River-Sea Freight Transport in Major Logistic Gateways: A Performance Evaluation of The United Kingdom And Continental Europe's Inland Waterways

A Thesis Submitted to Liverpool John Moores University for the Degree of Doctor of Philosophy

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Abstract

Globalisation and commercialisation have greatly expanded the growth, complexity, and competitiveness of logistic chains. Due to this growth, the high demand for intermodal transport systems has led to the need for continued and integrated transport planning to enhance transport reliability and efficiency. The ever-increasing acknowledgement of the external outcomes of transport has necessitated the development of a more sustainable transport mode. Inland Waterway Transport (IWT) has reinforced its reliance on maritime access even more strongly than in the past. According to the rhythms of increasing pressure from the globalisation market flow, European seaports with suitable inland waterway network connectivity form an interface. As a direct result, the IWT players have become more integrated into modern logistics systems due to increased freight volume and the integration of supply chains. The advancements are compelling the IWT industry to adapt and redefine its operations and strategic positionings. Incorporating waterways into the freight transportation network has led to the development of increasingly complex organisational structures that leverage cost, capacity, and regularity advantages. The expanding supply chain and the increasing need for efficiency and reliability require enhanced performance and assessment measures. Therefore, the study aims to develop a system model that shows how all pertinent aspects and factors influencing performance perception in IWT can be identified and modelled. This study undertakes empirical studies in the IWT sector of the Netherlands, Germany, Belgium, France, and the UK in order to accomplish the research objectives. The study design is segmented into three sections.

First, various IWT performance factors were identified through a systematic literature review. Next, the identified performance factors are validated through a series of empirical studies (experts were consulted using advanced questionnaires and semi-structured interviews). Finally, the performance factors are prioritised using a fuzzy analytic hierarchy process. The performance level of the case study countries was benchmarked using the technique for order performance by similarity to the ideal solution method based on the critical success factor. Their relative ranking has been determined according to the benchmark. This study categorises and verifies performance criteria into eight categories and forty-three subcategories. The novel eight categories are mobility and reliability, efficiency and profitability, infrastructure conditions, environmental impact and decarbonisation, safety and security, efficiency and profitability, innovative transport technology, and policy formulation and implementation. The capacity of IWT to provide efficient and reliable transportation services is crucial for the seamless operations of the supply chain. The findings indicate that performance

associated with mobility and reliability has the highest priority and is of the utmost importance, followed by infrastructure condition, which, to the competitiveness of IWT, largely depends significantly on the quality of waterway infrastructure as missing links and bottlenecks limits the effectiveness of the transportation network.

Finally, the performance approaches were ranked. The Netherlands (Rotterdam gateway) has the highest performance in terms of freight transportation via waterways, followed by Germany (Hamburg gateway), Belgium (Antwerp gateway) came third, next was France (Seine gateway), and the least among these gateways was the UK (Thames/Liverpool/Manchester) with a distance rating among the case studies. Statistics revealed that while the four European case study countries were high, the corresponding value for the UK regional gateways remained very low. The margin by which the Netherlands, Germany, Belgium, and France lead the UK shows how these countries and their strategic positioning have adapted inland shipping operations, aligning with the demands and dynamics of the global market. This study offers a more effective, robust, and efficient way to identify performance factors and enhance the efficiency of IWT operations. The study is the first to systematically identify, evaluate, categorise, and provide a detailed analysis of all pertinent performance measures in the field of IWT. Policymakers and industry practitioners can utilise the research findings to identify essential performance factors for enhancing decision-making and advancing progress. These performance index metrics can serve as new methods and tools, allowing stakeholders to measure the performance of their IWT.

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Abbreviations

FAHP – Fuzzy Analytical Hierarchy Process

AIS – Automatic Identification System

BSR - Baltic Sea Region

CCNR - Central Commission for the Navigation of the Rhine

CCS - Cargo Community System

CEF - Connecting Europe Facility

CO_2 - Carbon Dioxide

CR – Consistency Ratio

CLINSH - Clean Inland Shipping

DANTE - Danube Transnational Programme

DfT – Department for Transport

DINA - Digital Inland Waterway Area

EC - European Commission

ECMT - European Conference of Ministers for Transport

EFIP - European Federation of Inland Ports

EIBIP - European Inland Barging Innovation Platform

EMMA - Enhancing Freight Mobility and Logistics

EPCSA - European Port Community System Association

EU - European Union

EUROSTAT – European Statistical System

IT - Information Technology

ITS - Intelligent Transport System

IWT - Inland Waterway Transport

IWTS 2.0 - Inland Waterways Transport Solution

LJMU – Liverpool John Moores University

LSP - Logistic Services Providers

MCDA - Multi-Criteria Decision Analysis Method

MoS – Motorway of the Sea

NAIADES - Navigation and Inland Waterway Action and Development in Europe

NOVIMAR - Novel Inland Waterways Transport and Maritime Transport Concepts

OECD - Organisation for the Economic Cooperation and Development

PROMINENT - Promoting Innovation in the Inland Waterways Transport Sector

RI – Random Index

RIS - River Information Services

ST4W - Smart Track for Waterway

TEN-T - Trans-European Transport Network

TOPSIS – Technique for Order Preference by Similarity to Ideal Solution

UN - United Nations

UK – United Kingdom

US - United States

USA – United State of America

UNECE - United Nation Economic Commission for Europe

Publications

Publications resulting from this research.

The following papers have been published or have received acceptance for publication.

1. Gbako, S., Paraskevadakis, D., Ren, J. and Wang, J. and Radmilovic, Z. (2024) A systematic literature review of technological developments and challenges for inland waterways freight transport in intermodal supply chain management, *Benchmarking: An International Journal, Vol. ahead-of-print No. ahead-of-print* doi.org/10.1108/BIJ-03-2023-0164 (Published).

2. Gbako, S., Paraskevadakis, D., Ren, J. and Wang, J. (2024) Digitalisation and decarbonisation challenges of inland waterways freight logistics transport and their integration into regional supply chains – a case study, *Logistics, Supply Chain, Sustainability and Global challenges,* 14(1), pp. 1 – 23 Doi: 10.2478/jlst-2023-0008 (Published).

Chapter 1: Introduction

1.1 Introduction

This chapter offers a general research background, as well as precise research questions, the goals and objectives of the study, its scope and research techniques. The thesis outline covers all influencing factors that significantly determine the overall performance of Inland Waterway Transports (IWT), including identification of influencing factors, an integrated set of indicator assessments, and evaluation.

1.2 Background

Following the growth in world trade, the transportation industry has accelerated, placing the sector at the forefront of the national economy and social development (European Commission, 2019). Globalisation has increased the demand for local and international transport (Dobre et al., 2021) expanding the complexity of the business environment (Pondsorin and Ovsiannikova, 2021). With the recent boost in economic growth, these growing cargo demands have raised concerns about increased commercial traffic, which has contributed considerably to road traffic congestion and environmental issues, particularly from the point of view of traffic safety and road transport using fossil fuels and traffic safety. The ever-increasing acknowledgement of the external outcomes of transport has necessitated the direction of a more sustainable transport mode (Macharis et al., 2011; Barrow et al., 2022). One of the leading transport policy objectives of the European Commission is to shift the balance between modes of transportation. With the publication of its 2011 transport white paper (European Commission, 2011), "Roadmap to a single European transport area", – the European Commission aims to optimise the performance of the logistics chain by shifting 30% of freight transported by road over 300 km to environmentally friendlier modes with lower societal impact, such as rail and waterborne transport by 2030 and a little over 50% by 2050.

The current transport 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 (Kozerska, 2016; Borca et al., 2022). At the European level, inland navigation has continued to play a significant role in the hinterland connectivity of Western-European ports. European policymakers are more concerned about the stimulation of inland waterways as part of the modern intermodal logistic chain. As defined by Macharis and

Bontekoning (2004), intermodal transport refers to the transportation of goods using at least two different modes of transport stored within the same loading unit with most of the route transited using railways, waterways or ocean-going vessels with the initial and last leg of the journey performed by road. Inland shipping is seen as a sustainable, efficient, and good alternative to rail and road modes of freight transportation. Compared to other land-based modes of freight transportation, inland shipping has unused capacities in some geographical regions (Wang and Li, 2013; Golebiowski, 2016; Plotnikova et al., 2022), and is remarkably sustainable since it emits three times less Carbon dioxide (CO_2) than the road, has lower energy consumption, reduces external costs and is almost congestion-free (Hofbauer and Putz, 2020; Grosso et al., 2021; Bazaluk et al., 2021). Another significant supporting point for moving freight from the road onto waterways is its high degree of safety, particularly regarding transportation of dangerous (Huang et al, 2021).

Despite the benefits offered by this transport mode, some questions have been raised over its green credentials, digitalisation, transport system efficiency and reliability (Beyer, 2018; Restrepo-Arias et al., 2022; Specht et al., 2022). Both national and international authorities have advocated shifting from road to alternative modes of freight transport. For example, the European Union (EU) has, over the last two decades, devised and promoted various initiatives, including Macro-Polo (European Commission, 2013), Ten-T and Motorways of the sea (European Commission, 2020), the Navigation and Inland Waterways Action and Development in Europe (NAIADES I-III), an action programme with measures that will enhance the framework condition of the sector while also boosting economic and environmental performance. All these various initiatives were designed to induce a shift from road haulage to alternative modes of transport (Garcia -Menendez and Feo-Valero, 2009; European Commission, 2017; Razah et al., 2020; Takman and Aregall, 2023). Depending on favourable conditions, achieving a modal shift may be more or less complicated. An extensive portion of freight transport is transported via waterways in central Europe, including the Rhine-Main-Danube corridors (Havinga, 2020) and the hinterland of ports of Hamburg, Antwerp, Rotterdam, and Marseilles-Fos-Sur-Mer in North-western Europe (Kotowska et al., 2018). A significant fraction of freight movement is seen in this part of the region, with the Netherlands having the largest share of IWT within the EU (CBS, 2019; Calderon-Rivera et al., 2024).

In 2021, 6% per cent of the overall domestic waterborne freight traffic in the UK was accounted for by IWT (Department for Transport, 2022). Despite the available capacity, inland shipping is barely utilised for freight shipment in the UK. Whilst it must be acknowledged that much of Europe’s natural geography is also helpful, for example, such as the length of the Rhine-Main-Danube Corridors compared to the length of the Thames, there are undoubtedly lessons to be learned from continental Europe.

Increased competition is a common factor across all industries since it fosters better performance and a need for high-quality services. The constantly increasing supply chains and the affiliated demand for reliability and efficiency necessitate enhanced performance and standards of measurement (Djordjević et al., 2023). Countries like the Netherlands, Germany, and Belgium have increasingly integrated inland shipping into their transport networks and logistic chains. The Netherlands and Germany alone were accountable for a total EU flow of full containers on inland waterways of more than 70% in 2020 (Eurostat, 2022). The integration into supply chains requires that inland shipping enhance its services, planning ability, reliability, flexibility, and operation traceability. Such components are comparable with the affiliated features available in other modes of transportation today.

Despite the ample spare capacity in the UK, freight transported by waterways only accounted for 6% of the total inland freight volume as of 2021 (Department for Transport, 2022; Eurostat, 2022).The benefits of shifting more freight onto waterways are clear, apparent and in alignment with the policy of the UK government and globally. In particular, environmental policies provide a solid basis to support the use of inland waterways for freight transportation (Department for Transport, 2022). In continental Europe, the business competitive environment forces decision-makers to understand the key factors that drive performance on the individual or company level for quality improvement and benchmarking. Beyond the individual or company level, a common acceptable understanding of definitions, reference or measurement standards and performance indicators are needed to ensure correct decision-making and improved competitiveness, especially in the UK perspective. By identifying the causes and effects that directly and indirectly affect achievement objectives and production of the corresponding results, these performance indicators offer efficient and practically accepted approaches to enhance decision-making.

This thesis poses the following research questions, which are addressed in this study.

RQ1. What are the main relevant factors determining the perception of performance in the IWT industry, and how can those influencing factors be addressed?

RQ2. What are the primary sources of performance factors impacting the efficiency and competitiveness of the IWT system, and how can these factors be identified and categorised?

RQ3. Which influencing factors are relatively more significant in improving the performance of the IWT network?

RQ4. What best practices can the UK adopt from continental Europe regarding the use of waterborne transport for freight?

1.3. Aim and Objectives

The aim of this research is to analyse the influencing factors that significantly determine the overall performance of inland waterway transport in order to support appropriate decision-making and improve the competitive position of inland navigation in the modern industrial supply chain.

The objectives are summarised below.

RO1. To review the existing and current state-of-the-art implementation of performance measurement in inland waterway transport and also to explore the characteristics of the intermodal inland waterway logistic chain.

RO2. To identify and select appropriate research setting for gathering and analysing primary data as well as to evaluate the key performance factors and their interdependence within the boundary of inland waterway transport operations in the research setting.

RO3. To develop a decision-making model to measure and evaluate the performance and assess the state-of-the-art for inland waterway transport in the regional cases study.

RO4. To examine the appropriateness of the proposed framework and analytical models by conducting empirical research in order to identify the most effective and efficient approach for enhancing the performance of inland waterway transport within the intermodal transport chain.

RO5. To examine the river-sea transport logistics through a gateway case studies concept that will justify and demonstrate the practicality of the proposed framework in terms of services and operations.

1.4 Research Scope

The diverse entities involved in the IWT network include various aspects (i.e., information sharing, reliability, services, flexibility, and traceability of operation) and numerous stakeholders and actors participating in the IWT are intertwined into a complex system. This system has high complexity, many interdependencies and diverse stakeholders impacting system performance through decision-making processes. Intermodal inland navigation, on the other hand, is a significant issue with numerous viewpoints from which to examine the related process. As a result, it is essential to establish the study’s boundaries early on in order to create significant findings. The approach taken in the current study is centred on the unique characteristics of inland navigation. It detects the basic parameters, conditions, and influences of the inland waterway navigation system to establish a general overview of the system environment.

According to the existing literature, most research has concentrated on enhancing technical and economic performance, improving cooperation through information exchange systems, addressing environmental concerns, and ensuring safety. Comparing the IWT system to the single mode of road transport, there is a lack of general insight into the overall performance of the system. Moreover, when the performance of transport is assessed, it typically involves a single scenario unique to a particular country. From the point of view of improving quality benchmarking, there is a lack of insight into the variable that affects modal shift decisions and the factors that drive performance beyond the level of the country or the individual.

This study primarily focuses on how all pertinent aspects and factors, including infrastructures, resources, stakeholders, processes involved, critical success factors, traffic conditions, and policy, can be captured and modelled to determine how well inland waterway transport is perceived to be performing. Measuring the performance of inland waterway transport is the primary goal of the work discussed here. One of the key objectives is to draw attention to effective practices and help the entire transportation sector operate better. However, perceptions must shift from the company to the sector level to compare mode of transport. This will make possible system-wide performance improvements and increased competitiveness of inland navigation, with all relevant system participants effectively supporting the decision-making processes.

Therefore, the relevant aspects and factors covered in this thesis are related to performance improvement, increased environmental sustainability, increased competitiveness, management of growth, and shifting trade trends. The geographical focus of the research within this thesis is continental Europe and the United Kingdom (UK). The gateway approach used in this research is based on a pivotal European and UK maritime freight transport axis where modal transport changes could occur using inland waterways, roadways, and railways.

The study's gateways are geographically located between maritime and terrestrial flows within the geographical region under consideration. Each gateway has a different level of maturity and qualities to enhance the development and use of inland waterways in its domestic freight logistic system. The position of IWT along corridors depends on conditions in corresponding seaports and the density of waterway and inland terminals in their hinterland. The Netherlands, Germany, Belgium and the France have been selected for this research because the waterway transport network in these countries is connected to major ports such as Rotterdam, Hamburg, Antwerp, and the Seine form vital hubs for import and export from other parts of Europe.

The countries provide a good case for the research because they have similar features of river-sea connectivity and extensive inland waterways corridors. European seaports interact with river transportation by following the needs and patterns of globalised flows. Due to growing volumes of handled goods and supply chain integration, IWT involvement directly results in increased integration in modern logistics chains. In light of these developments, this region's IWT industry is being pushed to expand and redefine its goals, operations, and strategic positioning. The advantages of transferring much freight to the waterways are also evident, straightforward, and consistent with the UK government's top policy priorities. Several official reports in the UK highlight the advantages of shipping goods by waterways. Environmental policies favour freight transportation by inland waterways because they significantly reduce traffic congestion, energy use, and emissions. Consequently, even though it must be acknowledged that much of Europe's natural geography is more advantageous - the length of the Rhine and Danube, for instance, compared to the length of the Thames - there are undoubtedly lessons to be learned from the continent itself.

1.5 Research Methods

Every industry is united by increased competition, which spurs better performance and a desire for high-quality services. The need for increased performance and measurement standards is driven by supply chains constantly expanding and the associated demand for efficiency and reliability. This thesis employs a deductive research methodology, utilising data triangulation through a combination of qualitative and quantitative research approaches. The study’s primary objective is to create a comprehensive framework and an integrated set of indicators for identifying and assessing the factors that influence the performance of IWT. Notably, it explores and highlights current best practices contributing to the performance of IWT in the research setting. The empirical study was chosen better to grasp the system's high degree of complexity and help the researcher and practitioners thoroughly investigate these real-life issues. Few scholarly works report empirically based in-depth investigations of influencing factors that significantly impact the industry's performance. Even where performance is empirically analysed, it is primarily associated with cases specific to a particular country. Thus, the empirical studies were conducted in continental Europe (The Netherlands, Germany, Belgium, and France and the UK).

Relevant literature and statistics associated with the topic of interest were reviewed to identify the influencing factors that significantly impact the overall performance of IWT and the variables that influence decisions to switch modes in the domain of IWT. Data were gathered by reviewing extant literature papers on the topic and statistics on IWT in Europe and the UK to comprehend further the historical development, the state of the art with regards to freight transportation activities, respective infrastructures investment made by the government, as well as relevant input from some ongoing and completed transnational research projects in promoting inland waterways for freight transport. Experts' advice and guidance were then sought through a questionnaire and semi-structured interview for validation. Site visits and interviews with some sector players were chosen based on their expertise and contributions to the relevant field. They include industry practitioners, professionals in the transport domain, transnational research project partners, academicians from supply chains/intermodal inland waterway transport backgrounds, and researchers who better understand the practical scenarios of inland waterway transport and their related policies. The participant experts had experience ranging from 5 years to 40 years, providing the necessary balance of experience and ingenuity. Most of these survey respondents hold a position at or beyond the managerial level and have the authority to make decisions within their various operating organisations where they operate.

A pilot study addressed content ambiguity and other biases in the questions. The expert's opinions were gathered by emailing the developed questionnaires to the experts. First, the initial questionnaire and cover letter were drafted. A cover note or letter was attached at the beginning of the questionnaire describing the study's main aims and assuring the participant of the strict confidentiality and anonymity of the data supplied in the questionnaire, which is safeguarded under *Liverpool John Moores University’s Ethical Guidelines*. The study investigated the reliability and appropriateness of a proposed hierarchical model structure through a sequence of emails and planned interviews. The AHP (Analytical Hierarchy Process) and its fuzzy extensions, namely fuzzy AHP, were applied to analyse the responses collected from the questionnaire and obtain more definitive judgements. The study uses the TOPSIS (Technique for Order Preference by Similarity of Idea Solution) to benchmark the performance or rank the present case study with other case studies.

1.6 Structure of The Thesis

The thesis contains seven chapters. Figure 1.1 illustrates the arrangement of these chapters and is described as follows:

Chapter One - Introduction: Chapter one presents the general overview of this research background, research aim, objectives, scope, the methodological approach, and structure. It briefly reviews the research requirement and outlines how the study will be conducted.

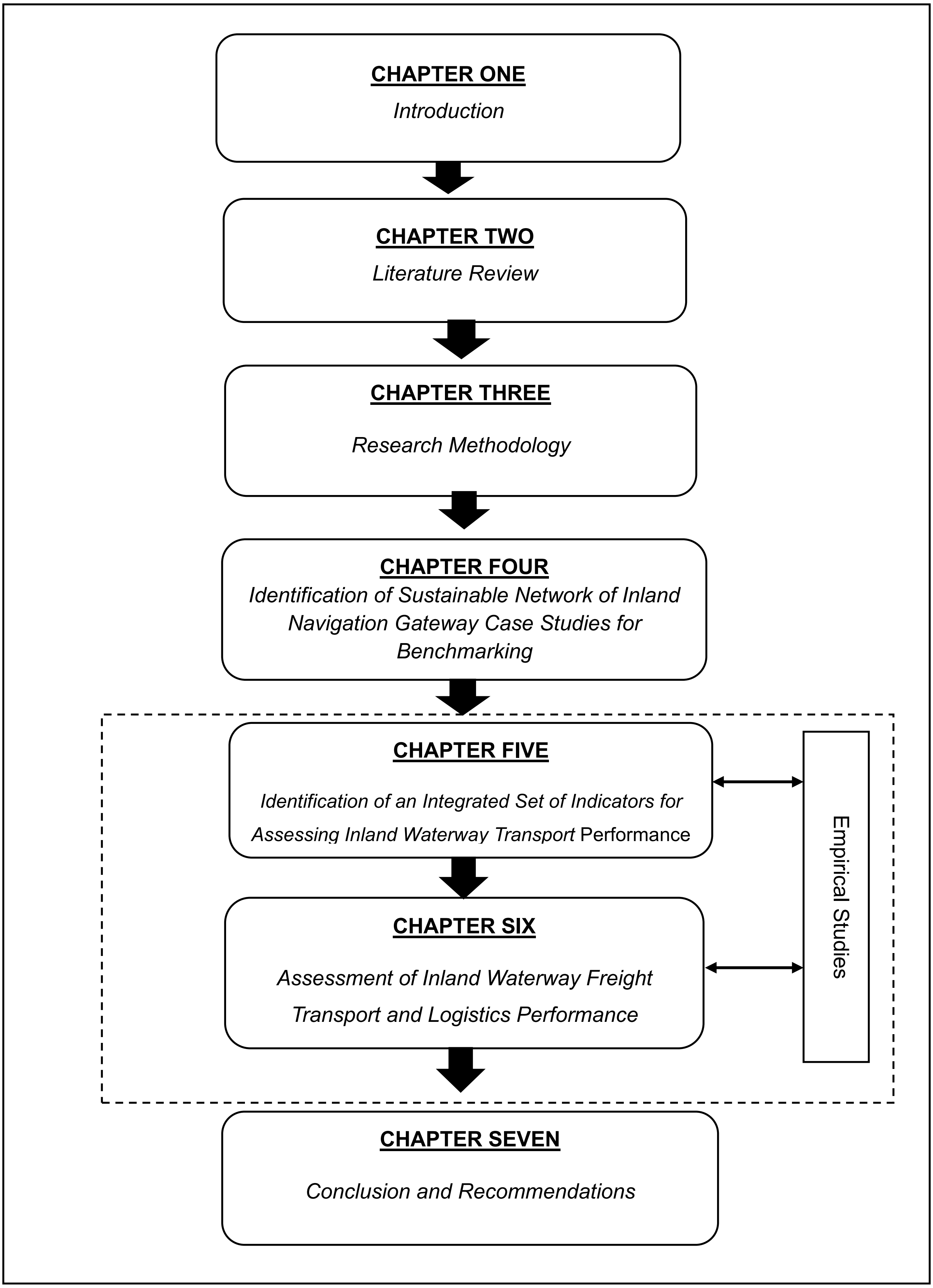

Figure 1-1: Structure of The Thesis

Source: Author work

Chapter Two – Literature Review: This chapter comprehensively analyses the existing literature on the concept and characteristics of the intermodal inland waterway transport and logistics chain in the European context. It also examines the present state of performance evaluation in the domain of IWT and the current studies that exist in relation to performance measurement. Eventually, certain research gaps are discovered.

Chapter Three - Research Methodology: The foundation on which chapters five and six of this thesis are built is presented in this chapter. This chapter presents the methodology used to address the research's objectives. The chapter further discusses the philosophical assumptions underpinning this research, research approach, strategies, choice, and design. The subsequent sections and sub-sections of the chapter explain and justify the research methods used throughout the study.

Chapter Four – Research Setting: Identification of Sustainable Network of Inland Navigation Gateway Case Studies for Benchmarking: This chapter sets the scene for this study. The chapter discusses the general overview of maritime gateways, particularly in Europe and other parts of the world, where waterborne transportation is an essential component of these gateway domestic logistics systems in more detail. The chapter concludes by describing the case study, which includes The Netherlands, Germany, Belgium, France and two UK maritime gateways, the Thames and Liverpool/Manchester gateway, for the application of the methodological tools and techniques for the assessment of appropriate transport services performance indicators for regional logistics gateways involving inland waterways. The next chapter offers an in-depth view of the selected maritime gateways by providing an integrated set of indicators for assessing inland waterways transport performance.

Chapter Five – Identification of an integrated set of indicators for assessing inland waterway transport performance: This chapter identifies performance indicators in the IWT transport domain. A questionnaire was designed, and survey was conducted to make inferences about the attitudes and opinions of industrial and academic experts. The aim is to show how all relevant elements and factors that define the perception of performance in the domain of inland shipping may be captured and modelled through experts' opinion surveys. Based on the results obtained from the survey, the outcomes are embedded into the structure of the system model and further validated through a series of emails with the experts so that they may comment on the final results.

Chapter Six – Assessment of Inland Waterway Freight Transport and Logistics Performance: Integrated Set of Indicators: This core technical chapter focuses on assessing the identified performance indicators in the IWT transport domain. This model aims to determine the relative significance and identity the performance criteria with the most significant weight to consider when performance measurement is carried out. Here the subjective knowledge and judgment of the experts in the field are utilised in the model to provide data for analysis using the two-step fuzzy analytic hierarchy process (FAHP) and the technique for order preference by similarity to ideal solution (TOPSIS) method. In this chapter, data were collected through empirical studies by rolling out the second round of the survey questionnaire.

Chapter Seven – Conclusion: The key findings and conclusion of this thesis are presented in this chapter. The actualisation of the research objectives is further discussed, as also the research's genuine contributions. The research limitations of this thesis are suggested, and the chapter provides the agenda for future research direction and recommendation.

1.7. Delimitation of the Study

A delimitation of this thesis is the studied geographical area. This thesis focuses on IWT in the Netherlands, Germany, Belgium and France due to their improved capacity to integrate IWT into their contemporary logistic chains where its cost, capacity and regularity advantages find their place. In the UK, the area of application of the findings from the case study countries is mainly the waterways starting from central London to the Thames estuary, and eventually, out into the North Sea. At the same time, the Atlantic gateway on the northwest coast of England in the port of Liverpool leads from the Mersey estuary straight into Manchester, as well as the interconnecting hinterlands which surround both cities. This Atlantic gateway provides services to consumers with multimodal options, including rail, road and waterways. In order to limit the report's scope and enable comparison of the researched areas, geographical delimitation is necessary.

1.8. Terminology

This section contains a glossary of the terms used to describe the key ideas in this thesis.

Transportation: The movement of people and/or products from one location to another. It combines traffic and transportation: Transport is the movement itself, while traffic is the mechanism by which it is carried out (Arnas, 2007).

Inland Waterways (IWW): Waters on the mainland that can be used by vessels with a minimum 50t carrying capacity when fully loaded are known as Inland Waterways. These include rivers, lakes, and canals that can be navigated (Mohanta et al., 2023).

Inland Waterway Transport (IWT): Any movement of goods made possible by navigable inland waterways that involve inland waterway vessels (Eurostat, 2020).

Intermodal Transport: The transportation of goods utilising at least two different modes of transport stored within the same loading unit, with most of the routes transited using railways, waterways, or ocean-going vessels, with the initial and last leg of the journey performed by road (Macharis and Bontekoning, 2004).

Modal Share: The term "mode share" refers to the proportion of total journeys, volume, weight, vehicle performance, or transport performance (measured in vehicle, tonne, or passenger-kilometres) that is attributed to different modes of transportation, such as road, rail, inland water, maritime, air, and non-motorized transport. The term "modal share" in this study specifically refers to the distribution of transportation usage across the three primary land transport modes: road, rail, and inland waterways (Eurostat, 2022).

Navigable Inland Waterway: A body of water not part of the sea that is navigable, especially by inland vessels due to its natural or artificial features. This phrase refers to navigable estuaries, canals, lakes, and rivers (Eurostat, 2021).

Inland Waterway Vessel: A floating vessel intended for public transportation of people or products that mostly travel in navigable inland waterways, the waters surrounding sheltered regions or other designated port-related areas (Eurostat, 2021).

RIS: River Information Services (RIS) are contemporary traffic management tools providing quick electronic data transfer between water and shore by exchanging information in real-time and advance (RIS COMEX, 2020).

tkm (tonne-kilometres): is a unit of measurement for tracking transportation output that represents the carriage of 1 tonne over a distance of 1 km and is determined by dividing the amount carried in tonnes by the number of kilometres travelled. Only the distance inside the reporting country's national boundaries is considered for national, international and transit transportation (European Court of Auditors, 2015).

Hub and Spoke Network: A distribution architecture where a central hub functions as a consolidation point for both incoming and leaving cargo. It serves as a central transportation hub, where goods from different areas are gathered, organised, and subsequently distributed along specific routes to their respective destination. The network structure facilitates the smooth movement of goods, enabling enterprises to optimise their transportation operations by cutting transit times and streamlining their transportation procedures (Pels, 2021).

Transport Performance Indicators: Measures used to empirically evaluate the technical performance of various transportation modes (Isoraite, 2005).

Chapter 2. Literature Review

Inland waterway transport and river-sea shipping have been widely recognised as sustainable and efficient road and rail freight alternatives. They play vital roles in connecting inland terminals with global supply chains by providing reliable, safe, low-cost, and environmentally friendly freight transport. The seamless integration of these transport systems into modern industrial supply chains requires improved services and quality, which is needed to allow competitive transport on inland waterways.

This chapter describes how a rigorous systematic literature assessment is carried out to identify gaps and define the research problems in this study. The literature review in this study comprises two key areas crucial to the research: IWT system performance and intermodal IWT. Each key area is meant to provide a precise focus on the Inland waterway freight transport system. The combination offers a thorough foundation for the current study.

2.1 Background and Rational for the Review

Transport is a critical services industry that promotes mobility and growth for regions and countries. It consists primarily of road, rail, waterways, and air. Transportation is identified as a required field for a competitive economy, especially in the European common market. It has been acknowledged that the freight transportation network is regarded as the backbone of the supply chain since it makes it possible to distribute commodities effectively while also making it easier to reach distant markets (Baran and Gorecka, 2018). The freight transportation industry has perceived the rising pressure from the globalised market flow, and cargo flow in the European Union (EU) has been actively growing in recent decades. The demand for transport services has increased the intensity of inland transport activities, explicitly on-road modes of transport. This situation has led to surging environmental concerns, traffic safety and reliability. It has become a dominant factor in motorisation and highway traffic congestion, which has led to a significant decrease in motorway capacity (Raza *et al.,* 2020; Struyf *et al.,* 2022). This has raised considerable concern amongst the research communities and policymakers regarding the need to consider alternative freight transport modes to reduce road network usage for freight transport and other related transport externalities (Riha *et al.,* 2022).

Within Europe, the European Commission's (EC) key policy objectives for freight transport have been to work towards a transport concept that provides sustainable, energy-efficient and environmentally friendly transport networks (Pietrzak and Oliwia, 2020). From a regional policy level, this has been characterised by promoting co-modality with the best use of two or more modes of transport independently and combined to get the most significant benefits for the entire journey. As environmental and sustainable concerns are becoming increasingly important (Sys *et al.,* 2020), these have prompted the European Union to outline its ambition to decongest and decarbonise freight logistics transport (European Commission, 2020). One of the EU's primary goals and its constituent member states is to significantly decrease Greenhouse Gas (GHGs) emissions to fulfil the targets outlined in the Paris Agreement. The European Green Deal articulates the aspiration to attain carbon neutrality by 2050. In the context of transport, which presently contributes to 24.6% of the European Union's overall emissions (Haas and Sander, 2020). The European Green Deal proposed a target of achieving a 90% reduction by the year 2050 compared to the emission levels recorded in 1990 (European Commission, 2019).

Similarly, European experts have projected road freight transportation activities to grow by 40% by 2030 and just over 80% by 2050 (European Barge Union, 2021). Hence, to meet these challenges, the freight transportation industry is compelled to develop measures to reduce GHGs while also handling the projected growth in freight transport that the increasingly globalised market flow has caused. As advocated by Plotnikova *et al.* (2022), freight transportation by inland waterways can play an essential role in sustaining and contributing to the low-carbon economy set out by the EU. Although, despite the increasing importance of environmental factors, they continue to be regarded as a secondary factor in decision-making, following transport prices (Jung *et al.,* 2019). The adverse effects of transportation, including pollution, climate change, noise, traffic congestion and accidents, continued to challenge European inhabitants' economy, health, and overall well-being.

Within Europe, there has been a rising acknowledgement of IWT’s potential to provide a viable and competitive alternative to road and rail modes of freight transportation (Roso *et al.,* 2020; Rogerson *et al.,* 2020; Specht *et al.,* 2022). This mode of transport has been identified as a viable long-term answer to the societal difficulties that road and rail freight transportation encounter. Inland navigation and river-sea shipping are essential in accommodating the projected increase in freight transportation activities and alleviating congested road and rail networks in some of the most densely populated areas (Felipe *et al.,* 2023). Nevertheless, the untapped potential of this transportation mode remains unexplored. IWT emits three times less Carbon dioxide (CO_2) emissions compared to road, and consequently, IWT stands out as the most energy-efficient mode of transportation. Therefore, to achieve the European Commission's objectives in reducing GHGs emissions, it is imperative to fully exploit the potential of IWT through a modal shift concept in its favour.

The European transport policies have promoted several improved strategies with a range of specific targets, one of which aims to optimise the performance of multimodal logistic chains; this includes a modal shift towards more sustainable and energy-efficient transport modes such as rail, IWT and short sea shipping (Russell *et al.,* 2019). The ambition is to shift 30% of EU road freight over 300 km to a more sustainable mode by 2030; this figure is forecast to increase to 50% in 2050, facilitated by efficient and green freight corridors as set out in the White Paper, "Roadmap to a single European Transport Area" (European Commission, 2011; European Commission, 2020).

