp. 879 – 910.

Osama, E, Hassel, V., Sys, C., Vanelslander, T. (2017)Developing a cost calculation model for inland navigation, *Research in Transport and Business Management*, Vol. 23, pp. 64-74

Oud, G., and Bedos (2022) CFD investigation of the effect of water depth on manoeuvring forces on inland ships, *Journal of Ocean Engineering and Marine Energy*, Vol. 8 No15, pp. 489 - 497

Peeters, G., Kotze, M., Afzal, M.R., Catoor, T., Baelen, S.V. Geenen, P., Vanierschot, M., Boonen, R. and Slaet, P. (2020), An unmanned inland cargo vessel: Design, build, and experiments, *Ocean Engineering,* Vol. 201 No. 107056, pp. 1 -17.

Peeters, G., Yayla, G., Catoor, T., Bealen, S.V, Afzal, M.R., Christofakis, C., Boonen, R. Storms, S. & Slaets, P. (2020) An inland shore control centre for monitoring or controlling unmanned inland cargo vessels, *Journal of Marine Science and Engineering*, Vol. 8 No.758, pp. 1-27

Pencheva, V., Asenov, P. and Beloev, I. (2019), study of the use of alternative energy sources in inland waterway transport, *Transport Problems*, Vol. 14 No. 3, pp. 109-120.

Perˇci´c, M., Vladimir, N. and Fan, A. (2021), Techno-economic assessment of alternative marine fuels for inland shipping in Croatia, *Renewable and Sustainable Energy Reviews*, Vol.148, pp. 1 -15.

Petticrew, M. and Roberts, H. (2008) Systematic Reviews in the Social Sciences: A practical guide. Oxford: John Wiley and Sons Publishing.

Pfoser, S., Jung, E, and Putz. L.M. (2018) Same River same rules? - Administrative barriers in the Danube countries, Journal of Sustainable Development of Transport and Logistics, Vol. 3 No 3, pp. 27-37

Pilbeam, C. Alvarez, G. and Wilson, H. (2012), The governance of supply networks: a systematic literature review, *Supply Chain Management,* Vol. 17 No. 4, pp. 358–376.

Plotnikova, E., Vienažindiene, M and Slavinskas, S. (2022) Development of inland waterway transport as a key to ensure sustainability: A case of study of Lithuania, *Sustainability,* Vol. 14, pp.1-15

Pradana, B.W.N, Fattah, T.A.M., Hidayat, R.D.R., Triyasa, D.H., and Yuliantini (2019), Analysis of the potential for CBL inland waterways as an alternative transport logistics using AHP, *Journal of Physics,* Vol. 1573 No. 1, pp.1-9.

Praveen, S. and Jegan, J. (2015), Key Issues and Challenges for Inland Water Transportation Network in India*, IJSRD - International Journal for Scientific Research and Development*, Vol. 3 No. 10, pp.653-658.

Randeniya, D.I.B. and Hilliar, M.R. (2013), Tracking and predicting barge locations on inland waterways, *Journal of Computing in Civil Engineering*, Vol. 27 No. 1, pp. 27-35.

Raza, Z., Svanberg, M. and Wiegmans, B. (2020), Modal shift from road haulage to short sea shipping: a systematic literature review and research directions, *Transport Reviews*, Vol 40 No. 3, pp. 1 – 25.

Razah, Z., Syanbergband, M. and Wiegmans, B. (2020) Modal shifts from road to short sea shipping; a systematic literature review and research, *Transport Review,* Vol. 40 No. 3, pp.384-406

Reim, W., Parida, V. and Ortqvist, D. (2015), Product-Service Systems (PSS) business models and tactics - a systematic literature review, *Journal of Cleaner Production,* Vol. 97, pp. 61-75.

Rogerson, S., Santén, V., Svanberg, M., Williamsson, J. and Woxenius, J. (2020), Modal shift to inland waterways: dealing with barriers in two Swedish cases, *International Journal of Logistics Research and Applications,* Vol. 23 No. 2, pp.195-210.

Roso, V., Vural, C.A., Abrahamsson, A., Engström, M., Rogerson, S., and Santén, V. (2020) Drivers and barriers for inland waterway transportation, *Operations and Supply Chain Management,* Vol. 13 No. 4, pp. 406 – 417

Roso, V., Vural., C. Abrahamsson, A., Engström, M., Rogerson, S. and Santén (2020), Drivers and barriers for inland waterway transportation, *Operations and Supply Chain Management*, Vol. 13 No. 4, pp. 406-417.