Since fitting significantly to a large extent on the political agenda, the usage of waterways for freight transportation has increased as the transport system has continued to play an essential role in the hinterland connectivity of Western European seaport (Kotowska *et al.,* 2018(a). According to the demands and rhythms of globalised flows, the seaport interfaces with IWT. Waterway transport players are becoming more integrated into modern logistics chains due to the increased handling of goods and the incorporation of supply chains (Beyer, 2018). This advancement compels the IWT industry to adapt and reinvent its operations and strategic positions. While the UK has an existing waterways route, the road remains the most dominant means of freight transportation within the UK (Bury *et al.,* 2017; Tardivo et al., 2022). The UK's inland waterways are used less for freight transportation than in continental Europe (Wiegmans, 2018). Although, to a large extent, the natural geography of the European mainland has been recognised to be of much support when compared to the UK, i.e., the Rhin-main-Danube corridor length compared to the River Thames or the Manchester Ship Canal (MSC) (Ines-Danube, 2017).

Nevertheless, Europe offers some valuable lessons. The benefits of shifting freight onto waterways are clear, conspicuous and in line with the increased policy objectives of the United Kingdom (UK) government (Department for Transport, 2017; Department for Transport, 2020). In particular, environmental policies provide a solid rationale to sustain the use of IWT as an alternative transport mode for freight. The Department for Transport (DfT), metropolitan transport agencies and other private entities have continued to explore different pathways to use investment strategies and modal shift incentives for effectively utilising all parts of the transportation system for freight.

Therefore, to gain from the increasing transport demand in Europe and the UK, the IWT must enhance the quality of its services. The continuously expanding supply chains and the associated demand for efficiency and reliability necessitate enhanced performance and measurement standards. Enhanced competitiveness serves as a uniting factor across various industries, leading to enhanced performance and a heightened need for high-quality services.

Therefore, it is necessary to develop new techniques and instruments for evaluating the effectiveness of IWT in order to ensure accurate decision-making and increased competitiveness. Hence, it is crucial to consider the interconnected processes, the stakeholders involved, and the extent of the underlying system.

2.2. Inland Waterway Transport System

The IWT has been under increasing pressure in recent years to improve its service quality in order to meet Europe's rising transport demand (Paulauskas et al., 2022). The increasing demand and competition in the freight transport sector have been attributed to several factors, including globalisation (Fruth and Teuteberg, 2017; Dobre et al., 2021), variation in customers' preferences (Bernardino, 2015), rapid advancements in Information and Communication Technology (ICT) (Chatti, 2021) and resources constraints experienced by both commercial and public services providers (Micheal et al., 2022). This development compels the IWT industry to adapt and reinvent its operations and strategic positions.

The European Commission has acknowledged the significant potential of IWT as a viable alternative form of transportation for freight. The sector is an integral part of the European supply chain and contributes to the competitiveness of the EU economy. According to Takman and Aregall (2023), European policymakers are more concerned about the stimulation of inland shipping within the intermodal transport chain due to their sustainability and less congested operational approach. Even more than before, the IWT has increased its reliance on maritime access. In accordance with the needs and rhythms of globalised flows, the seaport interface with IWT. IWT players are consequently becoming more integrated into modern logistics. Thus, most of the major seaports in Western Europe are now prioritising the role of inland waterways in their hinterland transportation (Rolbiecki, 2018).

Nevertheless, statistics reveal that there has been a noticeable trend of stagnation in the transportation of goods over inland waterways throughout Europe in recent years (European Court of Auditors, 2015; Némethy et al., 2022). Currently, there is a prevailing preference for road transportation in both the UK and the European freight transportation industry (Tardivo et al., 2022; Nkesah et al., 2023). The road reigns supreme in freight transportation and has kept its leading position in the modal split calculation in terms of transport performance (based on tonnes-kilometre performance). The rail and IWT have a small market share compared to road transport, and the fundamental cause is the inadequacy of rail and IWT to satisfy current customers' demands (Mako and Galierikova, 2021). Providing high service quality to customers has been found to result in both customer satisfaction and customer loyalty toward the service provider (Franceschini and Rafele, 2000; Davis and Mentzer, 2006; Baki et al., 2009; Arabelen and Kaya, 2019). As supply chains continue to expand, firms face the challenge of managing the complex networks of the chains (Gurzawska, 2019). This high complexity increases the risk of disruptions, delays and sometimes inefficiencies in the supply chain. In order to reduce these risks and ensure smooth operations, firms increase focus on improving performance and measurement standards. The freight transportation industry recognises that a well-functioning supply chain is essential for meeting customers' demands, cost reduction and gaining a competitive edge in the market. Hence, to effectively meet future challenges and improve the competitive advantage of IWT, these transport modes must enhance their servers' quality, reliability, planning capabilities, operational traceability, and flexibility. These attributes should be comparable with the corresponding aspects already offered in road freight transport. This is precisely where the laborious component becomes relevant. Due to IWT's substandard service quality, these modes have limited significance in the modal split. As a result of their small market shares, there is very little competition, thus preventing them from making substantial advancements to grow their market shares. According to Golner and Beškovnik (2021), a vicious cycle arises from this dynamic interdependence. Hence, it is necessary to explore new ground to deviate from routines while selecting a mode of transportation. Therefore, it is essential to create Performance Indicators (PIs) that accurately capture the IWT's overall performance.

In practice, there are many different taxonomies because PIs are often established at individual or group levels for quality improvement and benchmarking. The inland waterway freight transport industry has been negatively impacted by these diverse nomenclatures, which makes comparisons nearly impossible. This phenomenon becomes particularly evident when managers are inclined to address their supply chain issues by implementing myopic solutions. Lowering uncertainty and improving distribution channel controls requires extensive ties and collaboration between businesses and their upstream and downstream suppliers and customers. Bozuwa et al. (2012) proposed specific applications of benchmarking methodologies that fail to capture certain critical IWT features. According to Kozerska (2016), the primary methods for enhancing operational performance in the inland waterway sector are performance measurement and process redesign.

However, researchers and practitioners must possess a comprehensive understanding of the underlying process in order to derive an advantage from the selected methods. Similarly, it is imperative to have a thorough understanding of the interconnected problems that arise in the services delivery process and the supply chain within the context of freight transportation. This is because factors such as reliability, planning, flexibility, quality, quantity, cost and traceability of operations are almost interconnected (Huang et al., 2019).

In general, the freight transportation industry is currently experiencing significant and expeditious transformations in its operational dynamics. As such, it is critical to develop solutions that optimise the performance of the transport logistic chain while maintaining flexibility to the industry's shifting trends (Demir et al., 2020).

This section's objective is threefold. First, it presents an overview of the existing and state-of-the-art application of performance measurement in IWT studies conducted between 2003 and 2022. Second, it comprehensively examines the advancements in intermodal IWT and logistic research in the European setting. Third, the literature is analysed to investigate potential gaps.

2.2.1. IWT performance evaluation research methodology

A literature review is a significant addition to a research work since it offers a comprehensive examination of existing scholarly works, providing a historical context for various research domains and a detailed analysis of independent research work (Ahn and Kang, 2018). A systematic literature research study was employed to eliminate bias and increase the validity of the results. A systematic review entails a rigorous and comprehensive analysis of existing research, aiming to provide a critical synthesis of the available evidence to systematically identify, select, and synthesise all studies published on a specific topic or question (Owens, 2021). 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). Specifically, the research employed the rigorous scientific methodology suggested by Winchester and Salji (2016) for conducting literature searches and evaluating retrieved information. The research used four major phases: planning, searching, screening and extraction. As shown in Figure 2.1, the flowchart of the systematic research approach details the review process in detail.

2.2.1.1. The planning phase:

Identifying appropriate keywords for the literature search constitutes an essential component during the initial planning stage of the research.

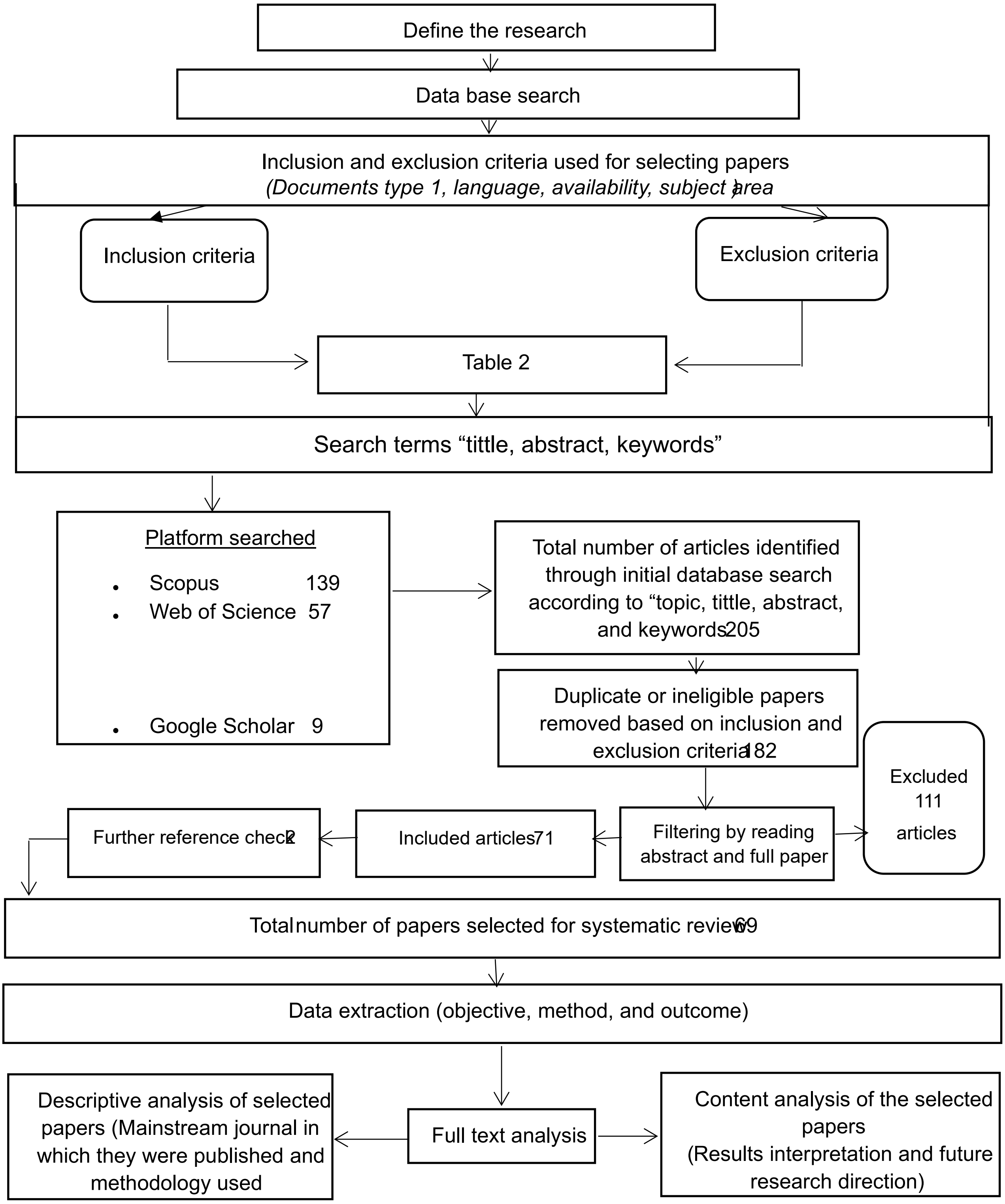

Figure 2-1: Main steps the systematic review followed.

Source: Author work using search keywords. Procedure adapted from Tranfield *et al*. (2003). Okoli (2015), Davarzani *et al.* (2016), Winchester and Salji (2016), Raza *et al.* (2020) and Chowdhury *et al.* (2021).

Designing a suitable structure for using keywords in a literature search was done through an iterative method following Davarzani et al. (2016). The procedure involved several stages: initial identification of keywords and search framework, evaluation of retrieved articles and journals to ensure adequate coverage, refinement of keywords to exclude irrelevant articles and subject areas, and subsequent adjustment of the keyword structure. Table 1 presents the tired framework of the literature search using Boolean operators and keywords (Davarzani et al., 2016).

The research 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 and title searches were used in this article selection based on the proposed topic and the questions. The following keywords and titles were included in the initial search strings: "inland navigation", “inland waterway transport” inland shipping", “waterborne transport”, “river transport”, "intermodal transport", "performance", "measurement", "environmental performance", "transport performance", "air quality performance", "logistic performance", "logistic service quality", “sustainability performance measurement” “economic performance”, and "performance measurement systems". The iterative keyword and titles 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, "measure" is obtained from "measurement".

When two keywords are separated by AND, each returned article must contain both. Using OR indicates that the retrieved article will have either or both keywords. Table 1 shows how the independent research was conducted using titles, abstracts, and keywords and presents the search strings used for the individual database.

2.2.1.2. 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 (Martinic et al., 2019). 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. The search scope was limited to papers published between 2003 and 2022. 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; Rivera et al., 2020).

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 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; Lame, 2019). Therefore, 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. 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. A total of 205 papers were found during the search. The publications' abstracts were thoroughly reviewed to verify whether they addressed IWT-related topics, including performance measurement, logistics services quality, and identifying research gaps. The search scope was limited to papers published between 2003 and 2022.

Table 2-1: Databases searching with a different tittle, abstract and keywords for relevant papers

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 (intermodal IWT OR waterborne transport) OR (IWT performance OR IWT measurement) OR (transport performance or transport measurement) AND (logistic performance OR logistic measurement) AND (environmental performance or environmental measurement) AND (sustainability or sustainability measurement) AND (economic performance OR economic measurement) AND (performance measurement systems OR performance measures) AND (performance OR measurement)
Web of Science	Title, Abstract, Keywords	(“All metadata”: (IWT OR IWT) OR (IWW OR IWW) OR (inland navigation or inland shipping) OR (IWT performance OR IWT measurement) OR (environmental performance OR environmental measurement) OR (transport performance OR transport measurement) AND (logistic performance OR logistic measurement) AND (economic performance OR economic measurement) AND (performance measurement systems OR performance measures) AND (performance OR measurement)
Google Scholar	Title, Keywords	TITLE-KEY (Title: IWT OR Key: IWT) OR (IWW OR Key: IWW) OR (Title: IWT performance OR Key: IWT measurement) OR (Title: environmental performance OR Key: environmental measurement) AND (Title: transport performance OR key: transport measurement) OR (Title: logistic performance OR key: logistic measurement) (Title: economic performance OR economic measurement AND (Title: performance measurement systems OR key: performance measures) AND (performance OR key: measurement)

Source: Author work

2.2.1.3. Screening articles

Three screening phases were applied to the articles that were retrieved:

- The process of IWT serves as a means to connect the operating procedures of pre-waterway carriage transportation (pre-carriage) and post-waterway carriage transportation (post-carriage). The system limits are established at both the port of departure and destination, encompassing the intermodal transhipment facilities. These facilities serve as the access points to the IWT system. The analysis from these studies does not consider the performance values of pre-carriage and post-carriage transportation as the system does not directly impact them under investigation. Therefore, the papers related to pre-carriage and post-carriage transportation were excluded. As a result, this reduced the number of the article from 205 to 84
- The retrieved articles were examined based on their citations and the respective journals' impact factors to ascertain their high quality. Following this phase, a cumulative sum of 69 articles met the inclusion.
- Additionally, a thorough examination was conducted to verify the accuracy and completeness of the selected publications' reference lists to ascertain that all relevant articles were included in the study. 69 articles met the inclusion criteria for the IWT performance management.

2.2.2. Data extraction and reporting

The review follows the quality assessment recommendation proposed by Kitchenham and Charters (2007). After retrieving all the relevant research papers for this review, a systematic data extraction step was applied. In this step, essential information from individual research papers was obtained. The assessment procedure was carried out on all papers identified before extracting their data. The connection of these identified papers to the research questions was equally accessed, along with scrutiny for bias and data validity, 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.

2.2.2.1. Data analysis

Descriptive analysis

The data retrieved from the systematic review were thoroughly analysed by descriptive analysis to create a comprehensive overview of the chosen literature. The articles were categorised and examined to understand better the concepts on which they focus. The papers that were subjected to the descriptive analysis were examined based on four primary characteristics:

- Distribution by the journal of publication.
- Distribution of research papers over time.
- Geographical scope or location.
- Distribution by methodology.

Distribution by the journal of publication

The number of studies published each year in different scientific journals is shown in Table 3 below. Although the papers appear fragmented, the quality of research papers addressing IWT performance has consistently increased over the past ten years, as depicted in Figure 2. In this study, 69 articles addressing IWT performance have appeared in 47 scientific journals. The top ten journals were the European Journal of Transport and Infrastructural Research and the Journal of the Transportation Research Board, which rank at the top with five published papers, each among all the journals that address the area of interest. The Journal of Transportation Research Part D: Transport and Environment, Sustainability, Transport, Research in Transportation Business and Management are second, with three papers each. Transportation Research Part E, Case Studies on Transport Policy, Sustainability, Transportation Research Records, Ocean Engineering, Applied Ocean Research, Journal of Hazardous Material and European Journal of Operational Research is third, with two publications closely following these. The remaining journals have one publication each. Table 2.2. presents the number of papers in dominant academic journals.

Table 2-2: Number of papers in dominant journals

Journal	Number of papers
Case studies on transport policy	2
Transportation Research Part E	2
European Journal of Transport and Infrastructural Research	5
Natural Hazards	1
Sustainability	3
Regional Environmental Change	1
Transportation Research Part D: Transport and Environment	3
Journal of the Transportation Research Board	5
Climate Risk Management	1
Journal of Transport Economy and Policy	1
European Transport Research Review	1
Transactions on Maritime Science	1
Transportation Research Part C: Emerging technologies	1
Applied Science	1
Reliability Engineering and System Safety	1
Computers, and Industrial Engineering	1
Ocean Engineering	2
Hindawi Complexity	1
Research in Transportation Business and Management	3
Asian Journal of Shipping and Logistics	1
Applied Ocean Research	2
World Review of Intermodal Transportation Research	1
Journal of Transport Geography	1
Transport	3
Polish Maritime Research	1
Journal of Hazardous Material	2
European Journal of Operational Research	2
European Research Studies Journal	1
Annals of "Dunarea De Jos" University of Galati Fascicle Xi-Shipbuilding	1
Silva Fennica	1
Atmospheric Environment	1
The Journal of Navigation	1
IEEE Transactions on Wireless Communication	1

Journal of the Transportation Research Board	1
The International Journal of Business Excellence	1
European Labour Law Journal	1
The International Journal of Marine Navigation and Safety of Sea Transportation	1
Scientific Journal of The Maritime University of Szczecin	1
IEEE Transactions on Intelligent Transportation Systems	1
African Journal of Business Management	1
Renewable and Sustainable Energy Reviews	1
Journal of ETA Maritime Science	1
Journal of Marine Science and Engineering	1
ACM Transactions on Intelligent Systems and Technology	1
Hindawi Mathematical problems in Engineering	1
Environmental Science and Policy	1
Sensor	1
Total	**69**

Source: Author work

Distribution of research papers over time

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). As a result, academic studies are growing towards improving the inland waterways transport system's efficiency and strengthening its competitiveness as a sustainable transport system worldwide. The year-wise distribution of papers from 2003 to 2022 (both years inclusive) is shown in Figure 2.2. This review observed that most of the papers were published in the last eleven years between 2013 and 2022. The observation figures show that research interest in this topic is growing.

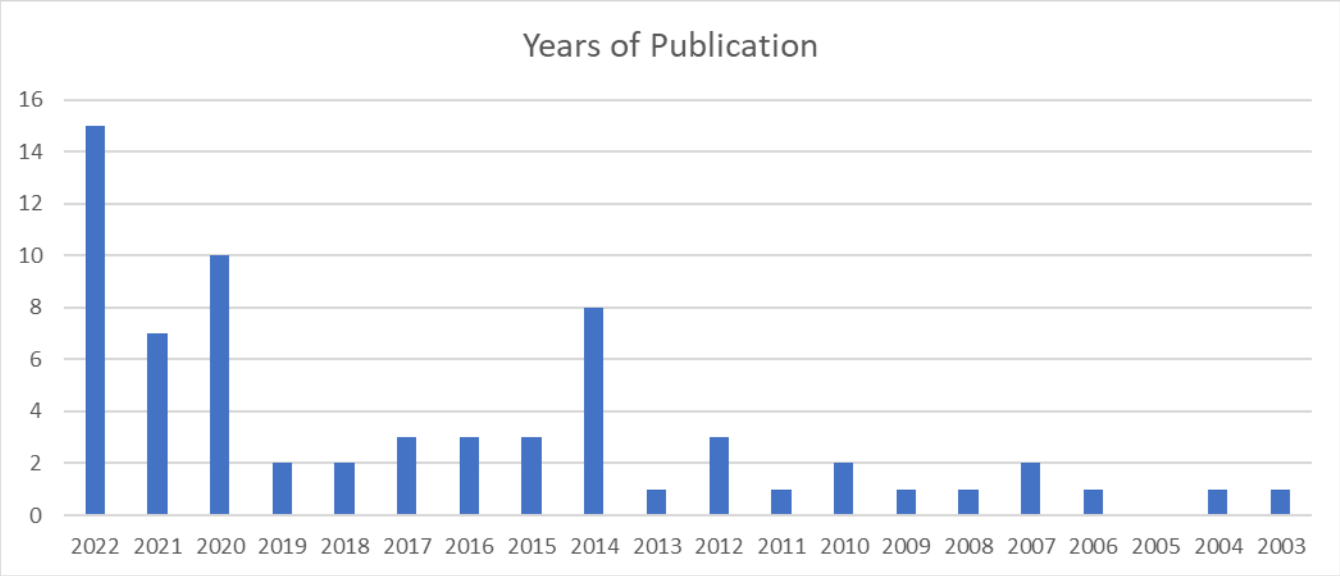

Figure 2-2: Distribution of publication over time 2003 to 2022

Source: Author own elaboration from three database

Geographical scope or location

Since freight transportation via inland waterways fits 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 IWT and the performance evaluation of these transport modes has attracted considerable attention. In this review, 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, including the United Kingdom (68 papers), with the Netherlands, Belgium, and Germany having one-third of the contribution from Europe. Other leading countries, including the United States and China, accounted for twelve and five papers, respectively. Only a few papers have addressed the performance of the IWT sector in the context of other countries, including India, Oman, Colombia, Venezuela, and Egypt, with one paper each. Figure 4 depicts the geographical location of the author's affiliated institutions.

The European authors accounted for a more significant part of the reviewed papers. According to the finding from Kotowska et al. (2020b), IWT is crucial in the sustainable transport and logistics industry, especially in the EU. In line with the European Green Deal and the EU's sustainable and smart mobility strategy, the European Commission suggests expediting the transition of goods transportation to environmentally friendly and energy-efficient modes, such as inland shipping, to decrease CO_2 emissions in the transportation sector. Academic scholars' emerging interest in integrating IWT into their domestic logistic chain is growing as an apparent body of literature (Caris et al., 2014; Plotnikova et al., 2022).

In the United States and China, academic researchers in this region are becoming increasingly interested in the prosperity of maritime trade in connection with inland shipping. Thus, the performance of inland waterway freight transport, along with informed system enhancement and suitable performance measurements, is crucial for the sector's competitiveness (Welch et al., 2022; Yuan et al., 2020). Figure 2.3. presents the share of academic studies in different geographical locations connected with the topic of interest

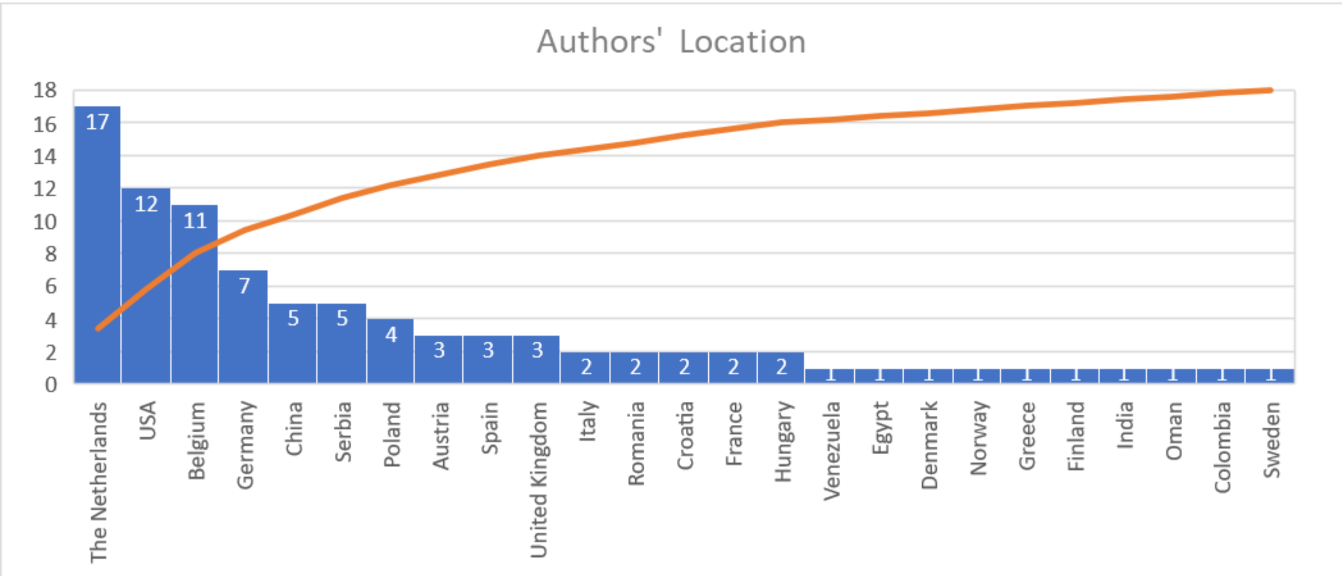

Figure 2-3: The geographical location of the author's affiliated institutions

Source: Author work

Distribution by methodology

Various academic researchers adopted different research methodologies in their papers, as shown in Figure 2.4. In this review, the methods mainly used are mixed methods, with about forty-four papers summarising their work. The authors combined models, case studies, surveys, interviews, and empirical studies with other quantitative and qualitative methods to establish a balanced methodology.

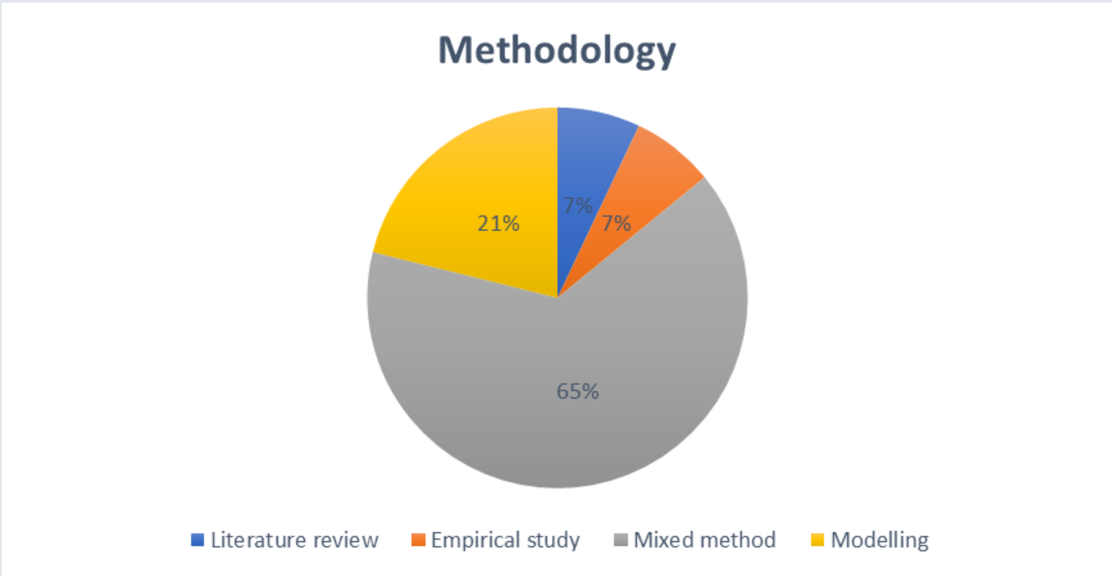

Figure 2-4: Methodology

Source: Author work

Model testing follows suit, with about fifteen authors presenting their work with different models. The authors of five papers employed an empirical study and literature review to qualitatively explore inland waterway freight performance.

Table 2-3: Authors, year of publication, methods, and geographic location of authors

Author(s)	Year	Methodology	Geographical Location of Authors*
		<u>Literature Review</u>	
Hofbauer and Putz	2020	Literature review	Austria
Poznanska and Montewka	2020	Literature review	Poland
Liu et al	2015	Literature review	The Netherlands
Saeedi et al	2022	Literature review	The Netherlands and Norway
Restrepo-Arias et al	2022	Literature review	Colombia

		Empirical study	
Brusselaers and Momens	2022	Empirical study	Belgium
Tzannatos et al	2016	Empirical study	Greece
Grzelakowski	2019	Empirical study	Poland
Mihic et al	2011	Empirical study	Serbia
Mihić et al	2012	Empirical study	Serbia
		Models	
Baroud *et al.*	2014	Mathematical modelling	United States and Venezuela
Ahadi et al.	2018	Optimization model	United States
Dorsser et al.	2020	General model	The Netherlands
Hassel and Rashed	2020	Error correctional model (ECM)	Belgium and Egypt
Hekkenberg et al	2017	Transport modelling	The Netherlands and Austria
Hossain et al	2019	Bayesian network model	United State
Caris et al	2011	Stimulation model	Belgium
Kalajdzic et al	2022	Mathematical models	Serbia
Păcuraru et al	2015	Numerical models	Romania
Karttunen et al	2012	stimulation model	Finland
Zentari et al	2022	Numerical model	Germany and Netherlands
Xing et al	2013	Numerical model	China
Łebkowski	2018	Stimulation model	Poland
Alias et al	2022	Stimulation model	Germany
Passchyn et al	2016	Mathematical modelling	The Netherlands, Germany and Belgium
		Mixed Method	
Schweighofer	2014	Empirical and case study	Austria
Jonkeren et al	2014	Literature review and empirical study	Italy and The Netherlands
Beuthe et al.	2014	Mixed transport modelling	Belgium, Germany and the Netherlands
Christodoulou et al	2020	LisFlood hydrological models, numerical models, general circulation model and regional climate models	Spain and Italy
Konings	2003	Empirical study and case study	The Netherlands
Vinke et al	2022	Literature review, case study and integral model	The Netherlands
Jonkeren et al	2007	Conceptual theory and model	United Kingdom

Meersman et al	2020	Mixed transport modelling	Belgium
Kortsari et al	2022	Empirical study and case study	Denmark
Colling et al	2021	Literature review and transport model	Belgium and the Netherlands
Colling and Hekkenberg	2020	Transport model and case study	The Netherlands
Hossain et al	2020	Literature review and Bayesian network model	United States
Hosseini and Barker	2016	Literature review, Bayesian network models and sensitivity analysis methodology	United States
Wang et al	2017	Literature review and stimulation model	China
Mostert et al	2017	Transport model, Mathematical modal and sensitivity analysis	Belgium
Wiegmans and Konings	2015	Conceptual theory and model	The Netherlands
Zentari et al	2022	Literature review, Numerical and stimulation models	The Netherlands and Germany
Lier and Macharis	2014	Literature review, emission model and life circle assessment methods	Belgium
Farazi et al	2022	Survey, interview, focus group and observation	United States
Farazi et al	2021	Survey, interview, focus group	United States
Defryna et al	2021	Literature review and mathematical Modelling	The Netherlands and Germany
Durajczyk and Piotr	2022	Literature review, descriptive statistics and taxonomic analysis tool	Poland
Keuken et al	2014	Literature review and Numerical model	The Netherlands and United Kingdom
Asborno et al	2022	Empirical and case study	United States
Yu et al	2020	Mathematical and stimulation model	Spain and China
Posset et al	2009	Survey, interview and focus group	United states
Vidan et al	2012	descriptive statistics and case study	Croatia
Tournave	2022	Theoretical and case study	France
Specht et al	2020	Literature review, Survey, interview, focus group	Germany
Totakura et al	2022	Literature review, Survey and MCDM tools	India and Oman

Huang et al	2021	Literature review, evaluation and simulation model	China
Hammedi et al	2022	Nonlinear optimization models	France
Guan et al	2021	Stimulation and mixed integer programming model	China
Mako et al	2021	Mathematic model and case study	Romanian
Vidan et al	2010	Literature review, transport and mathematical model	Croatia
Martin et al	2004	Case study and Hydrodynamic models	United States
Camp et al	2010	Hydrodynamic modelling, empirical and study	United States
Maras	2008	Empirical study and mixed-integer linear programming model	Serbia
Rohács and Simongati	2007	Modelling and simulation models	Hungary
Rigo et al	2007	Transport and emission models	The Netherlands, Belgium, and Hungary
Segui et al	2014	Literature review and survey	Spain, Belgium and the United Kingdom
Wilson	2006	Empirical study and empirical model	United States
Kruse et al	2014	Case and empirical study	United States
Santen et al	2021	Literature review, Case study, Focus group, interview and survey	Sweden

Geographical distribution of identified literature*

Source: Author work

2.2.2.2. Content analysis

Performance measurement is the first and essential stage in effectively controlling the performance of any organisation (Stuart, 1996; Dimitriou and Sartzetaki, 2022). According to Isoraite (2004), performance measurement is an information system that enables management practices to operate efficiently. The concept of performance measurement is not novel. Firms and government agencies are compelled to enhance the transparency of their performance. Performance measurement is essential to the transportation industry, particularly for the inland waterway freight transport sector. Innovative or alternative transport solutions often fail due to a lack of transparency resulting from inadequately selected or absent performance indicators (Posset et al., 2009; Borca et al., 2023). This contributes to the limited significance of IWT as a primary mode of freight transportation in multimodal supply chains.

Efficient measurement enables assessing and enhancing the efficiency of the inland waterway freight transportation network. Regular monitoring and evaluation of the system are crucial to guarantee optimal performance (Saeedi et al., 2022).

Given the importance of IWT in facilitating international trade and worldwide connectivity, assessing its performance enables stakeholders to make well-informed decisions, efficiently allocate resources, formulate new strategies and facilities, and implement new plans. Although performance measurement has been a popular area of research in the transportation industry (Chu and Fielding, 1992; Sulek and Lind, 2000; Lan and Lin, 2006; Dadesna et al., 2023), literature specifically addressing performance measurement in the context of IWT is fragmented and scarce. Existing studies tend to focus on specific aspects such as environmental performance (Mako et al., 2021), lock operations (Passchyna et al., 2016; Hammedi et al., 2022), infrastructure (Hosseini et al., 2016), transport safety (Camp et al., 2010; Liu et al., 2016), and fleet propulsive performance (Păcuraru et al., 2015).

In order to attain the most favourable outcome and enhance their overall efficiency, it is recommended that practitioners in the IWT industry take into account many viewpoints, including the economy (Kortsari et al., 2022), key metrics, including reliability, on-time delivery and agility in meeting customers' requirements, consumers' perspective (Hekkenberg et al., 2017; Alias et al., 2022), business growth (Totakura et al., 2020) and learning perspective (Vidan et al., 2012; Tournave, 2022),

Furthermore, Farazi (2022) emphasised that in order to thrive and maintain a position in the current competitive market, the contemporary IWT must prioritise the comprehensive analysis of its performance from several viewpoints. Therefore, to enhance and oversee performance, practitioners must assess the present level of performance and pinpoint the areas that require improvement and management. Although the process of IWT serves as a means to connect the operating procedures of pre-waterway carriage transportation (pre-carriage) and post-waterway carriage transportation (post-carriage), this review excludes explicability scholarly articles on pre-and post-carriage transportation. An IWT system's typical operational components and physical layout are shown in Figure 2.5.

Despite the significance of intermodal IWT and its cost and energy benefits, the performance measurement of IW freight transport has yet to be extensively studied compared to other transportation modes. While there has been an increase in IWT markets in certain European countries, the United States and China, the focus for transport and logistics operators is now on attaining optimal performance in these areas. Transport and logistic operators aim to optimise their performance, which can be influenced by various internal and external factors, including globalisation (Kotowska et al. 2018a), fluctuating fuel prices (Wiegmans and

Konings, 2015), stricter safety and social regulations (Yu et al., 2020), technological advancements (Restrepo-Arias, 2022), and consumers demands (Hassel, 2020).

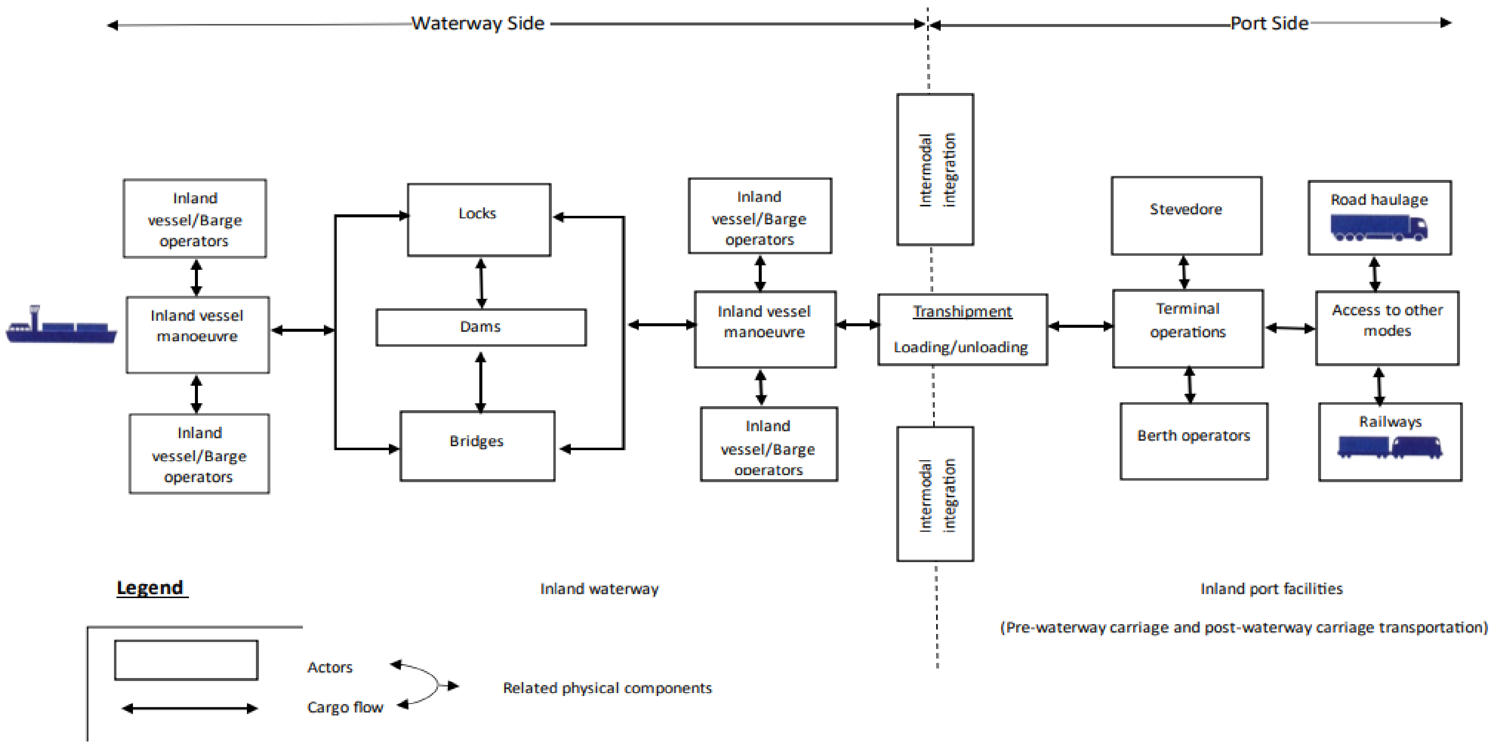

Figure 2-5: An IWT system's typical operational components and physical layout

Source: Author work

Practically, performance indicators for IWT are established at the company level or at least at the group level, leading to many taxonomies. The maritime transport industry, particularly the inland waterways sector, suffers from diverse nomenclatures. When performance measurement values deviate from the expected range, practitioners of inland waterways can use appropriate categorisation to pinpoint the precise elements of the system that need attention (Devendra et al., 2020). This information can be used to guide the allocation of resources towards system improvement.

Based on the literature review in this chapter, several research gaps were found: The current review discovered there is a lack of general insight into the performance of IWT compared to single-mode road freight transport. Where performance is evaluated, it is usually, in most instances, case-specific to a particular variable. Secondly, there is a lack of detailed insight into the aspects and variables that influence the perception of performance in the domain of IWT. No comprehensive framework is available to measure IWT performance, including identifying performance variables and conducting performance evaluations. Thirdly, the review found no systematic methods for classifying performance measurement in IWT exist. Finally, research has yet to prioritise the severity of different performance criteria to determine which should receive the greatest attention from relevant authorities and stakeholders involved in IWT.

In this study, the articles highlighting performance measurement in the IWT domain were classified into different groups, as shown in Table 2.4. The categorisation of performance is based on two factors:

- What needs to be measured
- Where the performance measurement is applied

The rationale is that the IWT system often encompasses various performance domains that require monitoring to maintain proper system functionality. The articles that were finally reviewed categorised performance measurement in the IWT domain into different areas in order to determine the primary focus of the theme under investigation.

Mobility and reliability

The efficiency and effectiveness of transport systems are vital for economic expansion and advancement. Comprehending and quantifying transport efficiency is crucial for maximising its functioning and making well-informed choices about infrastructure investment and policy formulation. Neely (1999) defines performance measurement as the act of measuring actions, where measurement involves quantification, and actions result in performance. Implementing measuring practices would assist businesses in aligning their capabilities and making progress through focused and ongoing improvement programmes (Baker, 2009).

Mobility is a vital metric for freight transportation (Fossheim and Andersen, 2017). Within the domain of IWT, mobility refers to the capacity of vessels and waterway systems to offer efficient and dependable transit (Ken and Szostak, 2022). It includes the speed, availability of transport infrastructure, port accessibility and efficiency of shipping operations. The mobility metric enables transport practitioners to evaluate the efficiency of the IWT system in terms of travel durations, waiting periods and the utilisation of available capacity (Borca et al., 2023). According to Pahwa and Jaller (2022), enhanced mobility results in expedited delivery, heightened efficacy and reduced expenses for shippers and consumers.

On the other hand, reliability refers to the consistency and dependability of the IWT system (Sulaiman et al., 2011a). It involves factors, including adherence to schedule disruption caused by weather and infrastructure maintenance. A reliable transport system guarantees that inland vessels/barges adhere to specified timetables, minimising delays or interruptions. According to Sulaiman et al. (2011b), it allows the sector to swiftly meet supply chain demands, reducing financial losses and ensuring customer satisfaction. Furthermore, reliable IWT systems improve the connections between different modes of transport and facilitate the integration of logistical networks, stimulating economic expansion and competitiveness (Caris et al., 2014). The inland waterways system comprises a network of rivers together with corresponding locks and dams. Dams create reservoirs of water that facilitate river navigation. At the same time, locks enable the passage of inland/barges between reservoirs at varying heights (See Figure 10 for the inland waterway system's typical operational components and physical layout. According to Guan et al. (2021), the efficiency of lock operations refers to the prompt movement of inland vessels across the river and is influenced by various factors. Wilson (2006) evaluated the performance of locks based on the structural design of locks from three perspectives: the attributes of the fleets (vessels and barge) and a range of environmental variables (river level, weather, etc.) and the attributes of vessels, lock, and the firm. The finding from his work reveals substantial variability among vessels, firms, and locks, leading to notable differences in the promptness of passage through the locks.

Some researchers (Passchyna et al., 2016; Guan et al., 2021; Hammedi et al., 2022) argued that one of the significant problems associated with IWT performance is scheduling problems at locks. Passchyna et al. (2016) highlighted that since inland vessels frequently encounter multiple locks during their journey, substantial delays can account for up to half of the whole transit duration. According to Hammadi et al. (2022), the delay negatively influences shipping expenses and negatively impacts other components of the transportation process, thereby hindering the expansion of this particular mode of transportation. The study by Passchyna et al. (2016) proposed a dynamic programming algorithm to improve and solve the lockmaster's problems in polynomial time, efficiently solving a single batching machine scheduling problems to enhance the performance of vessel passage through locks. The algorithm considers capacity, ship-dependent handling times, weight, and water usage and is applied in a realistic setting. The study compares the performance of the new exact algorithm with that of heuristics.

Guan et al. (2021) identified locks as an essential component of a waterway system. They evaluated the performance efficiency of the lock operations system, ship arrivals on inland waterways, and passing locks without spending unnecessary waiting time at lock entrances, as well as utilisation of each lockage operation. Their proposed approach shows that it significantly reduces congestion at locks for ships by 28% and lockage operation by 10%, thereby improving the utilisation of IWT and reducing the time spent waiting at the last lock.

Hammadi et al. (2022) presented a two-level performance optimisation solution to ensure a shorter waiting time at lock and improve IWT. Their work introduced a lock automation decision-making (Lock-ADM) method that uses a three-stage algorithm to calculate optimal lock numbers, measure the performance network importance and select the best automatable locks. The proposed method reduced lock waiting time by 33.7% and fuel consumption by 48.03%. Dynamic Lock Scheduling (Lock-DS) also efficiently manages vessel scheduling, reducing waiting time and fuel consumption.

Caris et al. (2011) assessed different bundling tactics for container barge transport in the port of Antwerp. They established various performance measures to evaluate the effectiveness of barge transport, including average waiting time, average turnaround time and average capacity utilisation at potential hubs and sea terminals. The study indicated that implementing an intermodal barge hub in the port vicinity can have two significant advantages. The turnaround time of the inland shuttle service can be decreased due to reduced waiting time in the port vicinity. Also, deep sea terminals can enhance operational efficiency by utilising vessels carrying consolidation loads inside the port's collection/distribution network. According to Hekkenberg et al. (2017), the predictability and generalisation of IWT are more challenging than road and rail, primarily because of the fluctuating conditions of waterways and the diverse range of vessels used. In their work, they proposed some performance indicators to measure the efficiency of navigable channels. Their study indicates that the dynamic fairway circumstance greatly influences the speed, fuel, consumption, sailing schedules and transportation costs. The findings of their study were corroborated by Defryn et al. (2021), who also conducted performance efficiency through skipper collaboration and joint speed optimisation for inland waterways. Using joint speed optimisation models, the authors presented a theoretical foundation for selecting effectiveness and efficiency performance criteria for a vessel entering a navigable channel. Their work demonstrated that changing fairway conditions impacts vessels' speed and sailing schedules.

Other researchers have identified Key Performance Indicators (KPIs) associated with navigability, traffic services, carriage and handling capacity as well as multimodal connectivity (Xing et al., 2013; Jonkeren et al., 2014; Schweighofer, 2014; Beuthe et al., 2014; Liu et al., 2015; Passchyna et al., 2016; Christodoulou et al., 2020; Dorsser et al., 2020; Yu et al., 2020). According to Xing et al. (2013), the navigability of the inland waterway system is a crucial factor in determining its overall efficiency and effectiveness. Yu et al. (2020) argued that it impacts both the velocity and capacity of the vessels, as well as the reliability and consistency of the transportation services. Berthe et al. (2014), Jonkeren et al. (2014), and Christodoulou et al. (2020) examine climate change's impact on the navigability performance of inland vessels in four distinct areas along the Rhine and the Danube rivers, which are significant hubs for freight operations inside the EU. Their various study examines the impact on navigability, carriage capability and handling performance, examining key factors such as rising sea levels, severe weather occurrences and changing ocean conditions. The authors concluded that climate change affects IWT performance in multiple ways. This was also highlighted by Schweighofer (2014) and Vinke et al. (2022), who also summarise their work by implying that navigable waterways that are easy to navigate allow for the use of larger vessels and the movement of higher amounts of cargo, leading to economic of scale, improved transportation operations and cost-effectiveness.

In order to facilitate multimodal transport, Hossain et al. (2019) suggested that it is essential to have infrastructure that links different economic regions. The availability encompasses the presence and sufficient capacity of infrastructure, such as waterways, terminal, railways, and other related facilities, as well as their level of quality. These factors directly influence the effectiveness and reliability of IWT (Farazi et al., 2021; Saeedi et al., 2022). A thorough infrastructural evaluation assessment by both Hossain et al. (2019) and Resetrepo-Arias et al. (2022) shows that physical infrastructure network significantly influences accessibility and reliability of the transport systems, availability of services like navigational aids and the levels of integration between different transportation modes.

Efficiency and profitability

A vital component of evaluating the effectiveness of IWT networks is their profitability and efficiency (Golaka et al., 2022). Profitable and effective transport networks are crucial for sustainable development and economic success as the world grows more connected (Bazaluk et al., 2021; Barrow et al., 2022). Efficiency in IWT is the efficient use of resources and minimal waste, resulting in streaming processes, smooth operation, and optimal utilisation of vessel infrastructure, which can reduce cost, improve reliability, and enhance system performance (Wang et al., 2020). Jonkeren et al. (2007) examined the impacts of reduced water levels on the European IWT (river Rhine market). The results indicated that water levels significantly impact freight price per ton and load factor, but their effects on trip prices are near zero. The study estimates the extent of these higher prices and their economic impacts, showing that low water levels (between January 2003 and July 2005) cause an average annual welfare loss of €28 million, with extreme lows causing €91 million loss, accounting for 13% of market turnover. Karttunen et al. (2012) conducted a study to evaluate the cost-effectiveness of IWT operations for forest chips in the Lake Saimaa region of Finland. The analysis was carried out through practical demonstration and discrete-event simulation. The findings from their work show that barge-based waterway transport offers a competitive advantage over other modes due to larger loads and higher bulk density of chips and that waterway supply chains were cost-competitive to road transport after 100-150 km. Wiegmans and Konings (2015) examined the conditions influencing the cost competitiveness of intermodal IWT. By evaluating the economics of intermodal IWT, the study compares transport costs of intermodal IWT and road-only transport, considering economies of scale and terminal operations. The findings reveal that roundtrips, drop and pick operations, and smaller containers improve intermodal IWT competitiveness, while high-cost operations in small terminals reduce their competitiveness. The analysis helps understand the sensitivity of cost performance in transport costs.

Monstert et al. (2017) emphasised that to gain market share, the IWT must generally have lower direct transportation costs than road transport. Roso et al. (2020) argued that for IWT to be a viable alternative freight mode of transportation, the transportation system must achieve cost competitiveness on par with road transportation. Other academic research has also empirically proven that IWT is energy-efficient, allowing one tonne of cargo to travel four times further than trucks, and offers competitive transport costs, decreasing unit costs over long distances (Flodén et al., 2017; Santén et al., 2021). These benefits make it an appealing choice for firms seeking to decrease carbon emissions. However, these studies highlighted that IWTs are commonly utilised for commodities that do not necessitate prompt delivery because of their slower pace than road modes of transport.

According to Bu and Nachtmann (2020), transportation time, cost and infrastructure are decisive factors for shippers when they choose their transport mode. Oztanriseven and Nachtmann (2020) argued that for IWT, these aspects are more uncertain and less straightforward for generalisation than road and rail transport. Hekkenberg et al. (2017) examined factors influencing sailing time and transport cost for IWT demonstrated in a Rhine-Danube corridors case study. The study shows that IWT is more uncertain due to variable waterway conditions, ship variety, dynamic fairway conditions, ship propulsion power, and captain's behaviour, significantly impacting speed, fuel consumption, sailing schedules and transportation costs. In their work, Xing et al. (2013) viewed energy efficiency as critical to enhancing waterborne performance. In addition to cost saving, energy efficiency also lessens its adverse effects on the environment (Kalajdzic et al. (2022). The study by Hofbauer and Putz (2020) demonstrated that by comparing primary energy costs, IWT costs per tonne-km 5 litres are significantly lower than rail, road and air transportation, with inland barges consuming 50 times less fuel. Energy efficiency in IWT performance offers cost savings by optimising energy consumption, reducing operational expenses, and investing in maintenance or equipment upgrades, ultimately enhancing overall performance and reducing long-term costs (Kortsari et al., 2022).

Oztanriseven and Nachtmann (2020) defend profitability in the context of IWT as a company's capacity to make earnings from its transportation operations. It is a financial metric that evaluates the relationship between revenue and the corresponding costs. However, Grzelakowski (2020) argued that the profitability of companies might differ based on their operating methods, cost structures and market conditions. According to Li et al. (2021), the close correlation between efficiency and profitability underscores the significance of IWT enterprises in achieving success. Enhanced efficiency reduces cost and resource utilisation, whereas inefficiencies negatively impact profitability, resulting in increased operating expenses and decreased income. The study stressed that a comprehensive understanding of this correlation is crucial for making informed decisions within this industry. Prus and Sikora’s (2021) study examines the aspects that influence the attractiveness of IWT. The study highlighted cost-effectiveness, transport reliability and environmental benefits as attributing factors to the transport system's overall attractiveness.

Other academic researchers have also acknowledged that efficiency in IWT is crucial for success (Totakura et al., 2020). In their work, Hekkenberg et al. (2017) highlighted time-saving measures in port transhipment to reduce costs, improve productivity, optimise infrastructure, and meet growing demands by optimising transhipment, faster turnaround times, and increased shipments. Furthermore, Munim et al. (2020) examined factors that influence transhipment costs in gateway ports linked with barges. The study shows that factors such as cargo volume, vessel distance, equipment efficiency, labour availability, automation, competition, port infrastructure, regulation and environmental considerations significantly influence the optimal performance of IWT in ports.

Environmental impact and decarbonisation

The environmental implications of IWT are substantial and must be addressed to enhance its performance. The impacts encompass emissions and pollutants, ecological ramifications, and implications for climate change (Christodoulou et al., 2020; Mako et al., 2021). Generally, maritime transport is a significant contributor to air pollutants due to their emissions of Sulphur oxides (SOx) and Nitrogen oxides (NOx) as well as particulate matter (PM), especially in coastal areas (Sys et al., 2020). Inland navigation performs less when comparing other air pollutants than CO_2 in transportation (Bouckaert, 2016). Therefore, the scale of advantage offered by inland navigation keeps it on top of the chart that, in many cases, its emission per tonnes-km does not exceed that of road freight transport (Grosso, 2021).

The earlier study by Rigo et al. (2007) proposed an integrated assessment methodology to evaluate the performance of new intermodal IWT chains in terms of logistics, economics and environmental impact compared to old ones. The study presented different scenarios for assessing environmental performance. According to the study, intermodal transport's poor NO_X and PM performance is due to lower ship emission standards, and the study suggested that this can be improved with filter and catalyst techniques and low sulphur fuel. Xing et al. (2013) analysed the operational energy efficiency of inland river ships. The study examined energy usage, GHG emissions, and inland river shipping compared to seagoing vessels. It analyses data from container shipping operations on the Yangtze rivers in China and concludes that the navigational conditions considerably affect these operational efficiencies.

Keuken et al. (2014) reviewed the effects of emissions from inland shipping on elemental carbon concentrations in the Netherlands' waterways' environs. The study examines the influence of inland shipping on air quality in Dutch waterways. Employing inverses modelling to determine emission factors and energy consumption statistics. The study reveals that 140,000 individuals residing within 200m of heavily trafficked waterways are subjected to heightened elemental carbon concentrations. They concluded their work by suggesting that targeting "gross" polluters is vital, as 30% of ships are responsible for more than 80% of total emissions in these areas. Segui et al. (2016) proposed an environmental performance baseline for the European inland port sector, including IWT ports. The findings from their work are organised and presented based on four areas outlined in their environmental survey: environmental priorities, environmental management, environmental monitoring and green initiatives. The findings not only set the standard for the environmental performance of inland ports in the EU but also identify the strengths and potential drawbacks of the resulting values.

Lier and Macharis (2014) proposed a life-cycle assessment (LCA) approach for evaluating the environmental effects of IWT services. The analysis examines emissions related to barge transportation in Flander, Belgium, with a specific focus on vehicle operation, barge fleets and transport infrastructure. In this research, The LCA methodology thoroughly analyses emissions, assessing their relative significance and emphasising the need to consider additional categories for sustainability. Academic research shows that IWT offers a viable and environmentally friendly option for transporting heavy and large quantities of freight, particularly when compared to road and rail transport (Monstert et al., 2017; Barrow et al., 2022). Nevertheless, the industry encounters significant impediments to carbon emissions and environmental consequences (Plotnikova et al., 2022). To address these concerns, reducing carbon emissions in IWT has become a vital goal in pursuing a sustainable transportation system (Némenthy et al., 2022). According to Păcuraru et al. (2015), implementing decarbonisation solutions in IWT is crucial for mitigating GHGs, fostering a sustainable sector transition to low-carbon fuels and exploring alternative propulsion systems.

Expensive investments and limited access to funding sources, both private and public, have hindered the creation of new services, upgrading of IWT fleets, and maintenance, restoration, and development of waterborne infrastructure (Camarago-Diaz et al., 2022). Kalajdzic et al. (2022) examined the carbonisation strategies to reduce emissions and promote sustainability in the IWT sector, including emission reduction funding. The study reviewed decarbonisation initiatives that have been introduced, which involve shifting from fossil fuel-based engines to low-carbon or zero-emission systems such as hydrogen fuel cells, liquefied natural gas/compressed natural gas, e-fuel and biofuel, integrating energy-efficient technologies and optimising vessel performance. According to the study, alternative fuels with technologies have proved a substantial capacity to decrease local air pollution, contributing to a more environmentally friendly IWT by optimising energy consumption and carbon footprint. Tzannatos et al. (2016) evaluated the energy efficiency and air quality performance of IWT freight service compared to land-based alternatives (road and rail mode) in South-Eastern Europe. The research shows that IWT services can be competitive and energy and carbon efficient. Nevertheless, the study further indicates that land-based services have a better impact on air quality due to stricter emission standards. They concluded their study by emphasising that enforcement mechanisms are crucial in reducing IWT pollution by establishing standards and penalties for polluters. These frameworks deter polluters, protect communities and ecosystems and foster a culture of compliance, ultimately reducing pollution at its source.

The ineffective enforcement of emissions standards, monitoring of emissions and collaboration with stakeholders pose an obstacle to IWT. These inadequate enforcement measures, imprecise monitoring methods and insufficient coordination impede the effectiveness of emission reduction measures and the overall performance of the transportation system (Xing et al., 2013; Keuuken et al., 2014; Wang et al., 2020). In the study by Grey et al. (2012), the IWT industry's expansion is causing growing environmental concerns, with noise pollution being a critical factor among the environmental factors associated with maritime activities. By incorporating effective noise management measures, stakeholders may enhance the sustainability and efficiency of the IWT industry while also addressing the need to combine economic expansion with environmental responsibility.

Similarly, Brusselaers and Momens (2022) examine the environmental impact of noise as a performance IWT by reviewing the sources, impacts and mitigation strategies concerning noise pollution and highlighting the importance of noise management in promoting sustainable and efficient IWT operation. The study reveals that noise comes from various sources, including proposition systems, onboard activities, engine vibrations, cargo handling, drilling, and construction. In this research, the authors stressed that understanding these sources is crucial for effective mitigation strategies. Additionally, the study recommends investing in technologies like quieter proposition systems and advanced insulation materials, developing ship-design standards, establishing quieter shipping routes, and adopting speed restrictions.

Infrastructure condition

Infrastructure is crucial in evaluating the performance and effectiveness of IWT (Roso et al., 2020; Wehrle et al., 2022). According to Ahadi et al. (2018), infrastructure plays a vital role in measuring the effectiveness of IWT by enhancing efficiency. Baroud et al. (2014) examine the significance of infrastructure in IWT operation and its influence on several performance areas. The study emphasised infrastructure quality, capacity, and reliability in deciding effective, reliable, and safe transportation operations. Hossen et al. (2019) highlighted that the quality of infrastructure directly impacts the selection of transport modes. To effectively implement multimodal services, Saeedi et al. (2022) suggested that ensuring high-quality rail and waterway connections and efficient transfer possibilities between modes of transportation and connections to customers, such as local rail networks in port areas, is crucial.

Konings (2003) and Totakura et al. (2022) further access other factors essential for optimising the transportation system, its integration and ensuring the smooth operation of IWT, such as limited geographical expansion, natural spatial distribution and directions of inland waterways. According to Konings (2003), the base of inland waterways consists of navigable rivers or lakes, which are by nature alone, not interconnected, save the tributaries. Its transformation into a network requires the construction of artificial canals across watersheds, which is very expensive (Beyer, 2018; Wehrle et al., 2022). The available network of inland waterways does not always cover the main cargo flows. Consequently, a particular problem with IWT is the cost of trans-loading and transferring from one mode (IWT) to other inland transportation modes. Thus, the supply chains have inefficient participation and management (Totakura et al., 2022).

Alias et al. (2020) examined the efficiency of IWT infrastructure on the Danube and East-west corridors. The summary of their work indicates that despite having significant spare capacity, the efficiency and competitiveness of IWT are hindered by adequate infrastructure quality at critical sections of the network. To a considerable degree, this has discouraged modal shift-aspiration for firms/shippers in search of boosting their green credentials through this transport mode. The effectiveness of inland navigation in these corridors is constrained by missing links and bottlenecks; Tokakura et al. (2022) corroborate that as a result of these missing links and bottlenecks, there are certain areas like the Baltic Sea Region where IWT can only limitedly compete with the dominant road and rail modes.

Besides connectivity (road and rail interchange) and transhipment facilities, other performance indicators related to infrastructure have been identified in the European setting, including infrastructure maintenance and modern fleets for competitiveness. The viability of river transport relies on a substantial capital investment (Baroud et al., 2014). Making a river suitable for navigation, such as upgrading navigation channels, excavating a canal, constructing a series of locks, and implementing state-of-the-art technology, carries significant financial consequences (Beyer, 2018). Infrastructure deteriorates with time in the absence of maintenance, resulting in a decline in their worth and potential disruption to waterways traffic. Without dredging, the barges are compelled to transport a reduced cargo. Consistent investment in infrastructure maintenance is essential to minimise the expenses associated with emergency repairs and prolong the lifespan of waterway infrastructure, guaranteeing ongoing and reliable services for IWT (Wehrle et al., 2022).

Păcuraru et al. (2015) examined the new engine designs and optimisation techniques for a highly efficient and environmentally friendly propulsion system for inland vessels. According to the study, modernising the fleets in IWT is essential in improving efficiency and reducing costs. Transport operators enhance their operations and streamline procedures by utilising newer vessels and equipment with advanced technologies. These contemporary resources

are engineered to optimise fuel efficiency, enhance cargo handling capabilities and minimise operational interruptions.

Hassel and Rashed (2020) explored the comparative performance of old and new smaller vessels with low-power sailing performance using a low amount of gasoil. Their study shows that new low-power engines' hybrid/diesel-electric configuration is more reliable and effective. The study of Łebkowski (2018) reveals that operators can substantially decrease their carbon footprint by replacing older, less efficient vessels with modern ones that comply with stringent emissions regulations. Contemporary ships integrate cleaners' propulsion technologies, such as low-emission engines and alternative fuels, to reduce air pollution and GHGs (Graya et al., 2021). Consequently, enterprises attain greater transportation capacity, optimise their routes, and decrease operational expenses. Companies can gain greater operating efficiency and significant cost savings by investing in fleet modernisation, resulting in increased competitiveness in the market (Păcuraru et al., 2015).

Furthermore, Meerseman et al. (2020) highlighted that the key developments in fleet modernisation are automation and autonomous vessels, which allow the sector to reach greater operational safety and efficiency standards. They suggested that lowering the environmental effects of IWT depends more on integrating renewable energy sources like solar and wind power. The study also indicated that another significant trend for the future performance of inland waterway fleets is big data and analytics, which enable businesses to harness data-driven insights for better fleet management and informed decision-making.

Safety and Security

The profitability and feasibility of IWT rely on safety and security Maras (2008). Martin et al. (2004) define safety as being free from accidents, incidents, and injuries. In contrast, Posset et al. (2009) define security as encompassing the means and protocols put in place to avoid and address threats, hazards and deliberate acts of harm. Jonkeren et al. 92014) argued that precise and straightforward descriptions of these topics are essential for formulating suitable performance indicators and evaluating the overall safety and security levels in IWT.

Wang et al. (2017) outline and analyse the essential KPIs to monitor and evaluate the safety and security performance of IWT in China. According to their study, the KPIs are tangible metrics that indicate the level of success in reaching particular goals. Within their research framework, the KPIs encompass proactive and reactive measures, such as accident rates, near misses, response times, inspection outcomes, and adherence to safety and security rules. Yu et al. (2020) examines the indicators and thoroughly comprehend the KPIs, which is crucial for evaluating the overall efficiency of safety and security protocols in the Chinese IWT domain.

The examination of safety performance indicators in the West-European waterways by Dorsser et al. (2020) offers a significant perspective on the various aspects that impact safety in river-sea transport. Their study analysed and highlighted that proactive safety measures, such as regularly inspecting and maintaining vessels, substantially diminish accidents and incidents. Furthermore, Restrepo-Arias et al. (2022) emphasised that using cutting-edge navigation technologies and following safety guidelines were essential for guaranteeing the security of operations on the waterway network. Additionally, they stressed the significance of ongoing safety performance indicators monitoring and enhancement in IWT as an essential criterion. According to Wang et al. (2020), the quality of traffic conditions of IWT exhibits distinct characteristics compared to road and railways traffic. The reliability of transportation is contingent upon the technical and operational circumstances of the navigable river, which might fluctuate and impose restrictions on vessel capacity and the number of vessels in tow (Schweighofer, 2014; Jonkeren et al., 2014; Beuthe et al., 2014; Christodoulou et al., 2020; Vinke et al., 2022). Based on the various aspects of traffic service quality, IWT has a distinct advantage over other modes of inland transport (Zentari et al., 2022). This is primarily due to the absence of congestion, allowing navigation to occur at any time, and the ability to arrange transit times (Defryna et al., 2021).

Given the growing need for effective and environmentally friendly transportation, observing and comprehending ships' navigation in water channels is crucial (Zentari et al., 2022). Restrepo-Arias et al. (2022) referred to vessel identification metrics as the diverse factors employed for analysing and quantifying the efficacy of vessel identification in IWT. Their study examines how vessel identification impacts operating efficiency, evaluates vessel tracking systems' precision and analyses the metrics employed to assess vessel performance. These metrics aid in evaluating the efficacy and reliability of the established identifying methods and technologies. The study demonstrated how accurate vessel identification enables efficient planning and optimisation of shipping routes. According to the study authorities can optimise the loading and unloading of cargo by having knowledge of the identity and capacity of vessels, thereby ensuring that vessels operate at their highest level of efficiency. Additionally, the identification of vessels also enhances efficient communication between vessels and shore-based infrastructure, preventing miscommunication or delays in IWT operations.

Durajczky and Piotr (2022) evaluate the timeliness, completeness, and quality of vessel identification data. The study shows that vessel identification is crucial for guaranteeing the safety of IWT operations. Their study reveals that identifying and monitoring vessels allows authorities to detect and monitor vessels that could represent a security risk. Using sophisticated identification technology like the Automatic Identification System (AIS) or radio frequency identification (RFID) greatly enhances the efficiency of monitoring vessels' movements and identifying potential security threats.

Furthermore, Asborno et al. (2022) further investigated the inland vessel identification procedure in the United States of America. The study highlights the metrics and offers important insights into several vessel operation-related topics, including how authorities can promptly and effectively address situations, including accidents, collisions and hazardous substance release through precise vessel identification and tracking. Identifying vessels in real-time facilitates efficient traffic management, enabling authorities to allocate vessel traffic, mitigate congestion and minimise the risk of accidents. With the increasing demand for IWT systems, it is crucial to prioritise suitable vessel identification in order to maintain efficient and sustainable operations. Durajczk and Piotr (2022) further provide recommended and best practices that to optimise the effectiveness of IWT; authorities can utilise modern identifying technologies and establish robust monitoring systems.

Economic development

The use of economic development in the inland navigation context provides a comprehensive viewpoint that offers insights into the competitiveness and attractiveness of the sector (Konings, 2003). Posset et al. (2009) agree that economic development indicators become particularly relevant when evaluating the IWT domain. The study underlined core areas, including Gross Domestic Product (GDP) contribution, job creation, trade volume and value, and aggregate added value (transportation and infrastructure investment), which are important metrics for this industry's economic success. Meersman et al. (2020) concurred that this measurement allows for comparisons between different transportation modes and underscores the roles of transport in driving economic growth and prosperity.

Transportation has been recognised as a vital factor in economic advancement (Lenz et al., 2018; Ševˇceko-Kozlovska and Cižiuniene, 2022), and IWT has played a substantial role in fostering economic growth and development in the areas it operates (Plotnikova et al., 2022). Hernández (2022) considered measures of aggregate added value based on factors like infrastructure, efficiency, and economic impact, acknowledging it to provide a perspective on the overall competitiveness and attractiveness of the particular sector.