Schoneich, M. Habel, M., Szatten, D., Abaslon, D. and Montewka, J.(2022) An integrated approach to an assessment of bottlenecks for navigation on riverine waterways, *Water,* Vol. 15 No. 141, pp. 1-22

Schweighofer, J. (2014) The impact of extreme weather and climate change on inland waterway transport, *Natural Hazards*, Vol. 72, pp. 23 -40

Segovia, P., Pesselse, M., Boom, T.V.D., and Reppa, V. (2022) Scheduling inland waterway transport vessels and locks using a switching max-plus-linear system approach, *IEEE Open Journal of Intelligent System,* Vol. 3, pp. 748 - 762

Shankur, S., Punia, S., Singh, S.P. and Dong, J. (2021) Trajectory of research on maritime transportation in the era of digitalisation, *Benchmarking: An International Journal*, Vol. 29 No. 1, pp. 194 – 216

Simić, A. and Radojčić, D. (2013), on energy efficiency of inland waterway self-propelled cargo vessels, *FME Transactions,* Vol. 41, pp.138-145.

Smith, V., Devane, D., Begley, C.M., and Clarke, M. (2011), Methodology in conducting a systematic review of systematic reviews of healthcare interventions. *BMC Medical Research Methodology*, Vol.11 No. 15, pp. 1-6.

Solomon, B., Otoo, E., Boateng, A. and Koomson, D.A (2020) Inland Waterway Transportation (IWT) in Ghana: A case study of Volta Lake transport, International Journal of Transportation Science and Technology, Vol. 10, pp.20-33

Specht, P., Bamler, Jovic, M., Meyer-Larsen, N. (2022) Digital information services needed for a sustainable inland waterway transportation business, *Sustainability,* Vol. 14. No 6392. pp. 1-14

Sys, C., De Voorde, E.V., Vanelslander, T. and Hassel, E.V. (2020), Pathways for a sustainable future inland water transport: A case study for the European inland navigation sector, *Case Studies on Transport Policy,* Vol. 8, pp. 686-699.

Tennant, J.P. and Ross-Hellauer, T. (2020), The limitations to our understanding of peer review, *Research Integrity, and Peer Review,* Vol. 5. No 6. pp. 1 – 14.

Totakura, B.J., Narasinganallur, N., Jalil, S.A. and Ajith, P.J.(2020) Factors affecting container shipping through inland waterways, *Journal of ETA Maritime Science*, Vol. 20 No. 3, pp.156-167

Tranfield, D., Denyer, D. and Smart, P. (2003), Towards a methodology for developing evidence informed management knowledge by means of systematic review, *British Journal of Management,* Vol. 14 No. 3, pp. 207–222.

Trivedi, A., Jakhar, S.K. and Sinha, D. (2021), Analyzing barriers to inland waterways as a sustainable transportation mode in India: A DEMATEL-ISM based approach, *Journal of Cleaner Production,* Vol. 295 No. 126301, pp. 8-16.

Trivedi, A., Kumar, S.J and Sinha, D. (2020) Analyzing barriers to inland waterways as a sustainable transport mode in India: A dematel-ISM based approach, Journal of Cleaner Production, Vol. 295, pp.1-11

Verberght, E. and Van Hassel, E. (2019), The automated and unmanned inland, *Journal of Physics,* Vol. 1357 No. 1, pp. 1-12.

Vilarinhoa, A. Libonia, L.B. and Sieglerb, J. (2019), Challenges and opportunities for the development of river logistics as a sustainable alternative: a systematic review, *Transportation Research Procedia,* Vol. 39, pp. 576-586.

Vinke, F., Koningsveld, M.,Dorsser, C.V., Baart, F., Gelderf, P.V. Vellinga, T. (2022) Cascading effects of sustained low water on inland shipping. *Climate Risk Management,* Vol. 35, pp. 1 -15

Wang, T., Qu, Z., Yang, Z., Nichol, T., Clarke, G., and Ge., Y. (2020) Climate change research on transportation system: Climate risk, adaptation and planning, *Transportation Research Part D: Transport and Environment,* Vol. 88, pp. 1-7

Wang, Y., Chen, X., Alistair, G.L., Borthwick, L., Li, T., Liu, H., Yang, S., Zheng, C., Xu, J. and Ni, J. (2020) Sustainability of global golden inland waterways, *Nature communications*, Vol. 11, pp.1-13

Wang. J. and Li, J.Y. (2012), Inland waterway transport in the Pearl River Basin, China, *L'Espace géographique*, Vol. 41 No. 3, pp.177-190.