Idan et al. (2012) examined and evaluated the sector's role in generating employment opportunities as part of economic growth. The study shows that work opportunities in this industry enhance the overall employment rate and support local economies. Their work further suggested that policymakers can gain insights into the job market dynamics and pinpoint regions that may necessitate more training or infrastructure investments by assessing employment generation. Colling and Hekkenberg (2020) and Tournave (2022) corroborated this, highlighting that examining employment statistics can provide insights for developing policies that promote the long-term expansion of the IWT industry while optimising employment opportunities.

Grzelakowski (2019) identifies marketing as a useful performance metric in the IWT domain. According to their study, marketing experts play an integral role in the success and expansion of the industry by assessing customers' demands, enhancing service quality, improving the IWT companies' brand reputation, promoting sustainability and fostering innovation. The summary of Collings et al. (2021) work shows that by examining cargo data, marketing professionals can evaluate the popularity of particular routes and ascertain customers' preferences and customer services to meet these expectations efficiently. Consequently, this enhances resource allocation and operational efficiency, thus yielding a performance indicator for the industry.

Innovative transport technology

Gkoumas et al. (2020) refer to innovative transport technologies as new and advanced solutions developed and implemented in the transportation industry to enhance safety, efficiency and sustainability. In the context of IWT, Durajczyk and Piotr (2022) define innovative transport technologies by their capacity to provide new and enhanced methods, systems and equipment that improve the operation and management of IWT. Asborno et al. (2022) highlighted that implementing RIS on the European inland waterway network has enhanced the safety, efficiency and eco-friendliness of IWT. According to the study, RIS has updated and improved inland to promote the transfer of transportation modes and make it easier to utilise inland waterways throughout Europe.

Plieg and Back (2006) define the RIS as standardised information services that aid in managing traffic and transportation in inland navigation while facilitating connections with other transportation modes. Equipped with harmonised electronic nautical charts, RIS offer topographical, hydrographical and regulatory data to authorities and fairway users. Specht et al. (2020) examined the concept of RIS in the European setting to identify the digital information services required for enhanced planning decisions before and during transport operations and specific information to carry out the respective planning tasks. The study further reveals that the RIS, smart fairway, and RIS corridor management concepts, along with their related infrastructure, have proven to enhance the efficiency of IWT. Durajczyk and Piotr (2022) evaluated the RIS as an advanced inland shipping tool to improve Poland's IWT logistics attractiveness, measured based on the logistic performance index (LPI). The research findings show that RIS has the potential to enhance the performance of IWT beyond its current focus on navigability information, traffic management and safety. Additionally, they emphasised that it could provide valuable information services for logistic operators and cargo owners.

Roso et al. (2020) highlighted that interoperability is crucial for the inland transport business to ensure unrestricted access and promote competition among service providers. Colling et al. (2021) define interoperability as the capacity of different systems and technologies to interchange and exchange information seamlessly. Durajczyk (2020) explores the impact of interoperability in the IWT domain, and the findings reveal that an interoperable RIS allows vessels and related stakeholders to obtain up-to-date standardised and reliable data regarding the inland waterway network, including information about navigation, traffic management and metrological conditions. The ability of different systems to work together effectively enhances IWT by improving the process of planning navigation, facilitating efficient logistics and guaranteeing the safety of vessels and personnel.

Furthermore, Specht et al. (2020) examined how interoperability with RIS improves IWT logistics efficiency. According to the study, interoperability with RIS increases logistic efficiency by seamlessly sharing real-time data (hierarchical tracking and tracing data at the logistic unit level) across different parties involved. This enhances the allocation of resources, synchronisation and cargo handling, resulting in reduced waiting times and improved fracture utilisation. Consequently, it makes the IWT supply chain more sustainable and appealing.

The study of Durajczyk and Piotr (2022) further revealed that except in Scandinavia, where there are no RIS services, however similar services like Automatic ship identification (AIS), single window data exchange, and Vessel Traffic Services (VTS) systems are in existence. According to their research, these transport technologies have empirically proven to increase efficiency, profitability and safety in shipping and further connect river-sea shipping better with other stakeholders as well as information flows in supply chains. Meersman et al. (2020) viewed these initiatives as the initial phase in developing remote traffic control systems and autonomous inland sailing. The IWT business has been transformed by implementing the AIS, which offers instantaneous vessel tracking and safety data (Posset et al., 2009; Asborno et al., 2022). Although the availability of AIS data for tracking vessels is widely recognised, the utilisation of AIS data for analysing IWT performance is a relatively new and developing area (Specht et al., 2020).

Asborno et al. (2022) explore the impact of AIS technology on enhancing transport operations. According to the study, an essential benefit of accessing AIS data to analyse IWT performance is the capability to track vessel speed and compare it to predetermined performance indicators. The study further reveals that shoreside operators can use AIS data to detect variations in vessel speed, such as unusually high or low speeds, which may suggest operational inefficiencies or safety issues. Additionally, examining this data can assist in optimising routes and schedules, guaranteeing that vessels maintain adequate speeds while minimising fuel usage and environmental consequences. The conclusion emphasises that the availability of AIS data for evaluating the performance of IWT is especially vital for waterborne enterprises aiming to improve operational efficiency and declare expenses.

Restrepo-Arias et al.(2022) examine the technological innovation and strategies introduced to enhance IWT performance. According to the study, the IWT sector is seeing notable technological progress, encompassing unmanned aerial vehicles (UAVs), intelligent sensors, robotic automation and artificial intelligence, blockchain, cloud computing and big data. The study underlined that autonomous vehicles and robots offer faster, more reliable, and cost-effective delivery services. At the same time, blockchain-enabled inland container shipping improves efficiency and reduces manual processes in freight operations. Meersman et al. (2020) and Durajczyk and Piotr (2022) further stressed that these technologies are improving the best path, increasing productivity and minimising human mistakes, contributing to a more environmentally friendly future. However, according to Collings et al. (2021), implementing cutting-edge technologies encounters regulatory and legal barriers and possible resistance from interested parties. Other researchers also highlighted the significance of tracking and tracing in the IWT logistics (Obreja et al., 2014; Specht et al. 2020; Restrepo-Arias et al., 2022; Durajczyk and Piotr, 2022). Niedzielski (2022) explores the use of global standard 1 (GS1)/ electronic product code information services (EPICS) and its implementation for tracking and tracing in the IWT domain. The research underlines the role of real-time monitoring in ensuring regulatory compliance, improving security, and facilitating stakeholder coordination. The research concludes that such systems can improve operational efficiency and resolve interoperability concerns.

Policy formulation

The development and execution of policies for IWT requires a thorough strategy that considers all aspects of the industry (Tzannatos et al., 2016). According to Hossain et al. (2019), IWT is vital for global trade, necessitating comprehensive policies addressing infrastructure, development, safety regulation, environmental sustainability and economic viability to ensure efficient and sustainable operations. Establishing policies is a critical phase in ensuring the efficiency of IWT performance (Mihic et al., 2012). The process has multiple crucial stages that must be meticulously carried out in order to attain the intended results.

Mihic et al. (2011) explore the freight policy framework for promoting waterborne transport as a sustainable transport mode in Europe - the Danube River. The key areas include four broad dimensions: the improvement of infrastructure, the promotion of environmental sustainability, the enforcement of safety laws and the assessment of economic feasibility. Furthermore, a thorough evaluation of the policy framework for assessing intermodal supply chain performance in the context of IWT has been proposed by Mihic et al. (2012). The policy framework encompasses enhancing infrastructure, optimising operating efficiency, promoting sustainability, ensuring safety and security and facilitating international cooperation. According to the study, governments and relevant stakeholders can translate policy objectives into concrete activities and initiatives by properly implementing policies. The implementation phase is vital for ultimately achieving the potential of IWT and improving its overall effectiveness.

Grezelakowski (2019) evaluates the growth of EU inland shipping and focuses on policy and freight transportation. The research identifies trends in IWT development in the EU, evaluating it from the perspectives of EU transport policy objectives and logistic market requirements by using statistical and economical methods to identify threats and barriers and assess opportunities and prospects for the future in the context of the EU transport market. The study also examines political and market-oriented scenarios of EU inland shipping development. The study's conclusion suggested that EU inland shipping should focus on increasing effectiveness, implementing low-emission fuels and driving systems to balance real and market-oriented development.

Totakura et al. (2020) identify ineffective policy as one of the factors affecting the performance of container shipping through inland waterways in India. The study suggested that the IWT sector policymakers must comprehensively understand the sector's present condition, pinpoint crucial concerns and prospects, and evaluate the environmental consequences. They must formulate strategies to tackle barriers and exploit favourable circumstances. Efficient vessel movement relies heavily on developing infrastructure, such as locks, bridges, ports, harbours, and shipping channels. In order to maximise the effectiveness of IWT, it is important to examine factors like capacity, connectivity and technological integration. According to Roso et al. (2020), incentives and grants are crucial for facilitating freight shifts to IWT. Kruse et al. (2014) explore the role of incentives and grants in promoting the modal shift of freight to waterways. According to the study, incentives and grants mitigate expenses related to improving infrastructure, converting vessels and establishing intermodal connections. Additionally, incentives such as improved operational procedures and prioritised infrastructure access further motivate the transition, rendering it economically feasible and expediting adopting sustainable transportation options. Kotowaska et al. (2018) and Rogerson et al. (2020) further considered these incentives and grants to significantly influence business decision-making and accelerate the adoption of sustainable transport solutions, making the transition financially viable and mitigating risks.

According to the study by Grzelakowski (2019), logistics clusters have developed as potential concepts in logistics, enabling the integration and coordination of different actors within a defined geographical area. Santen et al. (2021) examine the importance of collaboration in improving transport performance in the IWT sector. The study highlights the benefits of cooperation among stakeholders like shippers, carriers, terminal operators, and government agencies, as well as strategies like information sharing and joint infrastructure investments. Additional findings from the study show that policymakers and industry actors can develop effective measures to enhance the performance of IWT by comprehending the function and tactics of partnership.

Other researchers highlighted that education and skill development, knowledge transfer, and best practices are crucial in enhancing efficiency and safety. Vidan et al. (2012) argued that to maintain the attractiveness and competitiveness of IWT as a mode of freight transportation, a contemporary, flexible crewing system is required. In their work, Praveen and Jegan (2015) affirmed that the sector demands a vast, trained workforce for vessel operations as employees need more qualifications and training. The authors conclude by stressing the need for personnel training and valorisation.

Pfoser et al. (2018) emphasise the need to enhance capability building. Santen et al. (2021) noted the presence of a fragmented labour force and the challenges of dealing with an increasing scarcity of skilled personnel. Tournaye (2022) pointed out that a global problem associated with the inland waterway freight transport industry is that a highly qualified and motivated staff for port activities is a problem that often results in immense waiting times. The summary of the articles highlighting performance measurement in the IWT domain was classified into different groups as shown in Table 2.4.

Table 2-4: Articles highlighting performance measurement in the IWT domain identified in the literature in Europe and other countries

Category	**Performance Measures**	**Author(s) and Year of Publication**	**Areas**	
			Europe	**Other Regions**
Mobility and reliability	• Transit time	Wilson (2006), Caris et al. (2011), Passchyna et al. (2016), Hekkenberg et al. (2017), Defryna et al. (2021), Guan et al. (2021), Hammedi et al. (2022)	X	
	• Navigability	Xing et. (2013), Jonkeren et al. (2014), Schweighofer (2014), Beuthe et al. (2014), Liu et al. (2015), Christodoulou et al. (2020), Dorsser et al.(2020), Yu et al. (2020),	X	X

	• Availability and access to multimodal transport information	Farazi et al. (2021), Farazi et al. (2022),		X
	• Carriage capacity	Jonkeren, Caris et al. (2011), Jonkeren et al. (2014), Beuthe et al. (2014), Passchyna et al. (2016), Wang et al. (2017), Yu et al. (2020), Christodoulou et al. (2020), Dorsser et al.(2020), Guan et al. (2021), Vinke et al. (2022), Hammedi et al. (2022)	X	
	• Handling performance	Wilson (2006), Passchyna et al. (2016), Hossain et al. (2019), Hassel and Rashed (2020), Guan et al. (2021), Hammedi et al. (2022)	X	X
	• Quality level of traffic services	Passchyna et al. (2016), Restrepo-Arias et al. (2022)		
	• Availability of transport infrastructure such as river port and multimodal connectivity	Saeedi et al. (2022), Hossain et al. (2019)	X	X
Efficiency and profitability	• Total cost and expense of river freight	Konings (2003), Jonkeren et al. (2007), Karttunen et al. (2012), Jonkeren et al. (2014), Beuthe et al. (2014), Wiegmans and Konings. (2015), Hekkenberg et al. (2017), Hofbauer and Putz (2020), Poznanska and Montewka (2020), Christodoulou et al. (2020),	X	
	• Energy efficiency	Xing et. (2013), Lier and Macharis (2014), Tzannatos et al. (2016), Kalajdzic et al. (2022), Kortsari et al. (2022)	X	
	• Attractiveness of the transport system	Konings (2003), Karttunen et al. (2012), Brusselaers and Momens (2022),	X	
	• Price alternative (e.g., road and rail)	Karttunen et al. (2012), Brusselaers and Momens (2022),	X	
	• Transhipment cost in seaport (time-cost saving)	Hekkenberg et al. (2017), Hofbauer and Putz (2020)	X	
Environmental impact and decarbonisation	• Emission reduction	Rigo et al. (2007), Rohács and Simongati (2007), Xing et al. (2013), Keuken et al. (2014), Segui et al. (2016), Lier and Macharis (2014), Mostert et al. (2017), Christodoulou et al. (2020), Mako et al. (2021), Kalajdzic et al. (2022)	X	X

	• Renewable and alternative energy	Mihic et al. (2011), Łebkowski (2018), Kortsari et al. (2022),	X	
	• Emission reduction funding	Mihic et al (2012), Tzannatos et al. (2016)	X	
	• Enforcement/monitoring	Xing et al. (2013), Keuken et al. (2014), Wang et al. (2020),		X
	• Noise	Grey et al. (2021), Brusselaers and Momens (2022)	X	
Infrastructure condition	• Connectivity (road and rail interchange)	Hossain et al. (2019), Saeedi et al. (2022), Totakura et al. (2022)	X	X
	• Transhipment facilities for integration	Saeedi et al. (2022), Hossain et al. (2019), Totakura et al. (2022)	X	X
	• Modern fleets for competitiveness	Păcuraru et al. (2015), Hassel and Rashed (2020), Łebkowski (2018), Meersman et al. (2020),	X	
	• Congestion-free transport system	Konings (2003), Alias et al. (2022)	X	
	• Maintenance of infrastructure	Kruse et al. (2014), Baroud et al.(2014), Passchyna et al. (2016), Ahadi et al.(2018), Meersman et al. (2020), Guan et al. (2021), Defryna et al. (2022), Totakura et al. (2022)	X	X
	• Limited geographical expansion	Konings (2003), Defryna et al. (2021), Totakura et al. (2022)	X	X
	• Spatial planning	Konings (2003), Totakura et al. (2022)	X	X
Safety and Security	• Traffic condition	Posset et al. (2009), Restrepo-Arias et al. (2022), Defryna et al. (2021)	X	X
	• Navigation safety and route capacity	Martin et al. (2004), Maras (2008), Camp et al. (2010), Vidan et al. (2012), Schweighofer (2014), Beuthe et al. (2014), Jonkeren et al. (2014), Liu et al. (2015), Păcuraru (2015), Wang et al. (2017), Łebkowski (2018), Meersman et al. (2020), Dorsser et al. (2020), Hossain et al. (2020), Yu et al. (2020), Christodoulou et al. (2020), Zentari et al. (2022), Vinke et al. (2022).	X	X
	• Vessel identification	Restrepo-Arias et al. (2022), Durajczyk and Piotr (2022), Asborno et al. (2022)	X	X

	• Seaworthiness	Dorsser et al.(2020), Meersman et al. (2020), Păcuraru (2015), Zentari et al. (2022), Totakura et al. (2022)	X	
	• Weather forecast	Schweighofer (2014), Baroud et al. (2014), Jonkeren et al. (2014), Beuthe et al. (2014), Christodoulou et al. (2020),		X
Innovative transport technology	• Information and communication flow along the supply chain (Data exchange)	Posset et al. (2009), Specht et al. (2020), Durajczyk and Piotr (2022), Asborno et al. (2022)	X	X
	• Shoreside data availability (AIS coverage)	Durajczyk and Piotr (2022), Restrepo-Arias et al. (2022), Asborno et al. (2022)	X	X
	• Hierarchical tracking and tracing of data at logistics unit level	Specht et al. (2020), Durajczyk and Piotr (2022), Asborno et al. (2022)	X	X
	• Interoperability with customers systems	Grzelakowski (2019), Specht et al. (2020), Durajczyk and Piotr (2022)	X	X
	• Voyage planning	Specht et al. (2020), Restrepo-Arias et al. (2022), Passchyna et al. (2016), Meersman et al. (2020), Colling et al. (2021), Durajczyk and Piotr (2022), Asborno et al. (2022)	X	X
	• Tracking and tracing based on GS1/EPCIS	Specht et al. (2020), Restrepo-Arias et al. (2022), Durajczyk and Piotr (2022)	X	X
	• RIS and VTS services	Meersman et al. (2020), Specht et al. (2020), Colling et al. (2021), Restrepo-Arias et al. (2022), Durajczyk and Piotr (2022), Asborno et al. (2022)	X	X
Economic development	• Aggregate added value (of transportation and infrastructure)	Konings (2003), Rigo et al. (2007), Posset et al. (2009)		X
	• Development (regional and local)	Konings (2003), Mihic et al. (2012), Alias et al. (2022)	X	X
	• Employment (direct and indirect)	Posset et al. (2009), Idan et al. (2012), Vidan et al. (2012), Colling and Hekkenberg (2020), Meersman et al. (2020), Colling et al. (2021), Tournave (2022)	X	
	• Marketing	Konings (2003), Collings et al. (2021), Grzelakowski (2019)	X	

Policy formulation	• Administrative support for modal shift to inland waterways	Tzannatos et al. (2016), Santen et al. (2021), Totakura et al. (2022)	X	
	• Existing legislative framework for modal shift inland waterways	Mihic et al. (2011), Grzelakowski (2019), Mihic et al (2012), Huang et al. (2021), Totakura et al. (2022)	X	
	• Incentives and grants for modal shift	Kruse et al. (2014), Tzannatos et al. (2016),	X	
	• Knowledge transfer and best practise	Vidan et al. (2012), Santen et al. (2021), Tournave (2022)	X	
	• Logistic clusters formulation and collaboration	Rigo et al. (2007), Grzelakowski (2019), Santen et al. (2021), Alias et al. (2022)	X	
	• Education and skill development	Vidan et al. (2012), Pfoser et al. (2018), Tournave (2022)	X	
	• Integrated transport policy	Mihic et al. (2011), Mihic et al (2012), Tzannatos et al. (2016), Mostert et al. (2017), Totakura et al. (2022)	X	
	• Cooperation/collaboration	Mihic et al (2012), Hossain et al. (2019)	X	X

Source: Author work

2.3 Promoting Intermodal Inland Water Transport: The European Experience

The EU operates on standard policies that enable a single economic market within its member states. The common objective is to develop a regional transportation system, enabling good-quality services in efficiency, safety, security, and an environmentally friendly network. (Schulthof et al., 2022). The EU has explicitly tried to put the concept of sustainability at the centre of its transport strategy. In its 2011 transport white paper (European Commission, 2011), the union proposed measures to promote short-sea shipping, IWT, revitalising the railways and controlling the increase in air transport. These measures were explicitly designed to restore the shifting balance between different modes of transport, which over the years were seen to have inclined too far towards road transport (Aditjandra, 2018). However, of all the proposed measures, four were related to intermodal inland waterways, which were relatively modest: eliminating IWT bottlenecks, standardising technical specifications in IWT, harmonising pilots' certificates and the rules on rest times, as well as developing navigational aid systems (Wojewodzka and Rolbeiecki, 2019; Borca et al., 2023).

As part of the EU policy remains to promote intermodal IWT and make it more competitive, many argued that this could be enhanced through its integration into a co-modal logistic chain (Williamsson, 2020). To provide a solution for building new transport infrastructure, measures have been developed in the past and are continuing. Programmes, including the Navigation and Inland Waterway Action and Development in Europe (NAIADES I-III) and Trans-European Networks in Transport (TEN-T), were created to permit financing the sector through public funds (European Commission, 2017; Bak and Zalewski, 2021). Various other proposals to develop support to encourage start-ups through European funding were provided, including Marco Polo Structural Funds, Horizon 2020, and the Connecting Europe Facility (CEF) (Having, 2020).

2.3.1. Trans-European Network for Transport (TEN-T)

The Trans-European Network for Transport (TEN-T) Program was established by the European Commission to support the construction and upgrade of transport infrastructure across the EU. The commission adopted its first action on trans-European networks in 1990 (Jessen, 2015). The programme was established as an initiative to promote the cohesion, interconnection, and interoperability of all national transport systems and link somewhat isolated regions of Europe to the rest of the continent (European Parliament, 1996; Ines-Danube, 2017). Since its introduction, the EU has worked to promote the networks by combining different initiatives and, over time, policy, and regulation, which now define new routes and standards in the CEF.

2.3.1.1 TEN-T priority project approach

The TEN-T programme consists of hundreds of projects whose ultimate purpose is to improve economic and social cohesion through access to the trans-European transport network and its interconnection and interoperability. Thirty priority projects were selected in 2005, based on proposals from the EU Member States; according to the value they add to EU economic integration and their contribution to sustainable development, other horizontal priorities were also established (European Commission, 2014). Among all these priority projects receiving significant support, two were related to intermodal inland waterways:

- Priority Project Eighteen - Waterway axis Rhine/Meuse-Main-Danube

- Priority Project Thirty - Inland Waterway Seine-Scheldt

A significant proportion of the cost of this project was proposed from the EU's funds. Although a deadline of 2020 was proposed to complete all thirty priority projects listed by the EU, most of the projects were not completed, and funding was further extended until 2030 (European Commission, 2014; European Commission, 2020).

2.3.2 Priority Project Eighteen - Waterway axis Rhine/Meuse-Main-Danube

During the financial expenditures of 2007-2013, the concentration was on two priority projects for IWT, one of which was the Rhine/Meuse-Main-Danube inland waterway axis. However, in other regions of Europe, other activities have been undertaken by various Programmes such as those within the Directorate-General for Territorial Development (DG-REGIO) and the Directorate General for Enlargement (DG-ENLARGE) (European Commission, 2013; European Commission, 2018).

Other institutes have financed IWT in the past decades, but 2007-2013 was undoubtedly the first period when more than fifteen per cent of the total budget was allocated for IWT projects. Significant coordination efforts were dedicated to this project to establish a continuous connection between different European basins, starting from the Atlantic Ocean connecting the Belgian, French and Dutch basins and then finally running through the German and Danubian basins and ending at the Black Sea in Romania (See Figure 2.6).

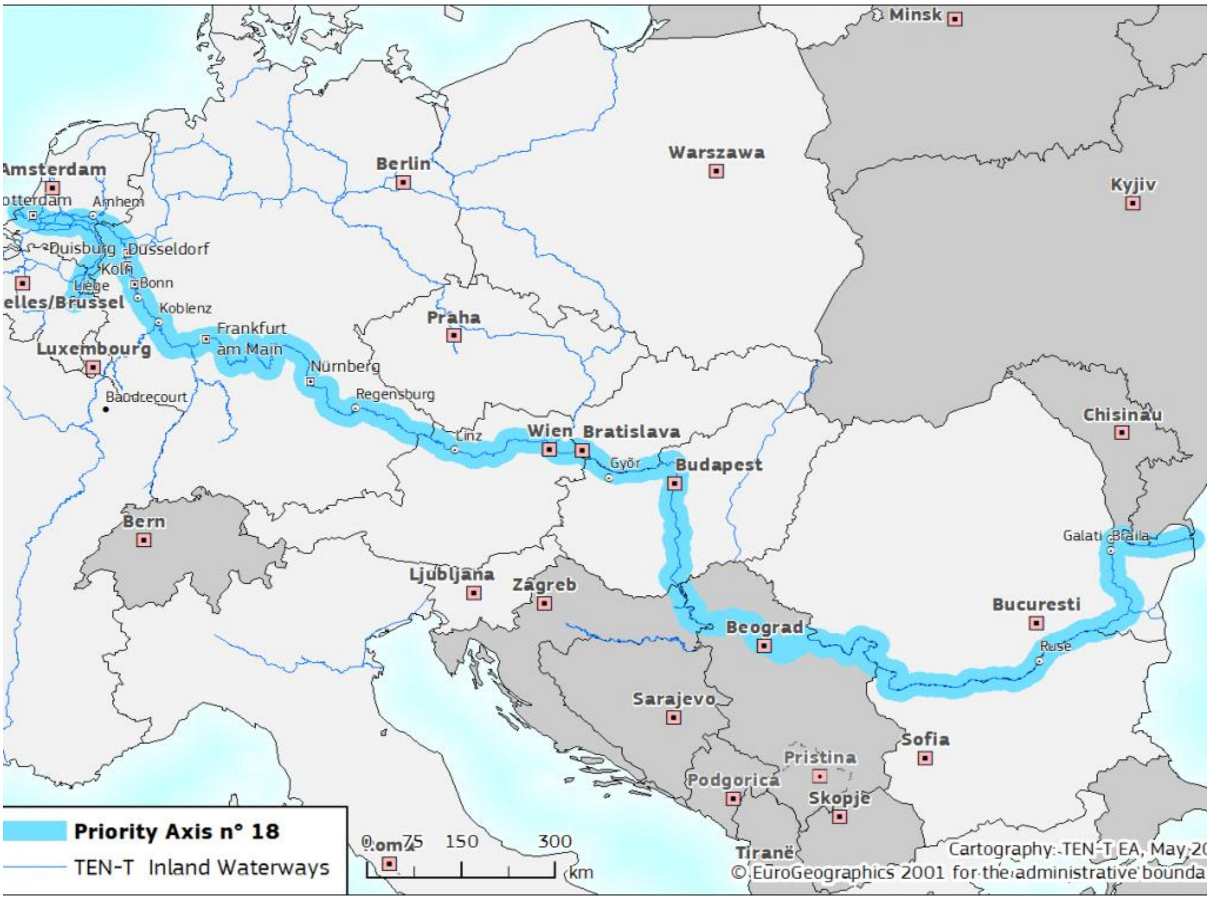

Figure 2-6: TEN-T Priority project eighteen.

Sources: European Commission (2017)

This corridor is one of the longest in the Trans-European Transport Network and crosses both EU and non-EU Member States. The intention is to achieve a 2.5m minimum draught throughout, allowing up to 3,000 DWT vessels. It was anticipated that a continuous connection between different European basins with an appropriate draught could transfer approximately 5 billion tonne-km of freight to waterways if the capacity of this link is increased by thirty per cent (INE, 2018; Jović et al., 2019). "The Rhine/Meuse-Main-Danube Inland Waterway Axis" was anticipated to be included in a TEN-T. As such, significant bottlenecks were tackled by financing detailed studies and specific infrastructural projects undertaken to either raise the river's capacity, construct larger capacity locks, lift bridges, or reconstruct bridges. The end goal of priority project eighteen was to concentrate on effective freight flow on waterways across different European countries by using river-based logistic routes to offer door-to-door services in combination with other transport modes. It will, in turn, help alleviate the congested European road network (ITF, 2018).

2.3.3 Priority Project Thirty - Inland Waterway Seine-Scheldt

The purpose of the Seine-Scheldt TEN-T priority project was straightforward. The project was anticipated to connect the French inland waterway network to the Belgian, Dutch, and German networks and ports and the main ports of the Northern Range (European Commission, 2018). Significant effort was made regarding the studies and work in order to achieve its set target. Its strategy was to explore a new solution for the river bottleneck in the north of Paris, where barges are restricted to 400-750 DWT in some places. The plan is to make routes more accessible for large gauge barges. Together with the Rhine/Meuse-Main-Danube inland waterway priority project eighteen, discussed above, the project aims to connect all significant inland waterway basins to integrate inland waterways solidly into the EU's transport network (European Federation of Inland Ports, 2015).

Removing existing bottlenecks could reduce the freight costs of IWT vessels by about two-thirds of the current cost. Achieving this would require partnership and cooperation through the involvement of various governmental administrations (Kaup et al., 2021). Currently, France, Flanders, and Wallonia are in close cooperation both at the political levels, through the Intergovernmental Committee (IGC), and at a technical level, in the European Group of Economic Interest (EEIG). This cooperation was vital to accomplish its aim of connecting all major inland waterway basins.

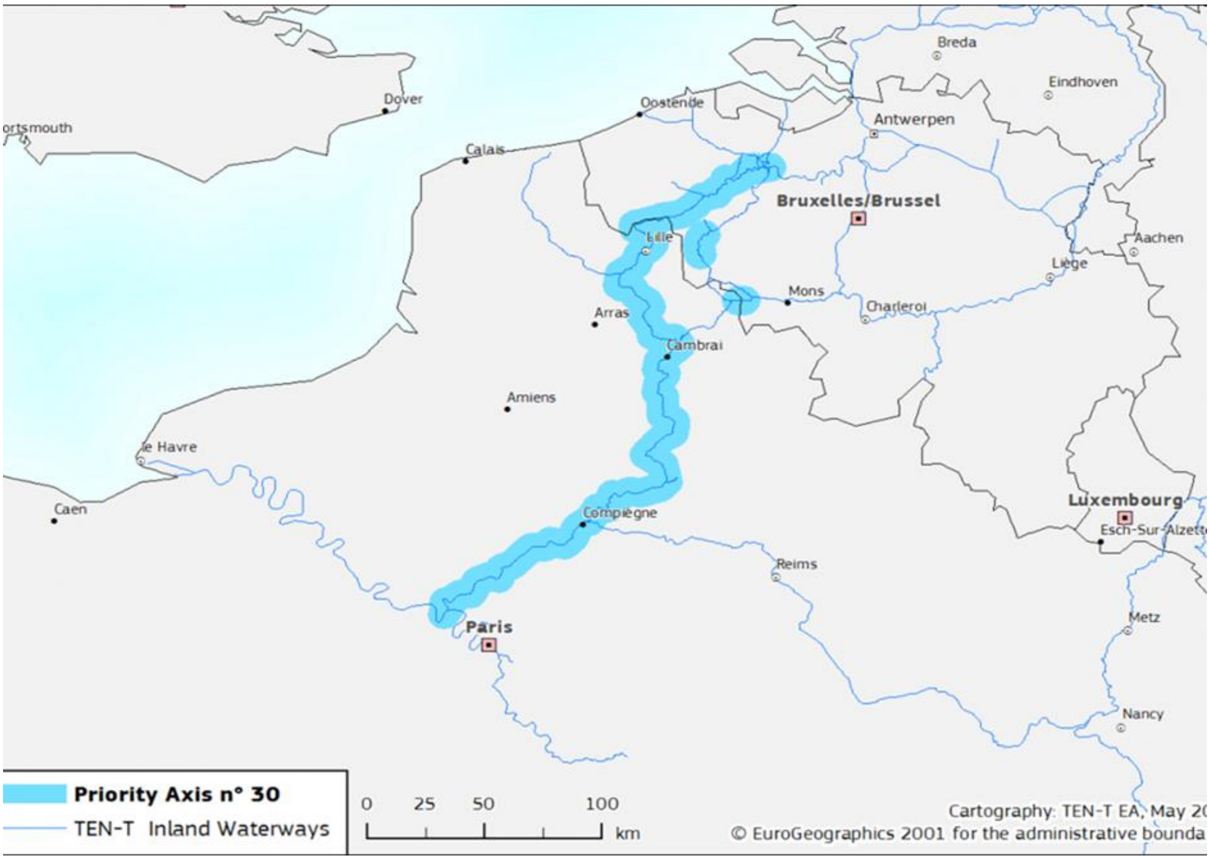

Figure 2-7: TEN-T Priority project

Sources: European Commission (2018)

2.3.4. TEN-T and Connecting European Facilities

Since the start of the CEF programme in 2014, various inland waterway action programmes have been granted through the CEF funding, with the sole aim of reinforcing the contribution of IWT and ports to a sustainable European freight transport network (Pradana et al., 2019). These focused on upgrading the network of TEN-T waterways in line with the technical requirement and priority of the regulation and enhancing safety and efficiency through deployment of harmonised and interoperable RIS across Europe. The aim is to facilitate the interface with other transport modes and introduce modern concepts, technologies, and innovation for the promotion of operation, sustainability, management, accessibility, multimodality, and efficiency of the network (European Commission, 2018).

2.3.4.1 The corridor project approach: RIS – Corridor management and RIS COMEX

The previous implementation of the RIS project was focused on the realisation of national RIS infrastructure linked to certain pilot activities, which are interconnected to the international exchange of RIS data. Building on the previous RIS Europe and CORISMA project results, it was indicated that such systems and services are crucial for efficient RIS corridor management. The RIS COMEX project addresses this issue. The project aims to implement RIS corridor services in a harmonised way. In parallel, it aims to better prepare national RIS infrastructures for the needs of global logistics (Lisaj, 2019). Figure 2.8. Present the phases of development of RIS in Europe.

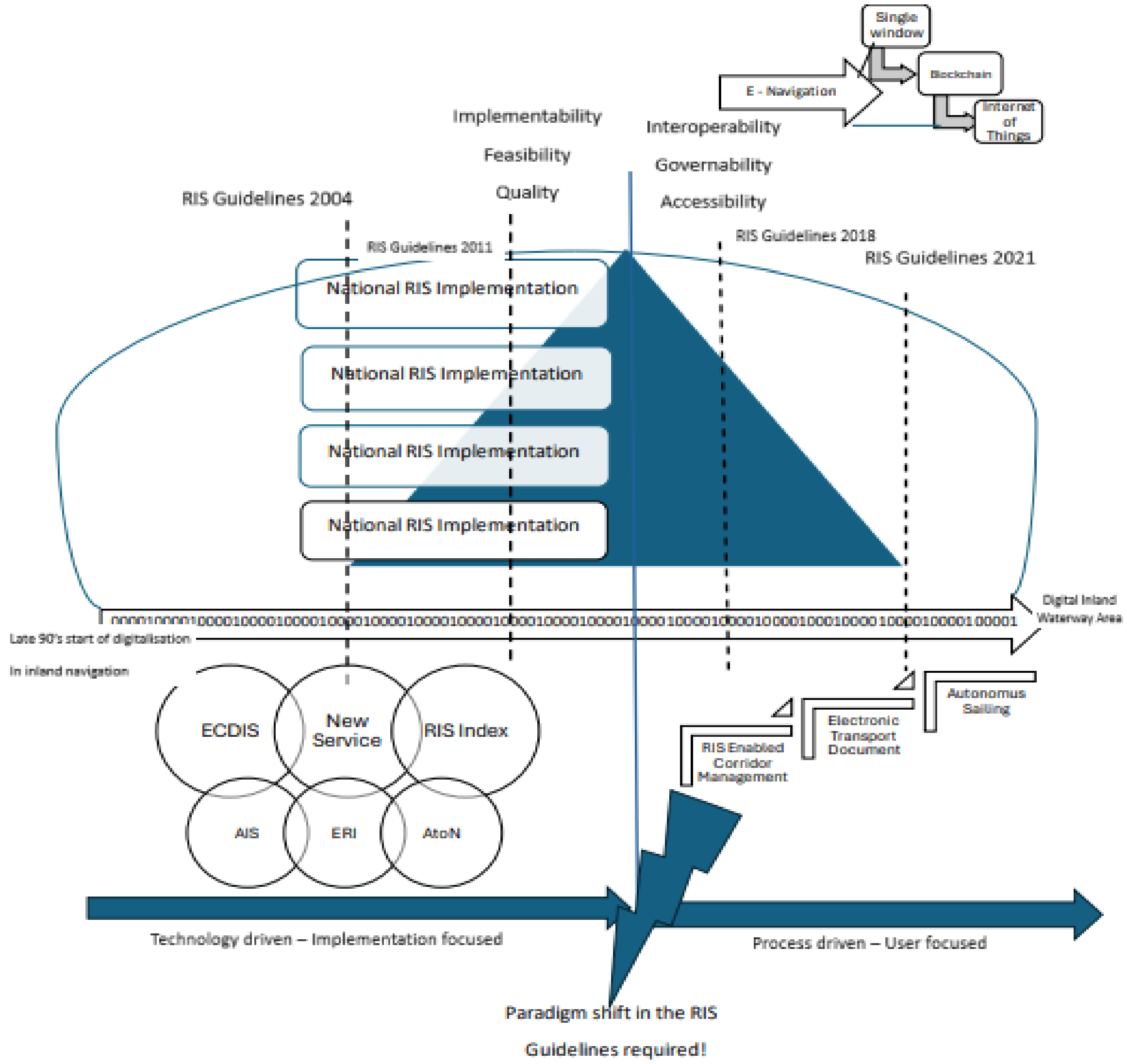

Figure 2-8: Phases of development of RIS in Europe

Source: Author work

The concept of "Corridor management" was to improve and link existing RIS services routes or supply RIS not just locally but on a regional, national, and international level. The project was to realise the RIS services in these corridors for services to authorities and logistic users within the sector and to transfer such services into sustainable operation (Viadonau, 2020). The ambition is to facilitate digital services (single window) to support voyage planning, transport, and traffic management. It would, in turn, make waterborne transport easy to use and reliable in the multimodal supply chains. The end goal of the process was to concentrate on the removal of administrative barriers (cross-border electronic reporting), leading to better reliability in the planning of the transport systems. Reduction in travelling time (cross-border travel planning) and, in general, efficiency improvement in inland navigation (cross-border exchange of information for logistic stakeholders) were the main priorities to be achieved from the project (RIS COMEX, 2020).

2.3.5 Navigation and Inland Waterways Action and Development in Europe (NAIADES)

In 2006, the European Commission adopted the first integral European action programme to promote IWT in the European Union territory called the "NAIADES". The NAIADES was a Commission initiative to enhance inland navigation as part of intermodal freight solutions in enabling sustainable, competitive, and environmentally friendly transportation networks in Europe (European Court of Auditors, 2015). To reach its full potential and contribute fully to the set objectives of the EU transport goal, the commission presented policy orientation for a joint approach to strengthening the IWT. It proposed action in five strategic areas: improving market conditions, modernising the fleets, improving human resources, raising image and awareness, as well as enhancing infrastructures (European Commission, 2011; INE, 2018). Several measures under this action programme were implemented through funding instruments like the TEN-T, Macro-Polo, and the seventh research framework programme.

To succeed in NAIADES I, NAIADES II was introduced and covered 2014-2020. NAIADES II aimed to improve the condition of inland navigation transport to become a quality mode of transport. It focuses on making long-term structural changes in the inland navigation sector to make the transport system more modern, innovative, and attractive. To achieve this, the sector's operational circumstances must be of high quality. Thus, the commission presented six critical areas of intervention. The areas include quality infrastructure, including filling missing links, clearing important bottlenecks, quality innovation, smooth functioning of the market, environmental quality through low emissions, skilled workforce and quality jobs and the integration of IWT into the multimodal logistic chain (European Commission, 2018).

Given the prospects and challenges the sector is encountering, the commission proposed an update and renewal of the NAIADES programme until 2027, leading to the NAIDES III support programmes to further boost the transport network's future-proof (Schoneich et al., 2022). Compared to its successor (NAIDES II), the action plans of NAIDES III were a modification of the transportation system to zero-emission and a modal shift concept within the EU (Plotnikova et al., 2022). The action plans proposed by the EU are taken into the following critical areas of intervention, achieving by the sectors digitalisation, quality, and efficient infrastructure for interconnection with other transport modes and better connectivity with other economic regions as well as including inland ports as multimodal hubs on European transport corridors and the deployment of alternative fuels (Mako and Galierikova, 2021).

2.3.5.2 Implementation of the NAIADES programme

To support the implementation of the NAIADES programme, the commission established the PLATINA project in 2008. (European Commission, 2011). The PLATINA is an organised system that contributes efficient actions and measures towards the promotion of IWT as a sustainable transport mode funded under the seventh framework programme for research and technological development. The project provides support in five strategic fields of the programme. Other actions by the PLATINA project include setting up information services for navigation and giving technical support for further development of the RIS (European Commission, 2018). The first phase ran from 2008 to 2012, the second from 2013 to 2016, and the final from 2017 to 2024.

2.3.2. EU funding for Services: Marco Polo Programme

The Marco Polo programme was proposed following the 2001 white paper on transport, in which inter-modality was a key concept (European Commission, 2001). The programme's purpose was straightforward; it aimed to ease road congestion and improve the environmental performance of freight through a switch to greener transport modes. The strategy was a modal shift action that shifted as much freight as economically as possible, meaning under its market position from roads to greener modes (Tomas et al., 2019). The programme provided grants to transport services to shift facilities from road to other modes like rail, short sea shipping inland waterways or combined modes where the journeys were as short as possible (Ecorys Nederland BV, 2007; Mason et al., 2015). The idea was to support intermodal transport freight initiatives and alternatives to road-only transport from the initial early stage until the process became commercially feasible.

The programme set a total of five funding areas. The first was the modal shift action. The second was catalyst action to promote modal shift; this involved technology-driven projects that supported Innovation by improving non-road freight transport to overcome structural barriers in the EU freight transport market. The others were "motorways of the sea" action, traffic avoidance and everyday learning actions to enhance knowledge and cooperation in intermodal transport logistic processes (Macharis et al., 2011; Meers et al., 2017). To achieve its set objectives, the programme supported transport, logistics, and other relevant markets that could shift the expected aggregate increase in international road freight traffic to other greener modes.

The Commission takes measures through the programme to return the market shares of all transport modes to their 1998 level by 2010. Viable projects with shift initiatives were funded until they became commercially viable. The overall duration of the programme was set to run from 2003 to 2010. The first stage ran from 2003 to 2006, while the second was from 2007 to 2013 (European Commission, 2014; Osama et al., 2017). The allocated budget for the first phase was 102 million euros. In comparison, the second phase rose significantly to 450 million euros because it added more features than its predecessor. Including the extension of the programme to third countries. At the end of the programme, the Marco-Polo was said to have fallen short of its set objectives. The next, advanced phase of the programme which started 2014, set out new strategies, although it has now been succeeded by the "Connecting Europe Facility" (European Commission, 2018).

2.3.2.1. The EU funding program Horizon 2020

The initial approach of achieving innovative, sustainable, and inclusive economic growth was outlined in the Horizon 2020 programme. The biggest EU framework programme for research and innovation focused on removing barriers to innovation and making it easier for the public and private sectors to deliver solutions (Razah et al., 2020). The initiative was adopted in 2014, with funding available over seven years (2014 – 2020). Under Horizon 2020, several projects enabled investment in Innovation, and the projects that had the most direct implications for IWT were:

- Promoting Innovation in the Inland Waterways Transport Sector (PROMINENT)
- Novel IWT and Maritime Transport Concepts (NOVIMAR)

• Architecture for European Logistics Information Exchange (AEOLIX), with waterways

The program ending in 2020 indicated that completing these projects would result in significant benefits in terms of economic growth and job creation (European Commission, 2020).

2.3.2.2. EU Project: Promoting Innovation in the Inland Waterways Transport Sector (PROMINENT)

In 2015, a proposal was created to advance innovation in the IWT sector. The aim was clear as it was initiated to help promote innovation in the IWT sector and address the key needs for technological development as well as the barriers to innovation and greening of the inland navigation sector in Europe (Zweers et al., 2019). The strategy was simple: "providing solutions which make inland navigation as competitive as road transport in terms of air pollutant emissions". PROMINENT was complementary to the European NAIADES II and III action programme. It lays emphasis on a further decrease in energy consumption and the carbon footprint of IWT in areas where the transport system has a strong advantage over the road network and aims to stimulate the further integration of the IWT into a sustainable transport chain (Šev˘ceko-Kozlovska and Cižiuniene, 2022).

The aspiration was in area where IWT has a strong edge compared to road, the existing fleet needed to be retrofitted or a new generation of innovative, smart, clean and climate change adapted vessels to be utilised. This was to enable the use of sustainable transport with low environmental impact and as well increase the performance of alternative and sustainable energy sources (Schweighofer, 2018). PROMINENT focused on action that supported the transition towards efficient and clean vessels to achieve its set objective.

2.3.2.3. Novel IWT and Maritime Transport Concepts (NOVIMAR)

Modal shifts to waterways are supported by an increasing number of projects that often focus on creating the necessary framework for such shifts to be achieved. Under the horizon 2020 programme, the waterborne community plays a critical role in helping to achieve the "Europe 2020" objective of innovative, sustainable, and inclusive growth. The Novitrans project enabled investment in innovation for IWT, the project aimed to improve the economic feasibility of waterborne transportation by introducing the concept of the "Vessel Train". This project was perceived as being different from others. The project moved towards adjusting inland/short-sea shipping to make optimal use of the waterborne system of waterways, vessels, ports, and terminals. Some saw the concept as one that would reduce operational costs and increase economies of scale due to better usage of existing infrastructures (Shankur et al., 2021).

In addition, compared to other projects promoting IWT, the Novitrans concept bridges the gap by providing a solution for overcoming barriers between transport modes and has a high potential for reducing road congestion (LOFT, 2019). Overcoming the barriers between transport modes as they exist today was argued to increase the economic viability of the transport sector hugely (Lauf, 2017). To achieve its objective, NOVIMAR introduces the platooning concept for transport by waterways, where a train consisting of one crewed leader vessel is followed by a few lightly manned or uncrewed follower vessels from different class sizes. The concept of reducing labour costs by sailing unmanned or lightly manned will go a long way to strengthening the overall competitiveness of the transport system and, more specifically, enhancing the economic potential for vessels of smaller size (Peeters et al., 2020a).

2.3.2.4. European Logistics Information Exchange with Waterways: AEOLIX Project

With the increasing need for information exchange between parties in the inland navigation sector especially, the exchange of traffic, transport, and logistic related in-formation, the EU has initiated several measures. Several European projects address the further enhancement of the RIS in a more harmonised way, utilising a common framework. Some see the RIS as able to support logistical transport and improve the position and performance of IWT in the intermodal supply chain (Troegl and Sattler, 2018).

However, efforts to implement the RIS over the past decades have not succeeded in achieving this ambitious goal. The AEOLIX project funded under the EU Horizon 2020 research and innovation programme stated that its principal objective was to overcome the fragmentation and lack of connectivity of ICT-based information systems for logistics decision-making and fill information gaps between logistics actors (AEOLIX, 2019). The AEOLIX Platform aims to connect logistics information systems with different characteristics, intra- and cross-company, for immediate (real-time) exchange of information. In doing so, logistics actors can better manage, (re) plan and synchronise facilities in the supply chain.

The "AEOLIX platform concept", which is expected to connect digital data streams from various sources and transport modes, is implemented in locations directly linked to the TEN-T network nodes across Europe. As a cloud-based platform, it is expected to support and increase the more substantial use of electronic reporting capabilities and connect with other data types, such as vessel position or the status of the inland waterway infrastructure. It was also anticipated that as a cloud-based platform or multi-enterprise "many-to-many platform", AEOLIX would capture and stream data in real-time. Doing so is seen to give companies the ability to react rapidly through a customised dashboard. In this way, AEOLIX overcomes bottlenecks and provides the supply chain actors with accurate, reliable, and trusted data in a secure environment (AEOLIX, 2019; Niedzielski and Durajczyk, 2022). The end goal of the connectivity process will be beneficial to factories, logistic service providers (LSP), carriers, terminals, public authorities, and customs.

2.3.3. Other EU funded programme: INTERREG

The use of alternative transport systems may be truly sustainable in terms of energy consumption, gas emissions, and traffic congestion, as explained in the EU's NAIDADES II programme. However, companies, producers, and hauliers have been reluctant to invest in changes in this very competitive sector of the economy (Rogerson et al., 2020). In addressing this, various EU-funded projects came into the limelight, one of which is the INTERREG program. The INTERREG community initiative ultimately focused on tackling common challenges and finding solutions in various fields, including sustainable transport. In parallel, it aims to promote the Union states' harmonious economic, social, and territorial development. As one of the EU's critical investments in supporting cooperation across borders through funding, the projects that had the most direct implications for the alternative transport system and promoting innovation in intermodal IWT were:

- Upper Rhine Projects
- Energy Barges – Building green energy and logistic belts.
- EMMA – Enhancing Freight Mobility and Logistics in the Baltic region
- ST4W - Smart Track 4 Waterway
- DANTE - Danube Transnational Programme
- IWTS 2.0 - Smaller waterway transport potential in a transnational context

Ultimately, from its inception in 1990 until 2020, INTERREG funded hundreds of projects, and the cooperation is structured around three strands: cross-border (Interreg A), transnational (Interreg B), and interregional (Interreg C) (European Commission, 2020).

2.3.3.1. INTERREG funded project: ST4W

Waterway transportation emits three times less CO_2 than road transport. An irreversible shift to this low-emission mobility alternative can achieve a sustainable transport system meeting the targets of long-term GHG emission reduction set by the European Commission to be achieved by the end of 2050 (Calderon-Rivera et al., 2024a). The purpose of the ST4W project was straightforward. It was to help reduce CO_2 emissions and road traffic congestion on Europe's busy roads by convincing shippers to ship palletised freight by waterways.

The ST4W "proposes a management solution for shipment by inland waterway transport, providing small stakeholders simpler and cheaper access to secure data and enabling them to share a hierarchical track and trace service of shipment at the logistics unit level" (Blic et al., 2018). It was argued that the use of pallets in place of containers for freight shipment offers opportunities to overcome many current limitations that hold back the exploitation of waterborne transport for freight shipment. To achieve its objectives, the ST4W aimed to develop a framework of innovative ICT tools enabling the synchronisation of data exchange between partners and easy access for SME inland operators. The solution is expected to provide end-to-end seamless visibility to supply chain stakeholders through a cloud-oriented platform (ST4W, 2020).

2.3.3.2. INTERREG promoting inland navigation in Baltic Sea Region: Project EMMA

Transport policies often focus on road and rail transport; project EMMA brought attention to the potential of IWT in the Baltic Sea Region (BSR). The objective is "enhancing freight mobility and logistics in the BSR by strengthening the sector and promoting new international shipping services". The rationale behind the programme is that transport volume in Europe and the BSR are expected to grow significantly in the following decades; these challenges could be reduced by transporting more goods on waterways (EMMA, 2016).

As a result, it focused on increasing the shares of IWT in the BSR. The project brought inland navigation to a broader national and European agenda by strengthening the sector's voice and demonstrating its potential in terms of transport and services. Based on the successful result and recommendation of project EMMA (2016-2019), the project was extended by two years (2019-2021). The second phase focused on the next steps towards the further market deployment of IWT by capitalising on the result and implementing practical solutions to IWT. The extension aims to enhance inland navigation by supporting the digitalisation of IWT and by implementing a new logistical concept. The introduction of modern concepts, technologies, and solutions to adapt to new market needs will provide inland shipping with a competitive edge over other means of transport in the region.

The project revealed that the sector's digitalisation is crucial to its competitiveness (Ionescu, 2016). In parallel, the extension aims to strengthen the region's RIS and VTS. Additionally, it was also anticipated that a web-based application of the inland waterways information system that allows logistics companies and skippers to plan their journey and operation better would increase the efficiency and reliability of the transport system (EMMA, 2019). In the end, this action by EMMA would provide an effective means for IWT integration into the logistic chain in the region.

2.3.4 Other regions initiatives in promoting IWT

The recent transport policy of many countries has been characterised by a trend of increasing interest in using other modes of transport for freight movement (Miloslavskaya and Plotnikova, 2018). The existing spatial limitation for road transport development and consequences of the economic crisis that made choice mode emphasis on costs and competition are among the initiatives and reasons for the interest in other modes. For decades, the US has actively funded and promoted waterborne transport to support the development of a more sustainable and efficient intermodal freight transport system. It launches a Marine Highways project (MARAD) to efficiently use its 29,000 nautical miles of navigable waterways for freight movement. The project leads the way in promoting the use of waterborne transport, including - short sea shipping. MARAD stated that its principle was to reduce freight congestion on both road and rail networks by increasing intermodal capacity through underutilised waterways (US Department of Transport, 2011).

Similarly, since the 1990s, the Chinese government has made significant investments in developing its transport infrastructure, particularly roads, rail, and airports (Asian Development Bank, 2016; Zhang et al., 2022). As recently as 2019, the IWT infrastructure in China represented six per cent of Chinese transport infrastructure investment. The strategic objectives of its transport policies have been to expand waterborne freight transport by substantially upgrading the transport system by 2020 (Yuan et al., 2020). Many other countries, including Japan and South Korea (Medda and Trujillo, 2010), Brazil (FAL, 2016) and India (Sharma, 2018; Trivedi et al., 2021), have also shown great interest in IWT development.

2.4. Transport and Environmental Performance

2.4.1. Transport performance

IWT in Europe represents about 145gt km per year in 27-EU countries, though it exits in a fraction of 11 EU territories where its modal share varies its ranks third in surface freight transport just after the road and rail network (European Commission 2018). About 550 million tonnes are shipped by waterways annually in EU 27. In 2021, the total volume of goods transported on the European inland waterways was around 524 million tonnes and transport performance amounted to nearly 136 million tonne-km (Eurostat, 2022(a). Compared with road and rail transportation, the modal share of IWT in the EU27 was 5.85 in 2020. The modal share of this transport system has gradually witnessed a steady decline. The road network has absorbed the carriage of goods over the latter half of the century due to its fast improvement, modern facilities, and range of services it offers potential customers (Mako and Galierikova, 2021). Although the road still reigns supreme in freight transportation and has kept its leading position in the modal split calculation in terms of transport performance (based on tonnes-kilometre performance). However, the IWT also play a considerable role in surface freight transportation, with countries like the Netherlands and Germany accounting for more than 70% of waterborne freight in the EU in 2020 (Havinga, 2021; Eurostat, 2022(b).

2.4.2. Environmental performance

Inland navigation is an inherently energy-efficient mode of transport (Bureau Voorlichting Binnenvaart, 2017). Its energy-efficient is often seen where high volumes over long distances contribute to sustainable performance (Lopez-Navarro, 2014). The transport mode is relatively sustainable due to its cargo-carrying capacity and the total amount of fuel consumed in proportion to the tonnage of the transported load. Whilst detained figures for CO_2 emissions depends upon a wide range of variables, it is generally accepted that waterway transport emits the lowest CO_2 in all transport modes due to its low fuel consumption (Grosso, 2021). Environmental arguments favour using inland navigation for freight transport, especially for its considerable potential in reducing CO_2 emissions. IWT emissions are approximately one-third of road freight (Zolfaghari *et al.,* 2019). For example, between Rotterdam and Duisburg, CO_2 emissions are approximately 50% favouring an intermodal chain using an inland barge in door-to-door container transport (Liimatainen et al., 2018).

Generally, maritime transport is a significant contributor to air pollutants due to their emissions of NO_X and SO_X, as well as particulate matter, especially in coastal areas (Sys *et al.,* 2020). The transport sector's share of total emissions of primary air pollutants is illustrated in Figure 2.9 below. When comparing other air pollutants than CO_2 in transport, inland navigation is said to be less performing (Bouckaert, 2016). Therefore, the scale of advantage offered by inland navigation keeps it on the top of the chart that, in many cases, its emission per tonnes-km does not exceed that of road freight transport (DG Move, 2011; Pinto et al., 2020).

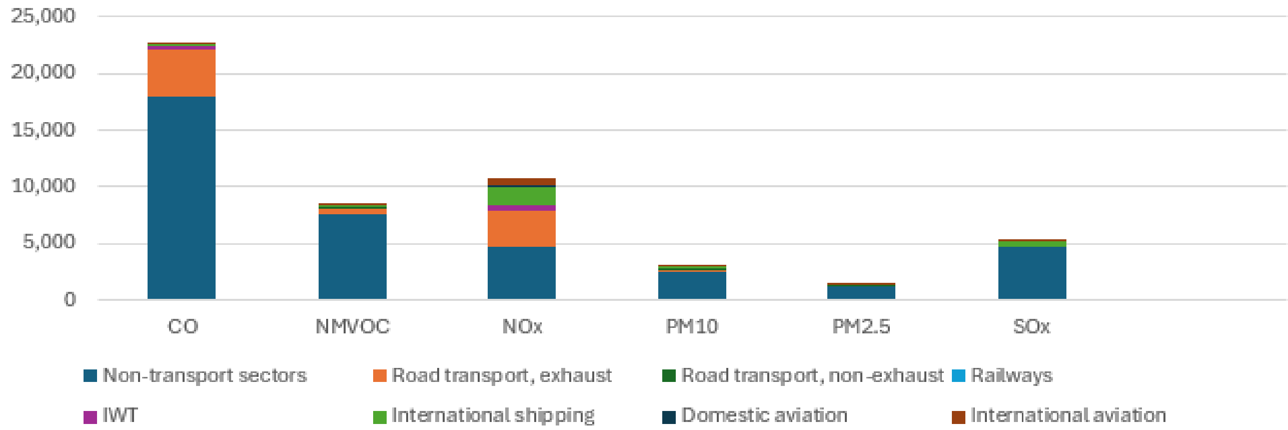

Figure 2-9: The transport sector's impact on overall emissions of major air pollutants

Sources: Author elaboration based on the European Environmental Agency (2020)

2.5. Inland Waterways Transport Sector in the UK

2.5.1. Inland waterway transport in the UK: characteristics and performance

Britain's inland waterways are highly diverse and comprise a wide variety of natural and artificial watercourses (Wiegmans, 2018). Table 2.5. presents those suitable for their use for freight transportation.

Table 2-5: Waterway Categories and Characteristics

Category	Characteristics	Other Roles	Examples
Estuaries and tidal rivers	• Channel size determines size of vessel. • Seagoing traffic extending journey inland, reducing length of road journey. • Traffic moving between tidal and non-tidal water. • Suitable for bulk carriage and containers • Suitable for abnormal indivisible loads	- Maritime and port uses. - Land drainage. - Aggregate extraction. - Some leisure use	- River Thames - Mersey Estuary - River Trent - River Yare - River Ouse - River Medway
Large non-tidal waterways	• Lock size determines craft size. • Lock size considerably larger than broad waterway • Vessel payload in hundreds of tonnes • Seagoing traffic extending journey inland if lock size sufficient • Traffic moving between tidal and non-tidal water. • Suitable for bulk carriage, may be suitable for containers. • Suitable for abnormal indivisible loads	-Land drainage - Some leisure use	- Aire & Calder navigation - River Weaver - River Severn - Manchester Ship Canal - River Thames - Gloucester & Sharpness Canal
Broad Waterways	• Locks approx. 4.5 metres wide and up to 30 metres long • Vessel payload 50 to 100 tonnes • Suited to specialist markets e.g., aggregates, waste. • Not suitable for abnormal indivisible loads	- Significant leisure use which may restrict capacity for freight. - Land drainage - Leisure use of towpath	- Grand Union Canal - Leeds & Liverpool canal - River Great Ouse

	• Unlikely to be suitable for containers		
Narrow Canals	• Locks approx. 2.1 metres by 21 metres • Vessel payload typically 20-25 tonnes • Long lock free lengths may accommodate larger vessels. • Not suitable for abnormal indivisible loads or containers	- Significant leisure use which may restrict capacity for freight. -Land drainage - Leisure use of towpath	- Trent & Mersey Canal - Oxford Canal - Monmouthshire & Brecon Canal -Birmingham Canal Navigations

Source: Remodified from the Department for Transport (2004; 2021)

England and Wales have around 3,170 miles - 5,100 kilometres of canals and other navigable waterways (Department for Transport, 2021). These waterways' characteristics vary in terms of the scale of operation and governance arrangement. Most of the system consists mainly of non-tidal canals and rivers that have been made navigable. Most of this network is characterised by seasonal recreational use, although several hundred miles of these canals and rivers are also used for freight transportation (Veitch, 2016). Despite the increasing cost of road transport and the benefits the IWT offers, freight movement on this network has significantly declined in recent years. In 2021, 6% per cent of the overall domestic waterborne freight traffic in the UK was accounted to IWT (Department for Transport, 2022). Similarly, as recently as 2019, domestic freight moved within the UK amounted to 196 billion tonnes-kilometres, of which 79% were by road, 8% by rail and 13% by waterways (Department for Transport, 2020). Figure 2.10. below shows the domestic waterborne freight goods moved and lifted in 2021 in the UK.

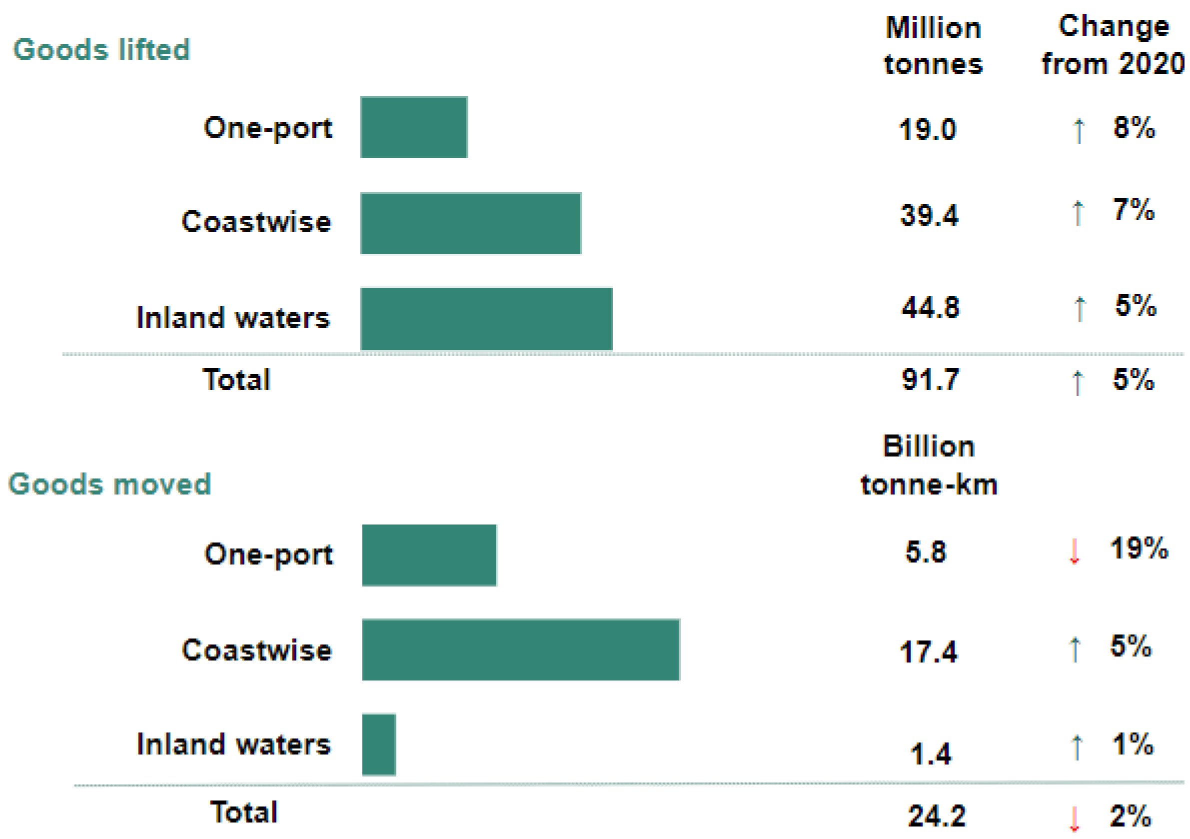

Figure 2-10: Domestic waterborne freight goods moved and lifted, 2021

Sources: Department for Transport (2022).

Analysing freight transport of many countries across Europe reveals that while freight statistics in Germany and Netherlands remain substantially constant over five years (2014 - 2019), the corresponding figures in the UK are seen to be much smaller and showing a significant decline over this year (Rogerson *et al.,* 2019). Table 2.6 shows freight moved by individual waterways in the UK in 2021.

Table 2-6: Domestic waterborne freight goods moved by waterway in 2021

River Thames	River Humber	River Clyde	River Forth	River Ouse	River Trent	Aire and Calder	MSC & River Mersey	River Medway	River Severn
0.79	0.15	0.06	0.14	0.08	0.05	0.01	0.15	0.03	0.01

Sources: Author work based on Department for Transport (2022)

A recent freight modal share study in the UK reveals that this decline has been mainly due to inland waterway infrastructure and the established freight routes within the country (Zolfaghari *et al.,* 2019; Terziev et al., 2023). These challenges range from poor maintenance (the channels' dimensions, the trail's depth and width, and the height of the bridge), terminal facilities, ageing vessels, low public perception of waterways potential and improved road network resulting in fierce competition from the road transport (Veitch, 2016). According to Gosling (2019), another attribute associated with the steady decline over the years is the death of the British traditional industrial base, such as the closure of coal mines and steelworks and the end of production of most factories alongside canals and rivers. Historically, as these canals were earlier developed to carry bulk products (coal, steel, wool, and aggregates), the residual freight transportation in the UK still follows the same pattern of bulk products (Vendela *et al.,* 2018). Although with the recent introduction of modern concepts, technology, and innovation, the IWT has also witnessed various goods, including oil, rice, steel, coil, fly ash, and heavy goods like wind turbines, which may be challenging to carry by road (Zolfaghari *et al.,* 2019). Figure 2.11. depicts freight transport volume via waterways in the UK between 2006 and 2021.

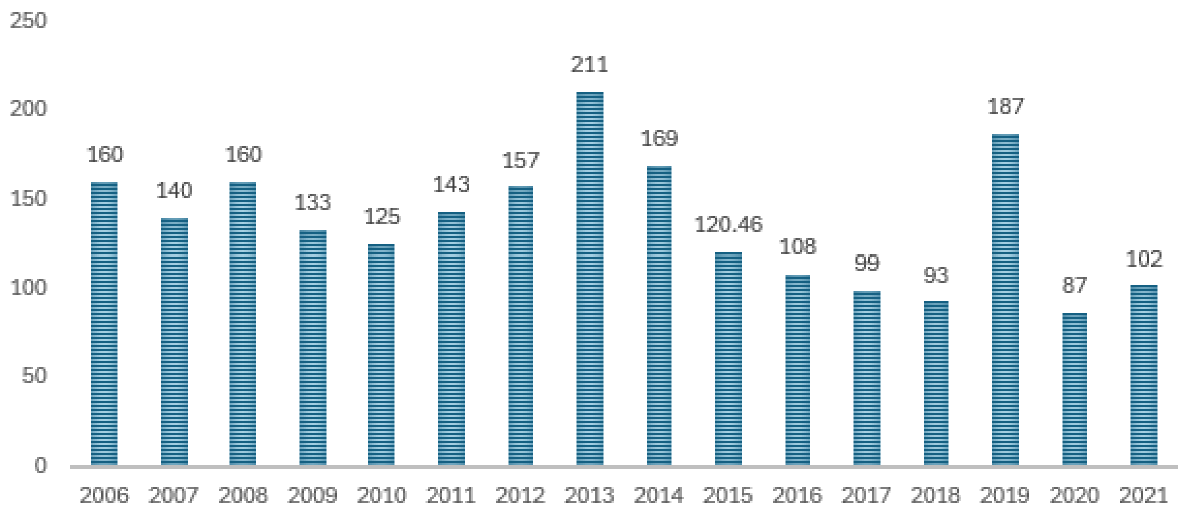

Figure 2-11: Amount of freight transported by inland waterway in the UK from 2006 to 2021 (in million tonne kilometres)

Sources: Author own elaboration based on Eurostat (2024)

2.5.2. Challenges and key issues

Compared to other transportation sectors with large economies, IWT, free capacity in some regions of favourable geography, is used significantly less and under-explored due to political issues and natural causes (Rogerson et al., 2019). Research has acknowledged that several challenges and issues impede its effectiveness and sustainability (Wojewodzka and Rolbeiecki, 2019; Sys et al., 2020). In the UK IWT domain, these critical issues are categorised into four major groups: technical, geo-political factors, investment, and cooperation through integrated transport development, as illustrated in Figure 2.12.

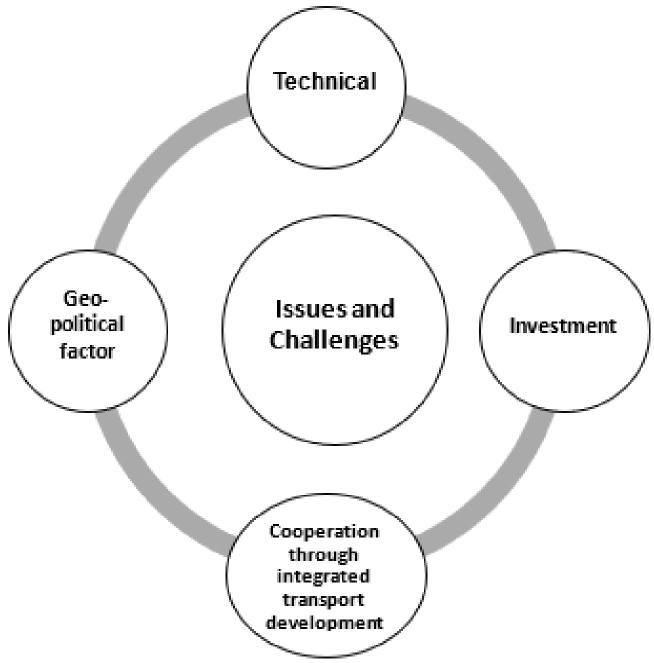

Figure 2-12: Key issues and challenges in the inland waterway transport sector in the UK

Source: Author work

Technical

Infrastructure is a significant transport development factor as it directly influences modal choice (Bury *et al.,* 2017). To a large extent, the competitiveness of waterborne transport depends on the quality of waterway infrastructure standards (Ines-Danube, 2017).