Welch, K., Lambert, W. L.H. Lambert, D.M. and Kenkel, P. (2022) Flood-induced disruption of an inland waterway transportation system and regional economic impacts, *Water,* Vol. 14 No. 753, pp. 1-20

Wiegmans, B. and Konings, R. (2015), 'Intermodal inland waterway transport: Modelling conditions influencing its cost competitiveness, *Asian Journal of Shipping and Logistics*, Vol. 31, pp.273-294.

Williamssona, J., Rogersonb, S. and Santén, V. (2020), Business models for dedicated container freight on Swedish inland waterways, *Research in Transportation Business and Management*, Vol. 35 No.100466, pp. 1-12.

Winchester, C.L. and Salji, M. (2016), Writing a literature review, *Journal of Clinical Urology*, Vol. 9 No. 5, pp. 308–312.

Wojewodzka, K. and Rolbeiecki (2019) The role of inland waterway transport in city logistics, *Transport Economics and Logistics*, Vol 84, pp. 103 -114

Xiao, R., Pan, L., Xiao, H., Xiao, H., and Zhu, Z. (2022) Research of intelligent logistics and High-Quality economy development for Yangtze River cold chain shipping based on carbon neutrality, *Journal of Marine Science and Engineering*, Vol 10, No. 1029, pp. 1-31

Xing, S., Xinping, Y., Bing, W. and Xin, S. (2013), Analysis of the operational energy efficiency for inland river ships, *Transportation Research Part D*, Vol. 22, pp. 34 -39.

Xinping, Y., Yapeng, H., and Ailong, F. (2023) Carbon footprint prediction considering the evolution of alternative fuels and cargo: A case study of Yangtze River ships, *Renewable and Sustainable Energy Reviews,* Vol. 173. No. 113068, pp.1-15

Yan. X., He., Y and Fan, A. (2023) Carbon footprint prediction considering the evolution of alternative fuels and cargo: A case study of Yangtze River ships, *Renewable and Sustainable Energy Reviews,* Vol. 173. No. 113068, pp. 1-14

Yannascoli, S. M., Schenker, M.L., Carey, J.L., Ahn, J. and Baldwin, K.D. (2013), How to Write a Systematic Review: A Step-by-Step Guide, *University of Pennsylvania Orthopaedic Journal*, Vol. 23, pp. 64-69

Yuan, Z., Liu, J., Liu, Y., Yuan, Y., Zhang, Q., and Li. (2020) Fitting analysis of inland fuel consumption considering navigation status and environmental factors. *IEEE Access,* Vol. 8. No.187441. pp. 1-14

Zhang, D., Yan, X., Zhang, J., Yang, Z., and Wang, J. (2016) Use of fuzzy rule-base evidential reasoning approach in the navigation risk assessment of inland waterway transportation systems, *Safety Science,* Vol. 82, pp, 352-360

Zhang, M., Sun, Q., Garme, K., Burman, M., Zhou, L., (2022b) Analysis of inland waterway ship performance in ice: operation time window, *Ocean Engineering*, Vol. 263, pp. 1 – 15

Zhang, Y., Sun, L., Ma., F, Wu, Y., Jiang, W., Fu, L. (2022) Collaborative optimisation of the battery capacity and sailing speed considering multiple operation factors for a battery-powered ship, *World Electric Vehicle Journal*, Vol. 13, No.40, pp. 1-24

Zhen, L., Wang, K., Wang, S., and Qu, X. (2018) Tug scheduling for hinterland barge transport: A branch-and-price approach, *European Journal of Operational Research*, Vol. 265, pp. 119-132

Zheng, Y., Kim, A.N. (2017) Rethinking business-as-usual: Mackenzie River freight transport in the context of climate impacts in northern Canada, *Transportation Research Part D,* Vol. 53, pp. 276 – 289

Zhu S. Gao J. He X. Zhang S. Jin Y. and Tan Z. (2021), Green logistics-oriented tug scheduling for inland waterway logistics, *Advanced Engineering Informatics*, Vol. 49 No. 101323, pp. 1-16.