I. *Inadequate fairway depth* – As illustrated in Table 2.5, a significant part of the UK waterways is for leisure and recreational use, resetting freight capacity. Fairway deep is critical because it determines if an inland barge/vessel can safely and simultaneously navigate upstream and downstream at the required speed. The water depth available in the fairway determines the tonnes of cargo a vessel can carry and is essential to make the commercially feasible through economies of scale (Wiegmans and Konings, 2015). The UK's inland waterways faced severe problems in this regard, thus restricting cargo movement via this mode of transport (Gosling, 2019).

II. *Inadequate air draught* - Simultaneously passage of inland vessels depends on bridge clearance (the highest fixed points of the vessels - lowest navigable waterways level). Air draught of a barge/inland vessel and vertical bridge clearance determines the parameters of safe vessel passage under any bridges with lower vertical clearance obstructing the safe passage of a vessel (Wiegmans, 2018).

III. *Maintenance* – With maintenance, transport infrastructure can retain its value (Zhang and Cheng, 2023). Making waterways navigable through the year, dredging, and constructing canals, and building a set of locks have substantial financial implications. Hazenberg and Bajwa-Patel (2014) highlighted that lighter loads are often carried on a barge in some waterways in the UK due to inadequate dredging. On the other hand, Treziev et al. (2018) stressed that infrastructure managers often postpone waterway infrastructure maintenance or modernisation due to underutilisation.

IV. *Fleet modernisation* - The inland shipping sector in the UK faces the necessity to renew and modernise its fleets and keep track of investment in new technologies (Prina et al., 2023). Compared to other sectors like road and rail, a poor margin characterised the UK inland navigation sector in fleet modernisation (Calderon-Rivera et al., 2024a). Largely, the competitiveness of waterborne transport lies in modern fleets.

V. *Lack of service centres* - The lack of infrastructure and service centres, for example, intermodal connectivity, terminal and terminal equipment, storage facilities, and value-added services, hinders the smooth cargo transfer between nodes (Calderon-Rivera et al., 2024b).

Investment

I. *Government investment* - Transport policy and associated investments in the UK tend to prioritise road and rail transport excessively (Riccardo et al., 2016). While the UK has inland waterways lying dormant, the sector has suffered severe setbacks in transport investment compared to the road and rail infrastructure over the past decades. This has discouraged a modal shift towards this transport mode in the UK due to the level attained by the transport mode (Gosling, 2019).

II. *Private sector investment* - In the UK, the private sector operators use specific waterways networks nationwide for freight movement. Veitch (2016) emphasised that policy measures on private sector participation (development and maintenance) can be explored, like in the road and rail sectors.

III. *Workforce/skill shortage gap* - A significant challenge currently being felt in the inland waterway transport industry is related to the workforce shortage. The sector faces a fragmental labour force and a growing need for more qualified vessel operators. Personnel training, improving career attractiveness and valorisation are required to utilise this transport mode effectively (Schonfelder, 2016).

Cooperation through integrated transport development

I. *Setting incentives* - Supporting modal shifts to other modes entails support from the government through proactive actions. Using inland waterways for freight transportation can be economically more attractive if the government sets out valuable promotions and incentives for waterborne transport (Prina et al., 2023).

II. *Tailor-made support instrument* - Support instruments to boost the use of waterways are significant. Using rivers for freight requires high investment costs, and access to public and private funding is necessary to introduce new services or modern concepts. Government funding in support of modal shifts should be made more accessible (Veitch, 2016; Camargo et al., 2022).

Geo-political factors

I. *Flow and integration of inland ports* - Inland ports along seaports with good inland waterway connectivity are efficient transhipment nodes. Projects encouraging the interlinking of inland ports are essential for these ports to reach their potential in serving regional supply chains (Mason et al., 2015). Due to their geographical position, the strategic importance of connectivity is essential to other regions with limited waterways (Tomas et al., 2019).

II. *Integrated river management system/Hydropower generation projects* - To ensure all year-round navigation, integrating the river basin is important (Lataire et al., 2012). This integrated river basin can create a water highway for economic and environmental prosperity between regions in the country. Mitigating seasonal waterways through a river management system can help manage the river efficiently for freight movement (Du et al., 2020). The use of hydropower dams to increase the waterway channel depth is essential to keep up all year-round navigation, as some waterway routes face severe economic viability challenges.

Hydropower generation projects are needed in the UK's inland waterway industry to aid the effective use of the available resources (Terziev et al., 2023).

III. *Regulatory framework* - Inland shipping is often a border-crossing transport network in some cases. Lack of an effective regulatory framework is often a challenge for the industry as, too often, there are always disparities between countries, and consequently results in administrative and operational delays (Wiegmans, 2018).

2.6. Infrastructure and Operations

Waterborne transport is an essential and often overlooked part of the freight transportation system. Freight transportation on this network is highly dependent on significant infrastructure investment, making waterway routes navigable, building bridges, and establishing locks, which have substantial financial implications (Smetanin and Zhogin, 2023). Without proper maintenance, the infrastructure’s value is gradually lost, and where routes are not dredged, barges must carry a lighter load. The dominant issue associated with waterway infrastructure is the capacity limit for vessels sailing through bridges, canals, and locks; for example, where the vessel is large, passage through narrow canals becomes difficult or impossible (Wiegmans and Van Duin, 2017). Bottlenecks can be easily created by locks, where barges must slow down or even wait long hours to pass them. Capacity issues have become a stumbling block for adequate movement; overcoming this might require an increase in capacity-building units (Defryna et al., 2021).

The principal competitive factors in terms of infrastructure are fairway depth and maintenance of bridges, locks, and port services. The width and shape of the fairway determine whether vessels navigating upstream and downstream can pass simultaneously and their navigation speed (Peng et al., 2022). On the other hand, the weight of goods an inland vessel can successfully carry is determined by the water depth (INES, 2018). For border-crossing transport and even multi-corridor transport, a comprehensive corridor perspective is crucial for developing and implementing the smooth functioning of the transport network.

According to Beila and Putz (2023), the lack of political focus to facilitate and promote the IWT-based intermodal system has made this difficult to achieve. Transport policies and linked investments are often focused on roadways and railways, whereas the waterways and infrastructure lie dormant. These actions by decision-makers have distorted and reduced the competitiveness of the transport system. The benefit of inland navigation with respect to external costs for society has not been considered sufficiently. As highlighted by the European Court of Auditors (2015), inadequate infrastructure (i.e., bottlenecks and missing links) limits inland and river-sea navigation. Despite the ample spare capacity, transport efficiency and competitiveness have been hampered by insufficient quality infrastructure at critical parts of the transport network. This has limited the areas where this mode can compete with the dominant road and rail transport modes (Roso et al., 2020). Uncertainty about planning and removing bottlenecks in some EU freight transport corridors has discouraged the modal shift aspirations of customers/companies searching for energy-efficient and reliable logistics operations in terms of transit time, price, and other comparable conditions (Baird, 2017; Borca et al., 2023).

Infrastructure quality directly influences the choice of transport mode (Lučić, 2021). To deploy full intermodal services, the quality of waterways and railways must be as good as the quality of transport interchange options between the modes. Investment in building operations of these missing links brings about socio-economic benefits and increases the modal share of multimodal transport, enabling geographic market expansion (Lisaj, 2019).

2.6.1 Port infrastructure

The problem of port limiting the overall efficiency and development of inland/river-sea shipping has been stated in previous literature regarding the seamless integration of IWT into modern industrial supply chains. To a large extent, the literature views the competitiveness of inland port to be predominantly affected by factors external to the ports themselves, connected mainly with the quality of the hinterland and foreland infra-structure (i.e., road and rail links to port) (Caris et al., 2014; Kotowska et al., 2018).

There are significant opportunities to substantially increase freight transport by waterways in the UK, with inland ports playing vital roles within the network. For example, Burn (1984), Lowe (2005) and Zolfaghari et al. (2019) examine the situation of British canals and inland waterways before and after, the 1990. The study explains the performance of IWT in the UK and point out that government ignorance on commercial activities on waterways was the main reason the IWT survived. The latter focused mainly on institutional structure, infrastructural condition, and hinterland connectivity routes, but the limited infrastructure investment in IWT impaired the river logistics chain Reliability levels and port services became limited (Arof, 2015). Questions have been raised regarding the availability and reliability of port transhipment facilities in adapting to new market needs (Wiegmans, et al., 2015). Thus, for inland ports to play a more significant role in freight operation aiming towards improving terminal port activities, a trade-off occurs between investing in facilities upgrades or developing the productivity of the present system.

2.6.1.1 Inland ports and the various role they play

The competitiveness of an inland port depends on the reliability and quality of services the port can offer as well as the extent to which the cargo handed in the port can successfully reach its hinterland destination (Acciaro and McKinnon, 2013). In most ports worldwide, hinterland access is recognized to be one of the most crucial is-sues in port competitiveness and development. The development of trade corridors significantly influences port competitiveness for the port system to be integrated into the multimodal transport network.

At the European scale, inland ports play a crucial role in the multimodal transport chain because of their close location to the hinterland. They operate as transfer points to other modes and relate to urban logistic centres, agricultural areas, industrial areas, or large consumer markets like metropolitan areas. According to EFIP (2015) and Wide et al. (2021), the various roles the inland ports play within the network are:

- Multimodal hubs on European transport corridors
- Interface towards urban freight transport
- Co-modal hubs on the European inland waterway corridors
- Industry matchmakers for the development of energy and green economy clusters and
- Facilitating the integration of inland waterway transport in the multimodal logistic chain

They consider the various roles of inland ports as actual intermodal nodal points in the transport and logistic chain. Some see the service provided by these ports to be a logistic marketplace where freight transport users, forwarders and shippers can come together to make various choices regarding products, logistical operation costa (both internal and external), and freight destination (Bosch, 2018).

In this context, these ports are seen to have become more of an orchestrator of logistic processes. Since sustainable and efficient logistics operations cannot be based on one transport mode alone, inland ports in this region function as multimodal hubs. In this regard, the introduction of new technologies, digitalization, and further integration of existing IT systems will help increase the efficiency of the logistics process and help manage flows of goods in the port more sustainably and cost-effectively (EFIP, 2017).

2.6.2 Management operations

Carrying out a successful inland waterway operation involves several different actors (Langen and Horst, 2008). The most important actors are usually shippers, LSP, vessel operators, port/terminal operators, truck operators for pre –and end –haulage as well as public authorities (see Figure 2.13).

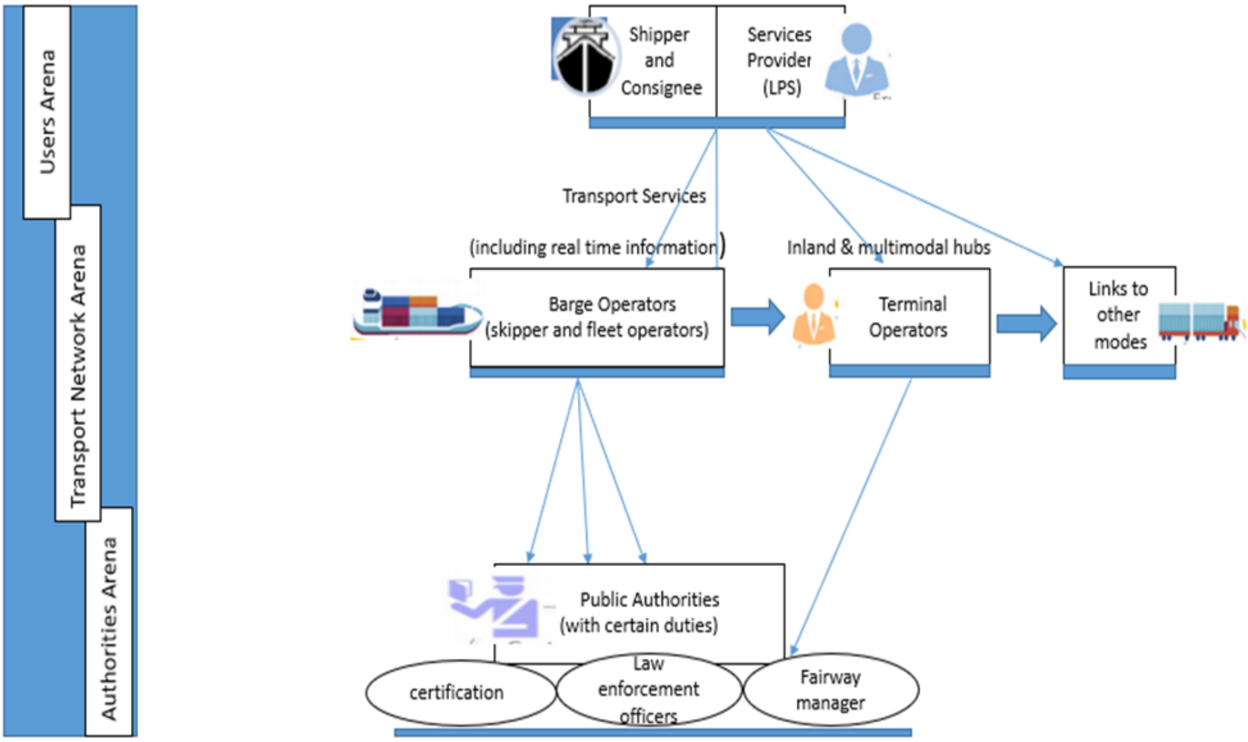

Figure 2-13: Actors and their interrelationship

Sources: Author work

As intermodal transport is often interpreted as a chain of actors who supply transport services (Caris et al., 2014), developing an efficient logistic chain capturing all actors involved in intermodal transport in administration is of great significance. Unlike other modes of transport, the maritime transport industry involves many procedures, including certification, inspection, and control, resulting in many paperwork requirements. This process has made the administrative infrastructure of waterborne transport somewhat complex. Easing the complexities of the measures to regulate such procedures is already receiving attention in recent times. For example, in Rotterdam and Antwerp, where IWT is of great importance, paperless (electronic) sailing has been enabled through a pilot project involving barge transport (Medda and Trujillo, 2010; Tadic et al., 2021).

In a similar context, in the Netherlands, where the modal share of inland navigation is the highest in Europe, waterways are often busy since they are used heavily for commercial purposes. The waterway authorities introduced the concept of a single electronic window as a one-stop shop to exchange information between the relevant authorities and stakeholders engaged in all the supply chain business processes to facilitate the administration. This initiative has dramatically reduced the complexity, time and costs involved in waterborne transport (Rokicki et al., 2021). Regulatory instruments such as these allow parties involved in the supply chain to lodge data in a standardised format at a single-entry point. In general, authorities usually implement them in national, regional, local, or international institutions.

Just as in other industrial processes found worldwide, the Dutch inland navigation sector is facing fundamental changes because of ongoing digitalisation; this change has been the initiative of the Dutch to stimulate the sector's market and increase its competitiveness in the modern supply chain. Another such initiative is the Blue Road Map (BRM), which is a digital (online) route planning programme that offers coordination of several goods flows for barges along inland waterway routes (Bureau Voorlichting Binnenvaart, 2017). With the programme having the capability to show all available possibilities, it helps provide shippers with various options. On the other hand, companies can effectively improve and optimise their goods transport using the online planning tool. This or similar tools can help the terminal better plan their schedules/services to avoid long waiting hours and improve high-capacity utilisation of the transport system (Bureau Voorlichting Binnenvaart, 2017; Ding, 2020). As more information can improve cargo planning at the terminal, a similar approach is the use of an AIS transponder fitted on vessels that can provide vessel and cargo location through its track-and-trace medium (Durajczyk and Drops, 2021).

2.6.3. Integration in transport corridors

As the significant role of IWT continues to expand in the European freight transport corridor, researchers have reviewed its intermodal opportunities. Notteboom (2008) considered the integration of waterborne transport with other modes and discussed intermodal network development. Caris et al. (2014) presented a proposal to integrate the transport system into the hinterland connectivity chain; they focused their studies on improving the affiliation between transport topology and logistics operation and the operational efficiency of the transport system. Miloslavskaya et al. (2020) examine the intermodal IWT based on the "just-in-time" and "just-in-sequence" concepts. As IWT has become an integral part of the multimodal door-to-door transport system, getting the best out of the transport system requires an efficient infrastructure (EFIP, 2011; Diaz et al., 2022). However, to play its role to the fullest, infrastructural maintenance, information streams, better connectivity to other transport modes, filling missing links and eliminating bottlenecks are critical success factors to be considered (Givoni and Perl, 2020; Bu and Nachtmann, 2020). The transport system is increasingly integrated into the transport and logistic chain, mainly in the containerised or finished product. Better access to digital transport data along the entire supply chain leads to a seamless information flow that facilitates the efficient servicing of the supply chain operation (Specht et al., 2022); this will help foster its seamless integration into the modern industrial supply chain.

Ruben and Ralf (2022) stressed that building a standard platform solution (e.g., a Cargo Community System) is a critical success factor. It will enable data to be comprehensively combined and shared across all stakeholders, thus improving the competitive position of IWT. As most containers are still transported via inland waterways in Europe, the transport system still functions exclusively as a hinterland transport system. Better planning of inland barges or shuttle services to improve their reliability can deal with congestion issues. A barge terminal situated in the vicinity of the port, or the direct hinterland of the port can help ease terminal congestion (Paulauskas et al., 2022). The geographical distance traversed is not the critical point but the regular barge rotation time. This forms a new logistical concept called "Transferium" directly in the hinterland of the port of Rotterdam, allowing containers in large numbers to be transferred via barges. The so-called transferium, according to Shobayo et al. (2023), is a point of consolidation for barges that eases the regular transfer from and to the deep-sea terminal. It is primarily designed to relieve large nodes of various transport functions through the outplacement via the transferium.

2.6.3.1. Synch modality

The synch modality concept has highlighted the integration of waterborne transport and logistics into the modern industrial supply chain. The idea, which emanates from the Dutch logistics platform, defines Synch modality as "the optimally flexible and sustainable deployment of different modes of transport in a network under the direction of a LSP so that the customer (shipper or forwarder) is offered an integrated solution for his (inland) transport". Since its emergence, it has been widely diffused in transport literature (Pfoser et al., 2016; Brümmerstedt et al., 2017; Giusti et al., 2019; Sakti et al., 2023).

As the name implies, synch modality entails an integrated transport approach where the optimal mode of transport and available capacity are used. The basic idea is that transport managers continuously check that mode choice. They then dynamically adjust for the best mode depending on circumstances and aspects such as availability and time (Brümmerstedt et al., 2017). When the inland water terminal is equipped as a trimodal network (i.e., connected by waterway, road and rail) and the terminal operators can offer integrated services, synchromodal transport can be implemented effectively. The logistic operators continuously deploy ICT solutions that support operational processes and provide end-users with informative services (EIBIP, 2017; Sakti et al., 2023). Reliable fairway information for route and loading plans and logistical information (e.g. cargo clearance, availability of terminal and slot at sender's location) are the most important. In contrast, for the end-user, cargo location and expected arrival time are of utmost. All these require a reorganisation of network architecture supported by planning and communication tools that can enhance the instantaneous exchange of relevant information while keeping all security rules and procedures intact. For example, integrating the information flow of the maritime logistics chain into that of the inland port can be achieved through CCS.

According to the European Port Community System Association (EPCSA) (2015), CCS is a neutral and open electronic platform that links multiple systems operated by public and private actors to intelligently and securely exchange information to improve the competitive efficiency position of the seaport communities. Acero et al. (2022) highlighted that a lack of relevant and accurate information leads to logistical inefficiencies in ports and terminals, and in some extreme cases, it results in "hidden cost," e.g., excessive inventories. To that end, inefficient processes can be optimised by sharing more information in the supply chain better. As such, reliability and fast cargo information systems have become increasingly indispensable for more extensive supply chain integration.

2.6.3.2. Emergence of cooperation between sea and inland port

With the emergence of increased trade, both globally and regionally, cooperation between seaports and riverports is also emerging. However, aspects of their development vary significantly in terms of the scope and intensity of their numerous links between inland ports. According to Tan et al. (2018), contemporary trends are fast gaining momentum, pointing towards the need for upscaling port governance. This developmental path is seen as a solution to the growing demand for cargo that has increased transport volumes lately. Recognising the critical role of the ports in the context of multimodal transport in Europe drives stakeholders (public authorities and private actors) to reorganise and better structure their policies. A fundamental shift between modes of transport can be achieved through initiating partnerships at various geographical levels. (Wiegmans et al., 2020). For example, inland ports have been recognised as efficient transhipment nodes on European transport corridors (EFIP, 2015). An integrated link between these ports can enable better coordination to meet users' expectations and improve their relationships around with other maritime interlocutors. This can take place in the form of river port mergers or transparent hierarchy cooperation on an equal footing (Chen, 2021). Figure 2.14. illustrates how collaboration might manifest in different ways, such as mergers between river ports, hierarchy cooperations, and equitable partnerships.

The growing interdependence among ports in terms of flows and transport services issued by private companies has been highted in numerous studies over the recent decades (Feng et al., 2019; Jia et al., 2023). In their study, Tang et al. (2020) comprehended this interdependence as value chain optimisation. As hinterland connections are viewed as critical dimensions of ports' competitive positions, active economic players supported by port authorities developed strategies to infiltrate and take charge. With the redefinition of the functional roles of ports in the value chain, inland logistics hubs have brought about a new stage in the advancement of port systems known as port regionalisation (Notheboom and Rodrigue, 2005; Raimbault et al., 2016).

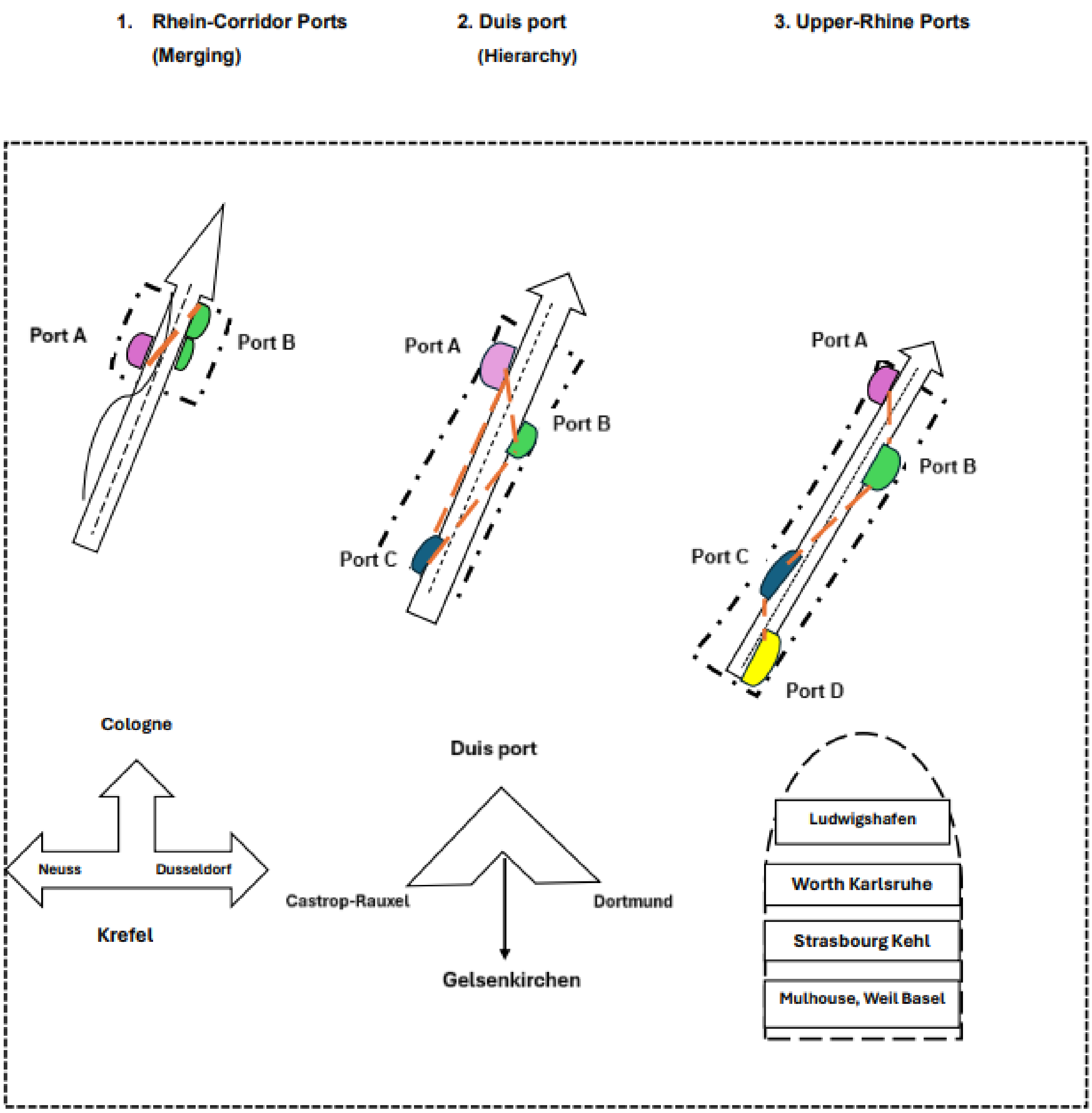

Figure 2-14: Emerging port coalition types

Source: Author own elaboration

2.7. Competitiveness

Historically, European transport policy has been based on a 'modal shift' approach from road to other alternative modes. This has been strongly encouraged in many policy documents of late due to the need to reduce carbon emissions. However, despite this longstanding policy, the share of the various modes has remained essentially unchanged for freight transport. The road still reigns supreme in freight transport and has kept its leading position in the modal split calculation because of its flexibility, reliability, price, and time over long and short journeys (ACEA, 2019). The modal share of each mode has remained similar throughout the last twenty-three years. Although the European Commission has initiated many initiatives to move freight from road to other sustainable transport modes through larger EU-funded projects, both the completed and ongoing projects have achieved limited success in transferring freight from the road to more sustainable modes (Domagala and Kadlubek, 2023).

Although there is a common belief that all forms of transportation compete, only certain modes compete for specific journeys or the transportation of certain goods. In general terms, all modes of transport are complementary to each other. However, several factors influence modal shifts and the choice of transport modes; for freight transport, the key determinants are related to shipment characteristics, which may depend largely on the cost, time, and quality of different transport services (Bury et al., 2017; Lučić, 2021). According to Boehm et al. (2021), until there is a general understanding of the characteristics of each mode of transport as well as interest within the freight transport industry, a modal shift to a less carbon-intensive transport mode is still far from being fully achieved. However, in recent times, much work has been done to understand the characteristics of each transport mode. Specifically, an analysis of the strengths and weaknesses of each mode of transport has been presented by researchers (Zgonc et al., 2019; Baran et al., 2019); others have also analysed the characteristics of mode choice in response to the development of a new freight transport system (Shin et al., 2019; Souza et al., 2020).

Equally, while there are potential benefits of transferring more freight from road to alternative modes, logistics firms should evaluate the potential advantage offered by this mode as only a change in mindset within the freight logistics industry can enable the modal shift to be fully achieved (Machairs and Nocera, 2019). Several concrete questions have emerged as to the realisation of the modal shift target, its expected benefits, and its ability to absorb the increase in freight volume. A few increasing projects have supported the possibility of a significant shift from road to alternative modes in the past decade. While several initiatives by the EU to support modal shift possibilities to waterways have been finalised, given the sector's prospects and challenges, the commission proposed updating and renewing some of these programmes until 2030 (Schoneich et al., 2022). To that end, many measures introduced under the overarching NAIADES I and II programmes have been implemented. Support from funding instruments such as the TEN-T, Marco Polo, CEF and the Seventh Research Network demonstrate whether the EU IWT strategies have been effectively implemented to achieve modal shifts to this mode of transport (Takman and Aregall, 2023).

2.7.1. The flaws in various modes of European freight transport system

Since the early nineties, the EU has been increasing the amount of attention to the transport sector, which has led to numerous policy measures and intervention. Today, transportation has become a strategic sector in building the economy, with transport services accounting for about five per cent of the EU's gross value added (European Court of Auditors, 2018). However, from the European single market perspective, a sustainable and fully interconnected transport network is necessary to achieve the EU's single market. Although major responsibility for developing, financing, and building transport infrastructures lies mainly within the member states, additional funding by the EU only acts as a catalyst to cover a fraction of its total needs to deliver the EU added value. As such, huge dissimilarities continue to remain between member countries regarding modal split for inland freight transportation (Antonio et al., 2020). Other factors in this difference are attributed to the geographic conditions' countries. For example, countries like Cyprus and Malta that do not have either railways or navigable inland waterways have a 100% share of road freight transport. Island nations, moreover, also have high levels of road freight transport due to their level of isolated from the rest of the continent. Table 2.7. presents the analysis of the strengths and weaknesses of each transport mode.

Table 2-7: The analysis of strengths and weaknesses of each transport modes

	STRENGTHS	WEAKNESSES
ROAD	- Several alternative routes - Enable and utilise network access. - Flexible and adaptable door-to-door service. - Small quantities have low unit operating expenses. - Well-suited for spontaneous processes. - Minimal regulatory and financial obstacles to entry.	- High operating expense per unit for high volume flows. - Open access to infrastructure results in network congestion. - significant environmental and social implications per unit of distance travelled.
RAIL	- Low unit operating expense for high volumes. - Transports substantial quantities in one rail trip. - It is ideal for consistent and anticipated patterns. - - - Timetabling typically prevents congestion and delays. - Automated loading and unloading are frequently feasible. - Minimal environmental and social consequences.	- Limited network coverage. - Constraints on route capacity and capabilities. - Expensive infrastructure provision and maintenance expenses - Road use is frequently necessary at one or both terminals of a railway journey. - Obstacles related to regulations and financial requirements that hinder new businesses from entering the market. - Transhipment expense and hazards.

IWT	- Transports a substantial amount of goods in one barge. - Often allows for automated loading and unloading - Low unit operating costs are achieved at high volumes. - Utilises natural transportation routes. - Minimal environmental and social consequences.	- Limited network coverage - Road use is frequently necessary at one or both ends of a waterway. - Transhipment expenses and hazards. - Low operational velocity - Regulatory and financial obstacles for new operators - The port infrastructure and vessels are expensive. - IWT is vulnerable to weather conditions - Limitations imposed by tides.

Source: Author work based on European Commission (2020); European Court of Auditors (2015, 2018), Department for Transport (2021, 2022), #IWT’s 2020 (2020); Rogerson et al. (2020), Raza et al. (2020), Shobayo and Van-Hassel (2020), Rodrigues et al.(2023).

2.7.1.1. Road freight

In 2021, maritime transport represented 67.9% of freight transport performance in the EU, while road transport accounted for 24.6%.

Maritime and road transport accounted for 92.5% of the goods transport in the EU in 2021. Rail transport accounted for 5.4%, IWT 1.8%, and air for 0.2% (Eurostat, 2024).

The modal split of land freight transport between the period of 2011 and 2021 shows that road transport continued to carry three-quarters (75.3 %) of the total inland freight in the EU (see Figure 2.15).

The road remains Europe's most popular choice of transport years after the completion of several EU initiative programmes to transfer road freight to alternative modes. From 2013 to 2014, the share of road freight was 73.9%; an increase of 0.2 percentage points was witnessed the following year (2015 to 2016), and in 2017, the share further increased by 0.8 percentage points. Compared to 2011, the EU's total goods transport share by road mode increased by 1.7% (Eurostat, 2024). In 2021, road transport accounted for 24.6% of the overall EU freight transport performance, reaching 1,863 billion tonne-km, which was a 0.6%-point increase from 2020. Between 2011 and 2021, road transport had its lowest point in 2012, accounting for 22.0%.

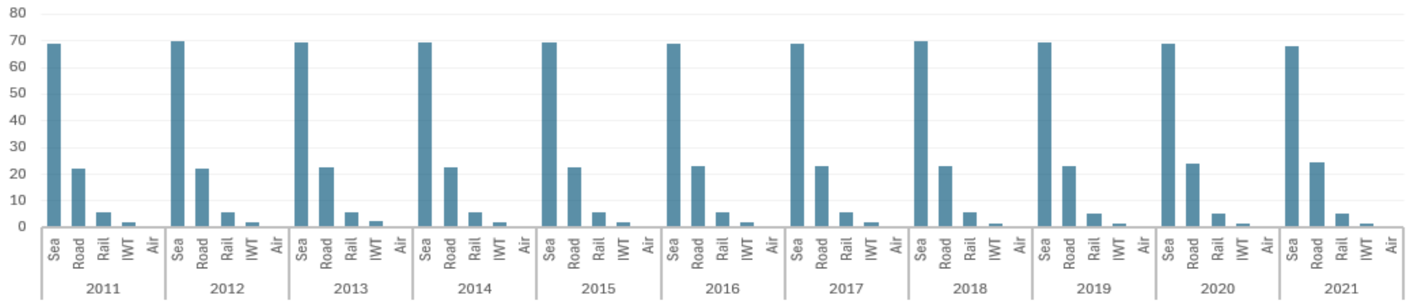

Figure 2-15: Modal split of inland freight transport, EU27, 2011-2021(% share in tonne-kilometres)

Source: Author elaboration based on Eurostat (2024)

Although the modal split varies considerably from country to country at the EU level, the split depends on the availability of a given mode in a country. For example, countries like Cyprus and Malta, which do not have either rail or inland waterways, have a 100% share of road freight by default, whereas in other countries, Luxembourg, for example, the road had a total share of 84.2%, Czechia 76.6% and Poland 70.2% in 2021 (Eurostat, 2024).

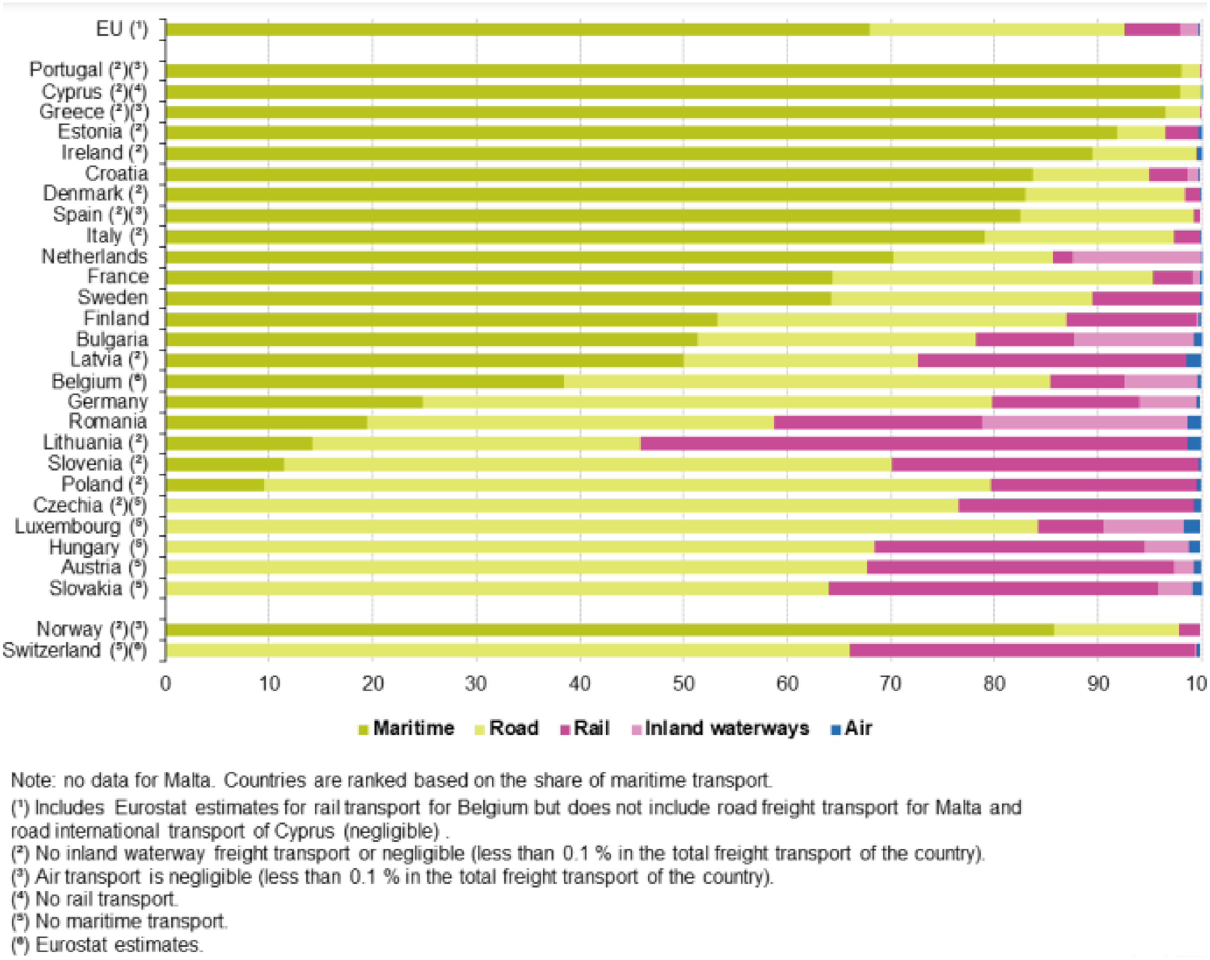

Figure 2-16: Modal split of inland freight transport, 2021(% share in tonne-kilometres)

Source: Eurostat (2024)

Road transport remains the main priority of transportation in most countries mainly because road transport services for freight are seen as to be available, flexible, adaptable, reliable, and affordable. This keeps it at the top of the chart (Guglielminetti et al., 2016). The transport system also allows LSP to deliver their services on a door-to-door basis.

The digitalisation of the transport system has helped improve transport management through more accurate information on traffic, infrastructure, and the location of the truck and goods.

Improvement of data exchange between different actors in the transport system has helped the supply and demand of freight to be matched in real-time (Poliak et al., 2021). Nevertheless, concentrating only on road transport for freight shipment has led to traffic congestions around the region. (Sternberg et al., 2020). Increased accident, and other negative externalities are affecting the quality of the environment and liveability. A report from the UK Department of Transport (DfT) shows that Heavy Goods Vehicle (HGVs) are estimated to currently account for around 17% of GHG emission and around 21% of NO_X emissions while making up just 5% of vehicle miles (Gielen et al. 2019; Gosling, 2019; Department for Transport, 2020).

2.7.1.2 Rail freight

The development of European rail freight has been central to the European Union's transportation policy, as has been the case for road transport. The EU's main policy option to promote sustainable rail freight has been through market opening, deregulation, and interoperability. However, only a few notable changes have occurred in the European railway system in the past years of rail liberalisation. The idea behind the liberalisation process was to strengthen member-state collaboration on infrastructure through better corridor management (Kuzior and Staszek, 2021).

Nonetheless, the transport system in Europe remains monopolistic. To overcome the natural monopoly, the reformation of nationwide and Europe-wide railway network is still ongoing. Geography plays a key role in modal freight share, and so does government involvement (Martseniuk et al., 2022). The more significant role the state plays in infrastructural investment and organisation management, the higher the market shares held by railways in the country. In 2021, rail freight transport represented 5.4% of the total freight transportation. The main contributor among the member states was Lithuania, with a share of 52.8%. This represents almost one-third of the total performance recorded (Eurostat, 2024). Several improvements have also been observed within other EU countries, like the Netherlands, Sweden, and Belgium. The development of a dedicated rail freight corridor called the "Betuwe Route" between the Port of Rotterdam and Germany also covers the Maasvlakte area (160 - km rail line). This rail route has played a vital role in hinterland connections and the competitiveness and development of the port (Balint, 2020; Bougette et al., 2022). In the United Kingdom, efficiency improvements have been critical to rail infrastructure funding for the Strategic Freight Network (SFN) (Woodburn, 2017). Its focus has been on corridors connecting ports and their hinterlands. According to Arup (2020), a multinational professional services firm, freight movement through the railways becomes more profitable than the road for journeys longer than 440 kilometres (273 miles) in an environment with a less rigid regime of central planning.

In general, European rail freight is regarded as underperforming against both its potential and the policy targets set (European Court of Auditors, 2016) despite decades of promotion. Woodburn (2017) confirms that road freight services are more flexible in terms of cost, service quality and network coverage, which has led to a requirement for the road to be used for "last mile" priority for freight on a mixed-traffic railway. For island countries like the UK, the road is still the predominant inland transport mode and, as such, has a large modal share when compared with other modes. This is because most of the freight journeys within the country are usually less than 500 kilometres; this gives the road a stronger competitive edge over the rail, which is only economically competitive over greater distances (Ali and Eliasson, 2022).

2.7.1.3 Inland waterways freight

The importance of IWW freight transport is linked to the presence of navigable rivers and canals in a country. In Europe, only half of the EU Member States have significant freight transport by inland waterways. Despite the substantial benefits they offer in terms of cost, it is best to maintain economies of scale and resolve the environmental issues caused by the road. Inland waterways are one of the least used modes within the logistic chain.

With more than hundreds of regions and industrial areas connected by inland waters in Europe, the highest modal share is found in the Netherlands, where the share of IWW almost matches that of road transport (44.6% for inland waterways against 49.4% for the road) (Pastori et al. 2018). However, other EU countries also have comparatively high modal shares for IWW; countries like Romania and Bulgaria had 29.4% and 27.2%, respectively, in 2016 (Eurostat, 2020). In 2021, the Netherlands and Bulgaria had IWT shares of 12.5% and 11.7%, respectively, both exceeding 10% (Eurostat, 2024). This high share has been partly attributed to the consistent flow of traffic along the Danube River. The most crucial inland waterway axis on the European mainland is the Rhine-Main-Danube Corridor. The Danube is 2.7 times longer than the Rhine, but Transport performance on European waterways has been driven by the performance countries along the Rhine countries, which accounted for about 84% of the total IWT performance in the EU, including Switzerland in 2018 (CCNR, 2019). This is due to different infrastructural preconditions of these two inland waterways: The Rhine provides good connectivity to a large European hinterland, while the Danube waterway has limited developed along it, enabling only spatially concentrated use requiring longer pre - and end-haulage by road or rail (INES, 2017; Kotowska et al., 2018). Fortunately, the UK also has an infrastructure of inland waterways, most of which are used for leisure travel. However, several hundred miles of these navigable rivers and canals, including the river Thames, are also used for freight transport. Most commercially usable waterway routes can be found in northern England, including Yorkshire and the north Midlands, the Humber estuary, the Aire and Calder Navigation, and the Manchester Ship Canal (MSC) and River Ouse, among others (Department for Transport, 2020). However, these navigable rivers and canals are used significantly less for freight when compared to continental Europe (Zolfaghari et al., 2019; Gosling, 2019).

Research has acknowledged that European natural geography has been of great help (Havinga, 2020), with the length of the two most important waterways in Europe, the Rhine and the Danube. Compared to the length of the Thames or the Liverpool/Manchester regional gateway, it is surely a lesson to be learned from continental Europe. However, there are significant opportunities to substantially increase freight transportation by inland waterways in the UK. However, changes in local and central government policy and a practical planning approach are needed for this to happen. Even though it is recognised that this transport mode is not expensive and has significantly less damaging impact on the environment than road transport, other factors have influenced its competitiveness. This includes the need to often use transhipment to other modes of transportation for cargo to reach the end customer. Other factors are poor operations visibility (real-time follow-up) to track and trace freight and manage freight flow; this has given road transport a competitive edge over the IWT (Comi and Polimeni, 2020).

2.8. Present Industry Performance Assessment and Challenges from the Supply Side and Demand Side of the IWT Market.

Numerous intrinsic merits characterise IWT. A lack of understanding of these inherent merits is an unlikely reason holding back the further development and exploitation of this transport mode. However, studies reveal that much work has been done on the topic area, and specific strengths, weaknesses, opportunities, and threats of IWT have been identified (DG Move, 2011; Colyle et al., 2023). The SWOT analysis (see Tables 2.8 and 2.9) identifies the positive and negative internal (strengths and weaknesses) and external (opportunities and threats) that the industry faces, both on the supply and demand side.

The table below was based on official documents, direct observation, interviews with experts in the field, scientific literature, and desk research. A balanced assessment is made of the strengths, weaknesses, opportunities, and threats the IWT sector faces. The main elements related to sustainable, operational, regulatory, and governance domains are pointed out. The work results are briefly summarised in Table 2.8 and Table 2.9.

Table 2-8: SWOT for IWT as seen from the supply side of transport.

	Strengths	**Weaknesses**
Internal Sources	• There is ample unused capacity on waterways to support an increase in traffic. • Adequate fleet capacity, especially with a focus on large barges • A high number of flexible entrepreneurs on the market.	• Inland vessels and engines have a long lifespan, leading to elevated levels of air pollutants being emitted. • Small and medium enterprises fragmented and atomised structure leads to limited cooperation and a lack of ability to integrate intermodal water transport in door-to-door chains. • Restricted utilisation of ICT systems. • Excess capacity and narrow profit margins. • Inadequate safety culture leads to substantial safety hazards for workers. • Insufficient infrastructure connections, poor fairway conditions, and inadequate transhipment locations and multimodal connectivity.
	Opportunities	**Threats**
External Sources	• Implementing initiatives to enhance the supply side of IWT. • Infrastructure funding programmes.	• Increasing demands on spatial planning, such as housing projects competing with transhipment services for waterborne transport).

	• Internalising external costs through pricing for competing transport modes: vehicle transport against the rail.	• Internalising infrastructure expense for waterborne transportation. Potential effects of climate change on water levels over an extended period. • Ecological conflicts in nature reserve

Source: Authors work - compiled from: DG Move (2011); Pencheva et al. (2019); Amr et al. (2020); Raza et al. (2020); Perˇci´c et al. (2021); Plotnikova et al. (2022); Colyle et al. (2023); Calderon-Rivera et al. (2024a); Calderon-Rivera et al. (2024b).

Table 2-9: SWOT of IWT activities in general as seen from the demand side

	Strengths	**Weaknesses**
Internal Sources	• Minimal carbon footprint • Reduced shipping costs • Current infrastructure capacity • Current transport capacity (inland barges) • Dependable transport services • Dominant market presence in conventional industries. • Relevantly stringent safety standards; external safety concerns (potential dangers to the public or the environment).	• Not all starting points and ending points are close together. Hence, the utilisation of transhipments and other transportation modes is necessary. • High quantities are required for consolidation, reliance on a small number of major clients and consolidation. • Insufficient visibility and unfavourable image among potential clients. • Slow operational speeds • Fluctuating water levels can obstruct import sections of the waterway system, leading to unpredictable service levels and fluctuating freight charges. • Lack of awareness of waterborne transport on larger supply chain advancements (end-to-end) and poor understanding of marketing and supply chain management. • Industry fragmentation and response to external shocks, such as the past economic crisis.

	Opportunities	Threats
External Sources	• Expansion of infrastructure such as Seine Schelde, Rhine-Rhone • Expanding global trade has led to a significant increase in the maritime container sector. • Enhancing collaboration in commercial activities and expanding the scope of operations in multimodal logistics. • Increasing need for environmentally friendly transport options • Motorway congestion and insufficient rail transport capacity • Expanding into new markets such as waste transport, biofuels, LNG, pallets, and continental containers. • Rising quantity and location of inland container terminal • Heightened recolonisation of safety and security issues.	• Market loss resulting from energy policy, such as coal and fossil fuel transportation. • Insufficient governmental backing and financing have led to the deterioration of numerous rivers and inland ports. • Effects of elevated oil prices on different industries that utilise IWT services. • Enhancing liberation, efficiency, and interoperability of rail transport markets. • Potential implementation of long and heavy vehicles for road transportation.

Source: Authors work - compiled from: DG Move (2011); Mostert, (2016); Pfoser et al. (2018); Pencheva et al. (2019); Amr et al. (2020); Raza et al., (2020); Perˇci´c et al. (2021); Plotnikova et al. (2022); Colyle et al. (2023).

To a large extent, the SWOT tables above presented many issues concerning the industry. For example, one of the significant weaknesses seen by the sector is the poor standard of organisation and cooperation (usually between freight carriers with other modes and shippers) and the extreme level of freight carrier fragmentation in the market (Calderon-Rivera et al., 2024). With highly diversified volumes transported, further consolidation of shipment on the market's supply side is necessary. Cargo consolidation through cooperation is an effective solution to optimise logistics operations. (Raza et al., 2020; Hasan et al., 2021). Consolidation would go a long way to improving operational performance, purchasing, and marketing power and increasing the quality of IWT door-to-door services by IWT (Kujawsk et al., 2018; INES, 2019). This could be achieved through the expansion of the associated companies. Also, to provide more efficient intermodal door-to-door services to the IWT market, effective transport services and links to other modes of transport are vital.

While IWT is dependent on significant infrastructure investment to achieve its full potential, a good labour market is also essential. In addition, inadequate infrastructure (i.e., bottlenecks and missing links) is a significant obstacle to inland navigation. The most common river bottlenecks and missing links are fairway depth, bridges, locks, maintenance, and ports (European Court of Auditors, 2015; Pencheva et al., 2019; Roso et al., 2020). Generally, a significant part of the European inland navigation sector faces difficulties, including slow development in terms of infrastructures and a lack of attention by a member state to the maintenance of waterways. Lack of political support causes the potential of this mode of transport not to be fully exploited, which is also confirmed by Rogerson et al. (2020). Economic difficulties are another issue, as demand is still low (Pfoser et al., 2018; Plotnikova et al., 2022). In contrast, capacity has continued to increase, translating into an imbalance between offer and demand, price pressure, decreasing utilisation of capacity and diminishing profitability. Finally, in the regulatory field, more coordination is needed to implement RIS and its integration into logistics services (Durajczyk and Drops, 2021).

2.9 Digitalisation

Information and Communication Technology (ICT) has developed rapidly during the last few decades, creating new functionalities (Bharadwaj et al., 2013; Verberght and Van-Hassel, 2019). These ICT tools and the latest technology concepts (i.e., extensive data analysis, artificial intelligence, internet of things, cloud storage and cloud computing) are penetrating more in the areas of social life. They are increasingly becoming of great significance in economic processes (Fruth and Teuteberg, 2017), and data sharing has started to become an increasingly important economic asset.

European IWT has substantially transitioned towards digitalisation in recent years (Zalewski, 2020). Technological improvements and demands for more efficient and sustainable transportation options have spurred this transition. Andronja et al. (2021) stressed that digitalisation in the industry could further enhance connectivity and data exchange among involved parties, resulting in improved logistical and operational procedures. However, Zalewski et al. (2021) argued that although digitalisation offers many benefits, the problems remain in implementing these technologies into the entire operation in IWT as Regulatory obstacles and compatibility concerns among many systems and parties can impede the complete incorporation of digital solutions. In line with the Digital Single Market Strategy, one of the main priorities of the European Commission is to move this trend forward into IWT by fostering new digital initiatives and driving digitalisation in the sector (Baelen et al., 2022).

2.9.1. Digitalisation of inland waterway transport

Digitalisation is an essential driver of efficiency, simplification, lowering costs, as well as better use of resources and existing infrastructure (CLECAT, 2017; Peeters et al., 2020). It has been part of many European Commission initiatives mentioned above to introduce intelligent transport systems in IWT, as has been the case with other modes of transport. In line with these developments, DINA (Digital Inland Waterway Area) was launched by the commission as an initiative aiming at fostering the digitalisation of logistics information flows in inland navigation (European Commission, 2017). DINA builds on existing investments and developments, such as existing components of RIS.

2.9.1.1 The European RIS

Information sharing among parties in a supply chain is regarded as a building block that characterises a concrete relationship (Lalonde, 1998). In the context of the supply chain, information exchange and the formation of a seamless information flow have been intensively discussed (Cachon and Fisher, 2000; Wiegmans et al., 2018). Better communication leads to high-level integration (Lia et al., 2006), facilitating organisational improvement in terms of reliability, speed, and dependability (James et al., 2019). Inland navigation is an essential component of the European transport system, with an increasing need for information exchange between all stakeholders in the industry (Montwiłł, 2014; Peeters et al., 2020b). According to Durajczyk, P. (2020), several services and systems dealing with vessel traffic and transport management have been developed and implemented recently, with few in operation. Due to the growing need for seamless information flow, RIS services have become increasingly significant in the transport and logistics sector (James et al., 2019).

The RIS involves harmonised information services (IT technology) designed to optimise traffic and transport management processes for inland navigation, including interfaces to other modes of transport (European Inland Barging and Innovation Platform, 2017), having the ability to streamline information exchange between waterway operations and users. Researchers, including Schilk and Seemann (2012), Heilig (2017), and Miler (2019), viewed the RIS concept as constituting a change in the IWT sector capable of improving safety, security, and efficiency in traffic and enhancing the efficiency of transport operations. The service has the additional connotation of harmonising system architecture and protocols across various EU countries where the primary waterways flow. Conceptually, RIS services comprise an electronic inventory and representation of waterway assets that are merged to form a single unit with the various components of the vessel's onboard AIS and global positioning to share transport data (Peeters et al., 2020a). According to Sanchez-Gonzalez et al. (2018), RIS does not deal principally with internal commercial activities between carriers but is made available for connection with other commercial processes. Its operational services include traffic-related information, which benefits all parties regarding safety and transport-related information, focusing mainly on efficiency (CCNR, 2018). However, the RIS services guideline also supports transport management, which has yet to be fully exploited. Several reports have been presented to evaluate the deployment and operation of RIS (i.e., towards a digital inland waterway area and digital multimodal nodes) (European Federation of Inland Ports, 2015; INE, 2018; Andronja et al., 2021). As the RIS gathers a large amount of data for voyage and route planning purposes, the European Commission has initiated an evaluation of the implementation of the RIS directives (Andronja et al., 2021). Niedzielski and Durajczyk (2022) further emphasised that the present data exchange could be expanded and integrated with information streams from other modes of transport.

2.9.1.2 Increasing transport performance through digitalisation

IWT, as an energy-efficient and low-external-cost system, stands to lose its comparative advantage if long-term structural changes are not made to improve its quality and operational process. According to Raza et al. (2023), traffic and logistics management requires intensive information exchange between partners in the transport chain. Digitalisation can foster the seamless information flow between all parties and help stimulate integration into the modern supply chain by improving traffic and transport management through more detailed information on infrastructure, traffic, cargo, and vessel location (EMMA, 2018). Extensive information exchange could increase the efficiency and profitability of the transport system. Wide ranges of new business opportunities can be achieved with better access to and sharing of digital transport data (Willems and Brodsky, 2018). This is possible because real-time information on order status is available for monitoring and invoicing (Vanpocke et al., 2014; Bekrar et al., 2021), leading to shorter waiting time and cost-saving (Heilig and Vob, 2014; Hassel and Rashed, 2020). Therefore, since inland navigation must be competitive to be integrated into a broader supply chain, the digitalisation of the transport sector is considered an essential driver for efficiency, lowering costs, simplifying and better use of existing resources and infrastructures. Achieving a modal shift to this mode of transport can only be possible if it fits very well and shows features comparable with those available in other modes of transport.

2.10. Chapter Summary

This chapter summarises the research carried out in the IWT system. The characteristics of the intermodal inland waterway logistics chain in the European setting, the current status of performance measurement in the IWT domain, and the methodologies approaches have been described. Due to the complexities of the IWT operational environment, an extensive analysis of the existing literature on performance measures is conducted. This chapter outlines many categories of the identified performance factors and further breaks them down into different subcategories. Overall, the analysis conducted in this chapter has significantly added to the subject of IWT. Lastly, gaps in the literature were identified and summarised as follows:

- This study found that there is a lack of general insight into the performance of IWT compared to single-mode road freight transport.
- There is a lack of detailed insight into the aspects that influence the perception of performance in the domain of IWT. No comprehensive framework is available to measure the performance of IWT, including identifying performance variables and conducting performance evaluations. Where performance is evaluated, it is usually, in most instances, case-specific to a particular variable.
- While there have been several research on performance metrics in the field of IWT, the present literature has not provided a systematic approach to identifying and classifying performance aspects. Also, previous studies have primarily focused on individual performance metrics without considering the interrelation and interdependence of performance factors.
- Research has yet to prioritise the severity of different performance criteria to determine which should receive the greatest attention from relevant authorities and stakeholders involved in IWT.

To close the gaps in the literature and connect the existing literature with the IWT system. The following research questions are proposed.

RQ1. What are the main relevant factors determining the perception of performance in the IWT industry, and how can those influencing factors be addressed?

RQ2. What are the primary sources of performance factors impacting the efficiency and competitiveness of the IWT system, and how can these factors be identified and categorised?

RQ3. Which influencing factors are relatively more significant in improving the performance of the IWT network?

RQ4. What best practices can the UK adopt from continental Europe regarding the use of waterborne transport for freight?

Chapter Three: Research Methodology

3.1 Introduction

Improved competitiveness is the unifying factor in every industry, driving higher performance and increasing demand for high-quality services. At present, reviewing existing literature on intermodal inland waterway transport shows that new methods and benchmarking tools are needed to measure the performance of transport systems. Such tool could provide a reliable performance assessment for the identified set of indicators and ensure appropriate decision-making for improvement. This chapter of the thesis will help in the selection of an appropriate methodology to validate and further develop the proposed model for this study. This chapter explains the methodology chosen and how the study was organised to achieve its objectives.

This chapter commences by presenting the philosophical stance of the research methodology. The next section focuses on data collection methods and analysis techniques that will be applied. It also needs to be mentioned that the research techniques and procedures used to obtain and analyse data for this study were based on survey questionnaires, empirical studies, semi-structured interviews, informal discussions, as well as both quantitative (statistical) and qualitative (non-statistical) analysis techniques. In addition, as part of the data input, the study involves secondary data. Figure 3.1 presents the proposed structure for the research methodology.

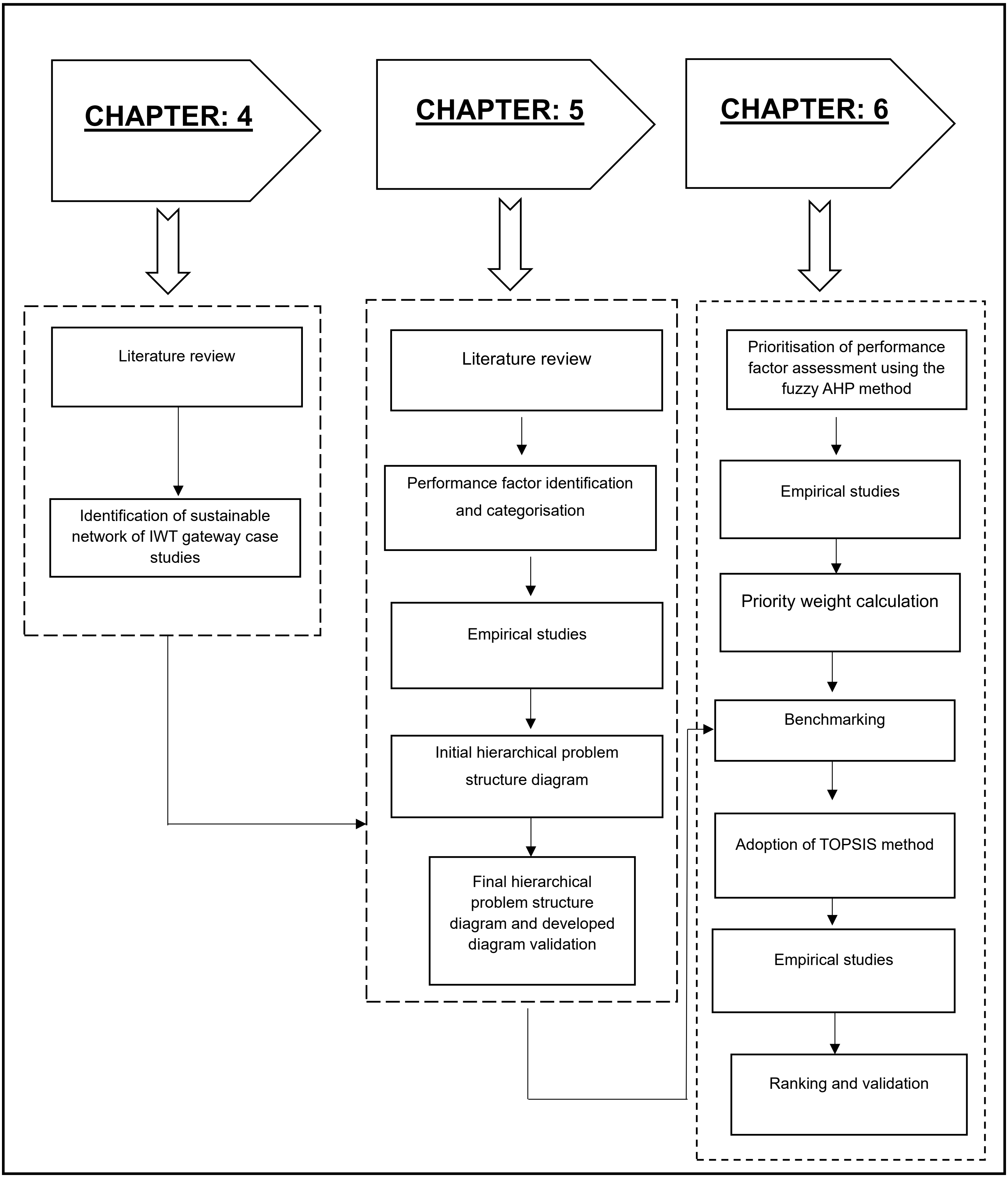

Figure 3-1: Proposed structure for research methodology

Source: Author work

3.2. Selecting an Appropriate Methodology

Comprehending the various research methods, their suitability, benefits, and drawbacks is crucial for making a well-informed choice regarding the most suitable methodology for a research study. Prior to selecting a study approach, the researcher undergoes intricate procedures. Multiple studies explore diverse methods and procedures that have been created for doing research in both social and natural sciences (Ragab and Amr, 2018). Furthermore, many techniques and strategies are associated with different philosophical and theoretical perspectives. This elucidates the reason why a researcher encounters difficulties when contemplating a study methodology. Nevertheless, several academic models have been expressly designed to assist scholars in making a selection (Saunders et al., 2009; Basias and Pollalis, 2018; Crewell and Crewell, 2018; Ganesha and Aithal, 2022). In reality, researchers are encouraged to refrain from categorising any model as correct or incorrect, as all accessible models strive to address the issue researchers encounter.

Wohlin and Runeson (2021) emphasised that despite the variation in techniques, none of them is inherently inferior to the other. Mbuagbaw et al. (2020) suggested that researchers should instead select a suitable, appropriate and applicable method for the specific subject matter's setting. Therefore, this study explains a detailed process of the researchers' methodological selection process.

3.3. Research Design

Research design is the first strategy for data collection and analysis (Asenahabi, 2019; Tomaszewski et al., 2020). Choosing the appropriate design is one of the most significant decisions made by a researcher. The research approaches are generally grouped into two main methods: qualitative and quantitative research. Both approaches take two forms of distinctive clusters of research methodologies, as qualitative research necessitates induction (theory building), and quantitative research entails deduction (theory testing). As the distinction between the two approaches (inductive and deductive) is mainly a matter of tendencies rather than a hard distinction (Bryman and Bell, 2007; Proudfoot, 2023), research work can combine both approaches in the same study (Saunders et al., 2019). As previously stated, there are multiple models available to assist researchers in navigating the research process. The model's objective is to provide the researchers with an array of options to choose from. The model illustrates the interdependence of philosophical, theoretical and methodological viewpoints. A model illustrating this concept is presented by Saunders et al. (2019) and referred to as the "research onion", as seen in Figure 3.2. Typically, a research plan is produced in response to a research question necessitating an outcome or a predicament in search of a resolution (Saunders et al., 2019).

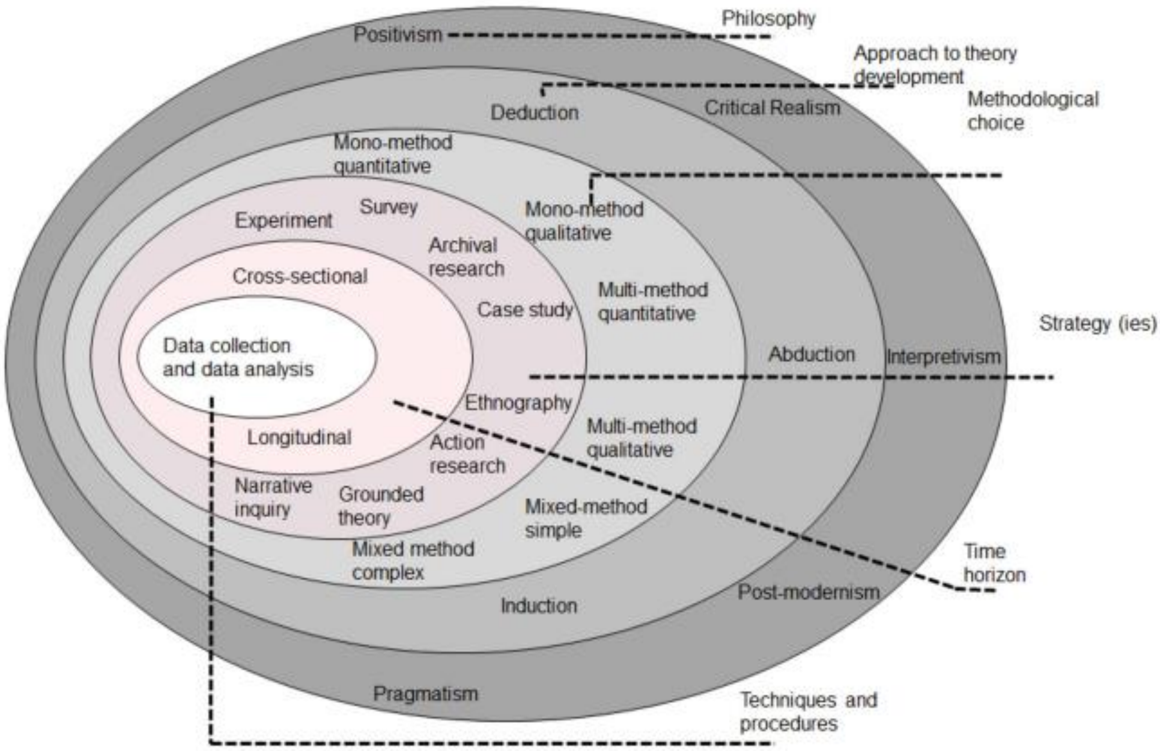

Figure 3-2: Research onion

Source: Saunders et al. (2019)

Following that, the research examines the relevant data and the methods for retrieving and analysing it, which are integral components of the research process that form the basis of the research onion. According to Taherdoost (2021), it is essential for researchers to explain the rationale behind their decisions about methodologies and techniques used for data collection and analysis. This is important in order to ensure that the research is thorough and applicable to others in the same field. The "research onion", as suggested by Saunders et al. (2019), illustrates the range of diverse difficulties a researcher may face prior to determining a final methodology. Specifically, it shows how a researcher goes through a number of stages to comprehend their philosophical presumptions before determining which data collecting and analysis techniques will yield the most accurate results. Thus, this research employs this model and methodically examines the various stages or levels of the process, referred to as the 'research onion', before reaching the central aspects of the process.

This approach is regarded as an overview framework that helps researchers facilitate the research process. As a multiple-layer model, the research onion approach details each inside layer more than the outside layer. As Saunders et al. (2019) presented, the model has six stages, starting with the research philosophies, approaches, strategies, choice, time horizons, techniques and procedures. Various stages have represented the model's layers to achieve an effective methodology. The first and topmost layer of the research onion is concerned with the research philosophy; in most cases, it is usually studied in the context of ontology and epistemology. As the philosophical stance influences data collection and analysis, four philosophical stances are connected to these philosophies: positivism, realism, interpretivism and pragmatism. The research approach is the second layer of these approaches and can either be deductive or inductive. It is followed by the third layer of the onions, which concerns the research strategies. This concerns how the study intends to collect data for its work. Depending on the nature of the research, these strategies include various methods (experiment, survey, action research, case study, grounded theory, ethnography). The research choice follows suit as the fourth layer, concerned with qualitative and quantitative methodologies. Here, decisions are made about what methods to apply to the research under investigation. The fifth layer of the onions has to do with the research timeframe, often providing the researcher with two options (i.e., cross-sectional and longitudinal). The sixth layer, which happens to be the innermost and last layer, represents techniques and procedures for the data collection and analysis process.

3.4. Research Philosophy

Selecting an appropriate design, approach, and methodology is one of the most significant decisions a researcher makes in achieving a credible piece of research. Research Philosophy is considered the bedrock of any credible research, and the core stands of this philosophy are often regarded as a guideline for researchers in making the right decisions. Underpinning a philosophy of enquiry suitable for the theme under investigation is essential. Given the various philosophical strands discussed in methodology, the most prevalent branch is often linked to ontology and epistemology (Bayraktar, 2020; Al-Ababneh, 2020). They are particularly important in research design because ontology is mostly linked to objectivity and subjectivity. Ontology is usually concerned with the of nature, reality or things that exhibit reality (Rehman and Alharthi, 2016; Salatino et al., 2020) and fundamental questions regarding the nature of reality. See Table 3.1. On the other hand, epistemology constitutes adequate knowledge in a specific field of study (Boon and Baalen, 2018).This branch consider alternative ways of approaching research (Ejnayarzala, 2019) and studies like Scott and Udeaja (2015) and Kelly (2020) acknowledge that epistemology can be subjective and objective. The two sides of epistemology are positivism and interpretivism. Positivism and interpretivism constitute two philosophical positions or paradigms in a broader spectrum. Unlike positivism which tends to emphasise quantitative analysis, interpretivism highlights qualitative analysis over quantitative or statistical analysis to obtain results (Al-Ababneh, 2020). Table 3.1 illustrates their crucial difference.

Table 3-1: Comparison of two research philosophies in management research

	Positivism	**Interpretivism**
Ontology: *The researcher's view of nature of reality or being*	External, objective and independent of social actors	Socially constructed, subjective, may change, multiple
Epistemology: *the researcher's view regarding what constitutes acceptable knowledge*	Only observable phenomena can provide credible data, facts. Focus on causality and law like generalisations, reducing phenomena to simplest elements	Subjective meanings and social phenomena. Focus upon the details of situation, a reality behind these details, subjective meanings motivating actions
Methodology: *Combination of different techniques used by the scientists to explore different situations.*	Highly structured, large samples, measurement, quantitative, but can use qualitative	Small samples, in-depth investigations, qualitative

Sources: Saunders et al. (2019)

As this study aims to access the state of the art for IWT, it is considered exploratory. The philosophical stance of the investigative approach is more affiliated with positivism as it appears more suitable for the investigative theme. As a philosophical stance of natural science, the researcher in the case of this study prefers working with an observable social reality and that the end product of such research can be law-like generalisations similar to those produced by physical and natural scientists (Coates, 2021). Positivist researchers often employ a highly structured methodology to facilitate replication (Park et al., 2020). This approach was also appropriate due to its suitability for analysing complex situations (Creswell, 2009; Kenaphoom, 2021). In addition, quantifiable observations will be highlighted, which may lead to statistical analysis (Matta, 2022).

3.5 Research Approach

As a plan of action that gives direction to conduct research systematically and efficiently, two basic approaches to research are possible namely, the deductive approach and the inductive approach, as presented by Al Zefeiti and Azmi (2015). The deductive approach usually identifies theories and ideas through literature for researchers to test using data. Pandey and Pandey (2015) indicate that this research approach flows from generic to specific. To conduct such research, researchers start with theory and then proceed to a hypothesis, which is then tested with collected data. The finding derived from the collected data establishes the truth of the hypothesis's or rejects it. This approach is mainly associated with quantitative research techniques.

In contrast, the inductive approach is concerned with the data collection process and then using the collected data to develop a theory based on the outcome of the result. This approach is often helpful when little research is available on the subject area (Bryman, 2012). This approach is often associated with the qualitative approach - Table 3.2. illustrates the main differences between the two research approaches.

Table 3-2: Fundamental differences between deductive and inductive research approaches

	Deduction	**Induction**
Logic	In a deductive inference, when the premises are true, the conclusion must also be true	In an inductive inference, known premises are used to generate untested conclusions
Generalisability	Generalising from the general to the specific	Generalising from the specific to the general
Use of data	Data collection is used to evaluate propositions or hypotheses related to an existing theory	Data collection is used to explore a phenomenon, identify themes and patterns, and create a conceptual framework
Theory	Theory falsification or verification	Theory generation and building

Adapted from: Saunders et al. (2019)

The need for intensive literature investigation is an essential part of this study regarding concepts, theory testing and possible practices. The development of the framework for this study will be supported by appropriate data collection, through empirical studies. As this study focuses on theory testing, this emphasizes that the study will adopt the deductive orientation.

3.6. Research Choice and Research Strategies

3.6.1. Methodological choice

Selecting an optimal research methodology is essential for the successful outcome of any research study (Snyder, 2019). The choice of methods will dictate the kind of data gathered, the manner in which it is gathered, and the approach taken to examine it. Irrespective of the approach or methodology chosen for a study, the data-gathering method must be appropriate and able to achieve the goals of the investigation. According to Cypress (2017), every research study is based on certain philosophical assumptions about what qualifies as "valid" research and which research approach is suitable for enhancing knowledge. The selection of the research paradigm (positivism, interpretive, transformative and pragmatism) provides guidance for the research projects. Scotland (2012) states that a paradigm is linked to the notions of ontology (the nature of truth and reality), epistemology (how researchers acquire knowledge of truth and reality), and methodology. Additional significant elements in selecting a research methodology encompass the study objective, epistemology considerations, researchers' behaviours and prior work in the field (Creamer, 2018).

A methodology encompasses the underlying principle and structure that are basically linked to the entirety of the research process. According to Garg (2016), *methodology* refers to the general approach taken in a research study, which is connected to the chosen paradigm or theoretical framework. On the other hand, the *method* refers to the specific systematic modes, methods, or tools utilised for gathering and analysing data. Three primary approaches are widely acknowledged for conducting research: quantitative, qualitative and mixed methods (Barnett and Thomas 2009). Rahi (2017) emphasises that researchers should not perceive qualitative and quantitative designs as completely opposed approaches. Rather, they can be seen as representing distinct points along a spectrum.

According to Allison (2010), a research project will either have a predominantly qualitative design or a predominantly qualitative design. A mixed-method study integrates qualitative and quantitative research approaches, including viewpoint, data collection, and analysis techniques, into a single study, either concurrently or sequentially (Creswell et al., 2007; Creswell, 2009; Aspers and Corte, 2019). (See figure 3.3).

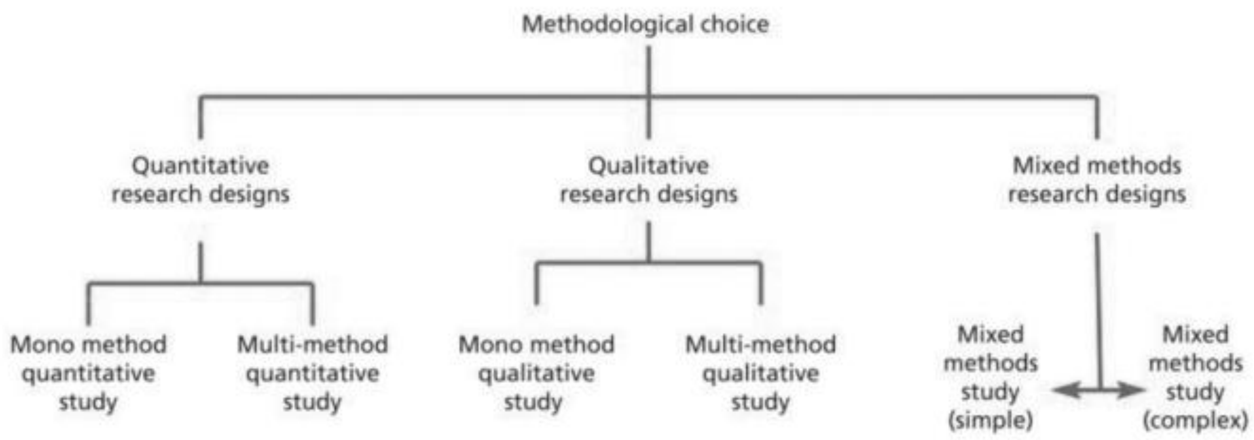

Figure 3-2: Methodological choices
Source: Saunders et al. (2019)

Saunders et al. (2019) highlight that quantitative studies depend on data that can be expressed in numbers or measured, such as a numerical value and closed-ended questions. In contrast, qualitative studies depend on personal narratives or written records that comprehensively understand an individual's thoughts or reactions within a culture, such as verbal expressions, pictures, audio files, video snippets, and similar resources.

Nevertheless, the author argues that this differentiation is limited, and scholars are expected to face difficulties. According to Cresswell et al. (2007), a more thorough technique of distinguishing between qualitative and quantitative research design can be informed by the researchers' philosophical assumptions, research tactics and methods used in the research process. Creswell (2009) highlighted that the connections between positivism and quantitative research design are due to the highly planned and predetermined nature of data collection methodologies. Jarvie and Bonill (2011) emphasise that there is a prevalent perception that the relationship between positivism, deductive reasoning and quantitative research design is philosophically excessive. Prasad (2019) elucidates that in qualitative research designs, researchers must establish and comprehend the subjective and socially created significance of the issues under investigation. Therefore, it is frequently associated with interpretive philosophy. Saunders et al. (2019) underline that qualitative research designs are sometimes referred to as naturalistic due to their tendency to be conducted in genuine settings or contexts, with the aim of fostering trust, involvement in access to meanings, and achieving comprehensive knowledge.

While both approaches exhibit distinct characteristics, neither is inherently superior to the other (Creamer and Edwards, 2019). Each study method has its limitations, but the advantages of both can offset these drawbacks. Qualitative research is more suitable for generating hypotheses and theories and defining processes like decision-making or communication than quantitative research, which is established for measuring the relationships between variables, testing hypotheses and figuring out a large population's opinions, perspectives and practices. By integrating qualitative and quantitative methodologies, a level of comprehensiveness can be attained that is attainable by either methodology when employed independently (Hands, 2022).

Gentles et al. (2016) and Azungah (2018) discuss the flexible and deductive nature of qualitative research design, which includes individual uncovering, investigation, and elucidating circumstances, emotions, perceptions, attitudes, values, beliefs and experiences and employing an inductive methodology for theory formulation. Quantitative research design encompasses the use of questionnaires and systematic observation, whereas qualitative research uses semi-structured interviews. Multi-methods research entails the utilisation of various approaches exclusively from their designs.

3.6.1.1. Mixed method design

Qualitative and quantitative research methodologies are distinct in their approach to addressing different types of questions, gathering diverse forms of data, and providing dissimilar types of responses. Every set of approaches possesses unique advantages and disadvantages, and each provides a distinct approach to tackle different types of research questions (Halcomb and Hickman, 2015). Mixed-method research entails the utilisation of two distinct methodologies within a single study, whereas qualitative research often aligns with positivism, and qualitative research aligns with interpretivism. Qualitative research operates on the assumption of a singular objective reality, whereas qualitative research relies on interviews and focus groups, acknowledging the existence of diverse subjective perspectives of the world (Zhang and Creswell, 2013).

Schoonenboom and Johnson (2017) defined mixed methods research as integrating qualitative and quantitative research methods, such as incorporating different perspectives, data collection techniques, analysis methods, and inference techniques. Timans et al. (2019) highlighted that the primary goals of this approach are to achieve a comprehensive and in-depth understanding of the research topic and to validate the findings. The adoption of mixed methods becomes evident in comprehending the various aspects of a situation, including its nature (the "what"), significance, standards and principles (the "why" or "how"). This approach involves integrating two distinct research methods to provide diverse perspectives on a single research subject, thereby harnessing the advantage of both methods (Wasti et al., 2022). Saunders et al. (2009) explore different approaches to integrating qualitative and quantitative research design, highlighting the numerous forms of mixed methodologies study design that have emerged (Creswell and Clark, 2011; Lindsay-Smith et al., 2018; Holcomb, 2019).

The study will employ a mixed-approach research strategy. Existing data will be gathered using a qualitative research design in order to develop a generic analytical model. To identify, assess, and evaluate the performance factor of IWT, a combination of qualitative and quantitative research approaches will be used.

3.6.2. Research strategies

In order to accomplish an objective, it is necessary to have a well-defined course of action known as a strategy. According to Saunders et al. (2019), a research strategy is a systematic plan that outlines how a researcher intends to address their research questions. It functions as a connection that joins a researcher's philosophical standpoint with other specific techniques, such as those used for gathering and analysing data (Mtisi, 2022). Various research methodologies are associated with distinct research philosophies and approaches to theory formation (Saunders et al., 2019). Nevertheless, it is optional to connect strategies to specific parts. The primary goal of a research strategy is to facilitate the researcher in attaining a consistent level of coherence throughout the research process and accomplishing the intended goals and objectives of the study (Saunders et al., 2019; Dawadi et al., 2021). A researcher can use more than one research strategy in a single project, as they are mutually incompatible. The strategy encompasses a variety of methods, including surveys, case studies, interviews, field experiments, simulations, laboratory experiments and action research (Wisker, 2009; Lavarda and Bellucci, 2022). However, not all of the various research methods available can answer the research question. Hence, it is essential to match the methodology with the purpose of the study (Dawadi et al., 2021).

3.6.2.1. Survey

The survey strategy is widely used in several fields (Mukhopadhyay and Gupta, 2014; Luff and Strurgisa, 2021; Quanquebeke et al., 2022). It is commonly linked to the deductive methods of theory formation in research and is very relevant for exploratory and descriptive objectives. According to Saunders et al. (2009), a survey is easily explicable and comprehensible. Nevertheless, prevailing opinions suggest this approach is commending and influential to the participants (Andrade, 2020). It is a very effective and economical research technique. This strategy allows for the collection of extensive and dependable data. Surveys are commonly employed in qualitative research projects and entail selecting a proportionate sample from the population (Ponto, 2015).

The survey strategy is mostly employed to observe the relationships between various data variables. The acquisition of extensive data enables the study questions to be addressed. Several ways to collect data for survey strategy include questionnaires, organised observations, and structured interviews. Researchers can easily compare results by using the questionnaire to obtain standardised data economically from a broad sample of respondents (Saunders et al., 2019). Nevertheless, alternative research methodologies will yield more extensive data than the survey. An inherent limitation will be the potential for the questionnaire survey to be conducted incorrectly due to its simplicity and capability (Taherdoost, 2022).

The survey approach will be adopted and used in this study at various stages of the research. The questionnaire survey will be used to gather empirical data on key determinants and factors that influence the perception of performance in the field of IWT. This information will be targeted toward critical actors, stakeholders and decision-makers. The study will employ semi-structured interviews and direct observations whenever feasible to acquire additional information for addressing the research questions.

3.6.2.2. Case study survey

A case study is a research strategy that is used to gain a comprehensive understanding of a current topic or occurrence inside a specific system. A case study is a highly prevalent and widely acknowledged qualitative research method in the field of social science (Takahashi and Araujo, 2020). The case study technique is centred on one or multiple individuals or a single region. The case study approach is highly valuable when there is a requirement to gain a comprehensive understanding of a specific topic, event, or phenomenon within its authentic real-life setting (Priya, 2021). Case studies allow researchers to delve further into a problem, thus enhancing their comprehension. Case study research involves evaluating a singular entity to identify its essential characteristics and make generalisations (Bryman, 2012).

Another helpful application of the case study research approach is determining the applicability of scientific theories and models. The case study is a highly adaptable research approach that enables the researchers to examine empirical events while keeping the comprehensive qualities of actual occurrences. According to Quintão et al. (2020), social science research can be performed in many different ways, each with its own advantages and disadvantages. For example, case studies are not the only methods available; other methods include experimentation, observation, surveys, and the use of archival materials.

This research used an in-depth analysis of multiple gateway studies in an industrial setting. The analysis involved the integration of both quantitative and qualitative data, as well as direct observation.

3.6.2.3. Time-horizon

The time horizon specifies how long the project work must take to finish. The research project's findings should accurately depict events within a defined timeframe, whether captured in a single instance or over a sequence of instances. The primary objective of this research was to provide a solution to a specific problem or at a certain moment. This study is regarded to be cross-sectional, capturing a snapshot of the situation. Chapter six of this research utilised a multiple gateway case study survey. The research specifies two distinct time horizons: cross-sectional and longitudinal (Saunders et al., 2019). The cross-sectional time horizon refers to the predetermined period over which data is collected in studies examining a particular occurrence at a specific time. In contrast, a longitudinal time horizon involves the systematic gathering of data over an extended period with the purpose of studying changes that occur over time.

3.7. Benchmarking Concepts for Performance Improvement

Benchmarking is a management tool widely used as a key element for continuous quality improvement (Merga et al., 2022). It is classically seen as a tool to improve organisational performance and competitiveness (Ratnayake et al., 2013). The process has been accepted as a structural approach for gathering and sharing data, providing information on areas and scales of potential improvement, as well as identifying best practices for improving performance (Castro and Frazzon, 2017). The main objective of benchmarking is to identify the best ways of doing things from top performers or those companies recognised as industry leaders while adopting these "best practices" for effective performance improvement.

Benchmarking and performance measurement are often used interchangeably, even though they differ. The benchmarking process has many defining features of both present and future focus, which makes it different from performance measurement. Performance measurement is about gathering and comparing the performance data of any organisation with regard to its past. Benchmarking, however, encompasses key elements of performance measurement, including comparison, measurement, and identification of the highest standard of practice leading to superior performance (Dattakumar and Jagadeesh, 2003; Išoraite, 2004; Geerlings et al., 2006; Wang and Jeppsson, 2022).

Xerox Corporation in the USA has been acknowledged as the first pioneering company to conduct benchmarking in the late 1970s to meet the Japanese competitive challenge (Bhutta and Huq, 1999; Horvathova et al., 2021). Following the company's success story, the benchmarking process has been extensively applied both in private and public sector organisations to improve the efficiency and effectiveness of products and processes. Several authors have documented extensive research studies on benchmarking in the literature, and quite a few academic researchers have expressed interest in these techniques, including Hanman (1997), Andersen (1999), Yasin (2002), Dattakumar and Jagadeesh (2003), Dokin et al. (2020) and Aalam et al. (2022).

Many benchmarking processes have been reported in the transport industry. For instance, the study by Geerlings et al. (2006) demonstrated a benchmarking methodology for public transportation organisations, McKinnon (2009) benchmarked the UK road freight transport, Henning et al. (2011) assessed a benchmarking tool for measuring the advancement of sustainable transportation in New Zealand, Georgiadis (2012) examined the role of benchmarking in Greece's public transport, Dewan et al. (2013) conducted a performance evaluation of online benchmarking tools for European freight transport chains, Savkovic et al. (2015) used benchmarking as a tool for improving the operations of transport companies and Awad et al. (2023) benchmarked the performance of an urban rail transit system with a machine learning application.

Within the transport industry, benchmarking has been identified as an essential tool for identifying potential improvement. The essence of benchmarking is to enable improvement that involves continuous, systematic evaluation of organisations' products, services or processes that are recognised with the highest standards of practices. It involves identifying important best performance and best practices, analysing the reasons for differences, and suggesting potential changes that decision-makers could implement. It is an essential tool for continuous improvement, and when properly utilised, it leads to actual fundamental process improvement.

As an improvement tool, benchmarking can help transport enterprises grow their business. It enables transport enterprises to monitor and assess performance against industry leaders constantly. The goal is to learn from other best practices, as it gives an insight into how other businesses operate and how they have achieved their turnover and profitability. There are several benefits of using the benchmarking technique in transport, which can be listed as follows (Isoraite, 2004; Rostmzadeh et al., 2021); benchmarking can help transport enterprises to:

- Locate their strength.
- Pinpoint weaknesses.

- Provide consistent and comparable performance data.
- Discover what it is possible to achieve.

In turn, this will help the transport industry develop important best practice strategies (Sutia et al., 2020) and take measures that will:

- Eliminate weaknesses.
- Improve products, services, and processes.
- Build upon their strength.
- Improve business relationships.
- Increase efficiency.
- Increase productivity.
- Attract investment and
- Take advantage of new opportunities.

The benchmarking process is composed of a set of consecutive steps. The basic principle of a benchmarking process applied to any topic or sector remains the same, but the number and description of steps may vary among researchers (Camp, 1989; Andersen, 1999; TRB, 2010; Willmington et al., 2022). Figure 3.4 shows the planning layout of the benchmarking process in this study. In addition, numerous studies have employed various methodologies in benchmarking. For example, the AHP has been effectively used by Korpela and Tuominen (1996) for logistic performance, process performance (Frei and Harker, 1999), strategic performance (Partovi, 2001), quality performance (Min and Chung, 2002), logistical performance of the postal industry (Chan et al., 2006), performance improvement (Joshi et al., 2011; Zhuang et al., 2018), competitive service (Singh, 2016) and technical efficiency (Yetim et al., 2023). The competitive business environment in the freight transportation industry forces decision-makers to understand the key factors that drive performance. In the IWT domain, the sector requires a systematic and structured approach in order to gain a competitive advantage over other transport modes due to their sustainable nature. In this study, benchmarking has become indispensable for superior performance and supporting the IWT system. The study aimed to identify and analyse the various factors that influence the perception of performance in the field of IWT and evaluate and rate these factors by analysing the components using Fuzzy Analytic Hierarchy Process (FAHP) and benchmark the performance or rank the present case study (UK) based on critical success factors among four European case study countries using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. Based on the benchmark, the results of the benchmarking process are presented in terms of relative rankings (The subsequent section provides details of the data collection and analysis methods).

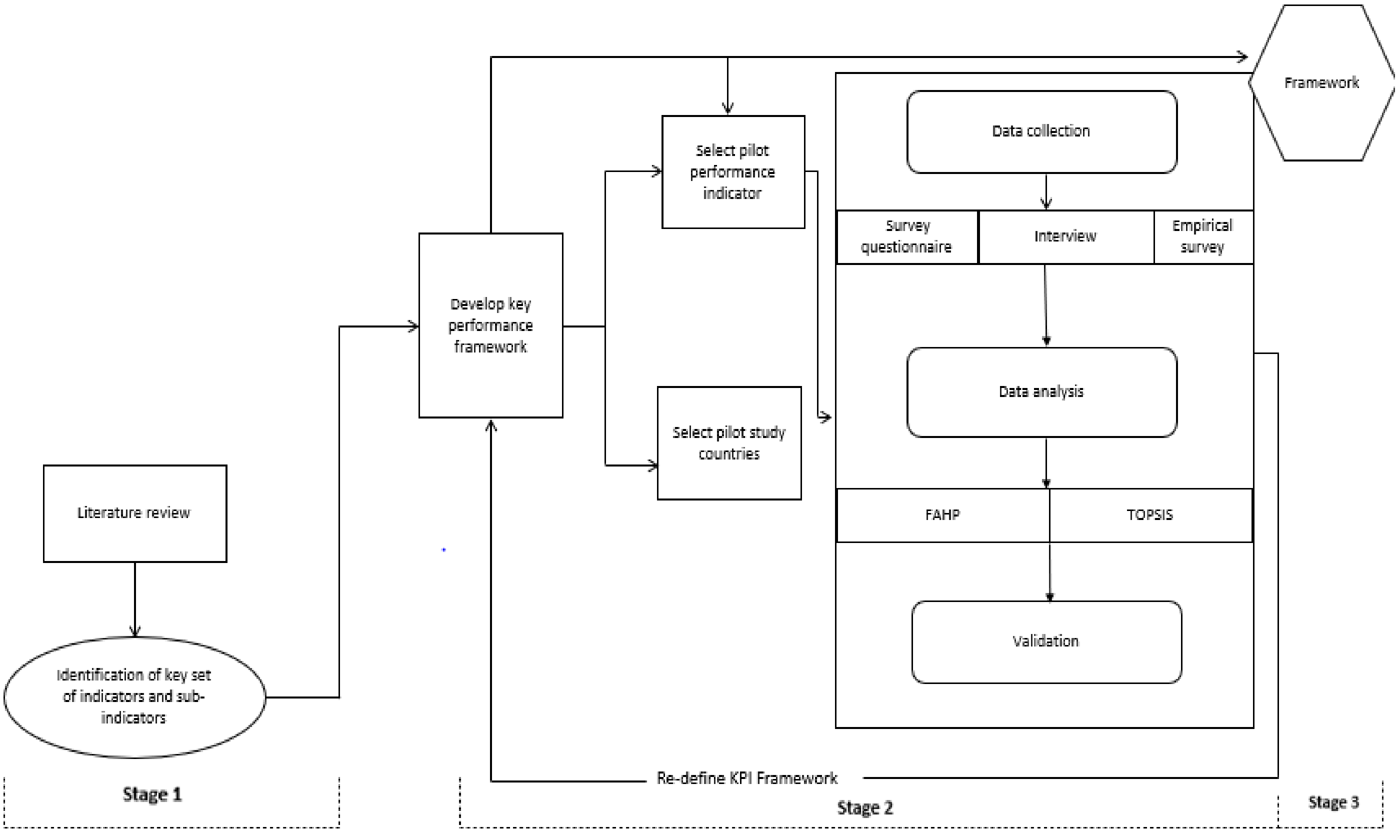

Figure 3-3: Planning layout of the benchmarking process
Source: Author work

3.8 Data Collection and Analysis Methods

A detailed explanation of the data type, collection and analysis methods used in this research has been presented in this section. The data types selected for collection for this study are incredibly important, and many factors shape this decision. This research chooses the most relevant data applicable to the theme under investigation. A mixed-method study strategy is employed on the key determinants and factors that influence the perception of performance in the field of IWT.

The mixed methods approach is a research methodology encompassing gathering, examining, and amalgamating quantitative and qualitative data inside a single study or a series of studies. The main idea of this statement is that using both quantitative and qualitative methodologies together is more effective in comprehending research challenges than using either approach individually (Timas et al., 2019). Kang and Evans (2020) highlight mixed methods research as an approach in which researchers gather and analyse both quantitative and qualitative data, combining them in various ways, giving priority to one or both types of data and employing them in a single study or multiple phases, commonly referred to as the triangulation technique. According to Enas et al. (2021), there is a growing concern among scholars and researchers in the modern period to examine the same occurrence using both qualitative and quantitative methodologies. This is why there is a discernible increase in the use of "triangulation" in practices.

Triangulation is an idea that facilitates data validation through cross-verification from more than one source (Campbell et al., 2020). As a technique to enhance the credibility and validity of study findings, it ensures that biases arising from using the single method or single observation are overcome (Noble, 2019). Credibility pertains to the level of trustworthiness and believability of a study, while validity is focused on the degree to which a study accurately represents or assesses the notion or concepts under investigation. Santo et al. (2020) used the concept to observe a phenomenon of interest from a diverse point of view. This method positions the importance of the mixed-method approach and emphasises multiple-method approaches in researching a single phenomenon. Farquhar et al. (2020) emphasise that researchers can use the triangulation approach for two primary objectives: confirmation and comprehensiveness. In their study, confirmation entails verifying the findings of a qualitative study with quantitative studies; at the same time, completeness enriches the depth of information and comprehension of the issues being investigated by integrating many approaches and theories. The selection of the data collection strategy should align with the research questions, objectives, and overall aim of the study (Saunders et al., 2019).

The study by Almalki (2017) indicates that this mixed method helps mitigate the weakness of both the qualitative and quantitative methods by allowing both methods to strengthen each other. Wasti et al. (2022) shows that the approach can be both inductive and deductive. For this study, triangulation will serve two primary purposes: to validate the research finding and to give the researcher a holistic understanding of the current state-of-the-art implementation of performance measurement in the domain of IWT by employing various perspectives in data collection.

The method suits research studies as it employs both interview survey techniques and questionnaires to gather all the appropriate primary data for both qualitative and quantitative analysis. As the study is associated with various stakeholders, geographical sitting, innovative technology, transport and logistics, the triangulation method is adopted since it covers all of the numerous data sources. This thesis will employ three distinct data collection methodologies.

In the first stage, the various relevant aspects and factors that influence the perception of performance in the field of IWT are ascertained. The study employs a literature research review and questionnaire surveys to examine and classify the unstructured performance factors. The questionnaire is intended to assess the comprehensiveness and validity of identified performance factors and evaluate the suitability of the performance factor categorisation technique. The second stage will assess the performance factor evaluation and quantify the significance level between the identified performance factors. Data collection in this phase is conducted through additional questionnaire surveys and semi-structured interviews. In the third phase, a questionnaire survey will be adopted and used to rank the present case study. The initial survey will validate the performance factor identified from literature research and extract more relevant elements and factors from professionals in both industry and academia. This survey will guarantee the research's robustness and comprehensiveness. Afterwards, the final survey will be utilised to compare the current case study with four others, and their relative ranking will be determined based on this comparison.

This study’s primary data collection approach is predominantly reliant on expert assessments. The performance factor data gathered are utilised as inputs for the suggested integrated set of indicators for assessing IWT performance and comprehending these indicators' priority. The subsequent sections will provide comprehensive information on research methods and techniques. Table 3.3 summarises and describes all the techniques used in the three stages of the integrated set of indicators for assessing IWT performance.

Table 3-3: Summaries of the research methods for collecting and analysing data

Steps	Approaches	Purposes
Performance factors identification	Literature review	To identify the existing influencing factors that are likely to have a significant impact on the overall performance of inland waterway transport.
	Questionnaire survey	To investigate the reliability and validation of identified factors and categorizations method, and to explore if there are more factors that are not mentioned in previous studies.

	Face to face interviews	To validate the identified performance factors / To further explore the appropriateness of the developed hierarchy model.
Assessment of indicators	Benchmarking	To accomplish superior performance to support the inland waterway transport. Fuzzy Analytic Hierarchy Process (FAHP) approach was used to support the whole benchmarking process.
	Fuzzy Analytic Hierarchy Process Survey (questionnaire)	To evaluate the degree of importance of the identified factors based on pair-wise comparisons respectively.
Performance factor evaluation	TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) (Questionnaire survey)	To rank the present case study (UK) based on the critical success factor among the EU market leaders (the Netherlands, Germany, Belgium, and the France).

Source: Author work

3.8.1 Data collection methodology

When evaluating an inland waterway system, it is crucial to include all system elements. Every stage of the performance measurement process will be discussed in connection with the data collection. To comprehensively capture the factors influencing the sustainable development of the transport network, it is essential to employ a combined approach of qualitative and quantitative methods. This approach will enable collecting and examining influencing factor sources, which is crucial due to the limited research available in this field. The process of data collection is an essential component of statistical analysis. There are several ways to collect data for research, and these approaches can be divided into two groups: primary and secondary data.

Three different methods of collecting data are used in this study, including questionnaire surveys (primary data), interviews (primary data), and previously published literature surveys (secondary data). The fundamental difference between primary and secondary data is that primary data refers to data the researcher acquires; in contrast, secondary data refers to pre-existing data. Therefore, this study employs a thorough and robust research approach known as a mixed-method research design. The research approach incorporates qualitative and quantitative methods throughout the study.

Generally, empirical research refers to a type of research that relies on the researcher's direct observation and measurement of phenomena. The collected data can be compared with a theory or hypothesis, but the outcome is still derived from actual empirical observations. Empirical studies make use of concrete and verifiable evidence. Empirical studies are employed as part of data collection techniques in this research to refine the understanding of the performance factors that influence the sustainable development of IWT in the UK.

A performance rating (or ranking) benchmarking process is undertaken for the UK's IWT sector and four other European case studies. Comparing four European countries with active inland navigation activities validates this model by testing the propositions developed. The areas of interest for comparison include the Netherlands, Germany, Belgium and France. The study is conducted using different data collection methods specific to the case of inland navigation in these geographical areas of interest. Empirical studies are conducted separately for chapters five and six of this research. The initial sub-section presents the introductory data collection methods for identifying key performance indicators.

Consequently, a questionnaire survey method is adopted for this study. As Katja and Alvesson, (2021) highlighted, this method provides an efficient way of collecting data from a large number of respondents and enhances the researcher's understanding through self-observation. Hence, structured survey questionnaires were developed for this study. The initial subsection will present the data collection procedures employed in chapter five. Chapter five will address the process of identifying and categorising performance factors in the research. The chapter will examine questionnaires, surveys and interviews to ascertain all relevant aspects and factors that determine the perception of performance in the field of IWT. Additionally, it will validate the suitability of the categorisation and hierarchy model.

Afterwards, the second sub-section discusses the data collection methods for the key performance indicator stage employed in chapter six of this research. At the same time, the second category of the survey questionnaire will be proposed to evaluate the weighted priorities and contextual relationships among the identified set of indicators.

Site visits/direct observations, official documents, and semi–structured interviews form parts of the evidence-based source in the empirical studies. The primary purpose of this data collection method is to explore the current state of the art for IWT, the current status of freight movement and the investment (projects) made in the sector in both the UK and the four selected countries across Europe. The third sub-section describes the data collection methods for an integrated set of indicators for identification, validation, and analysis. The third survey questionnaire (see Appendix IV) analysis was conducted on identified integrated sets of indicators by ranking (or rating) their priority.

The third sub-section describes the data collection methods for an integrated set of indicators for identification, validation and analysis. Next, the third survey, the questionnaire, will benchmark and compare the performance levels of the UK's IWT sector with four other European case studies. Their relative ranking will be determined based on the benchmark.

3.8.1.1 Data collection method for identification and categorisation of key performance indicators

The initial phase in the data collection process involves identifying and catering to all relevant aspects and factors that influence the perception of performance in the field of IWT. Extant literature highlights systematic methods for identifying performance factors, including interviews with industrial and academic experts, document reviews and group meetings commonly used in academic research (Feng, 2014; Waal, 2017). Researchers have also used an extensive literature review search of published articles to gather a broad list of applicable performance indicators to support appropriate decision-making and improved competitiveness in the transport sector. Table 3.4. lists previous literature sources that used literature review to identify transport performance indicators.

One of the benefits of using a literature review is that resources available in the field of studies have already been collected and published (O'Gorman and MacIntosh, 2016, p.32). This study first reviews published literature and statistics relevant to intermodal IWT in chapter two in order to identify all relevant factors influencing the sustainable development of the transport network, directly addressed over the past years by academic researchers.

Table 3-4: Identification of transport performance indicators from literature sources

Authors and Years	Transport Study Domain
Talvitie (1999)	Road sector
Isoraite (2005)	Transportation
Litman (2007)	Comprehensive and sustainable transport planning
Stenström et al. (2012)	Railway transportation
Mishra et al. (2012)	Public transportation
Onatere et al. (2014)	Urban transport development
Bentaleb et al. (2015)	Dry port-seaport system
Dumitrachea et al. (2016)	Improvement of transport companies
Arca et al. (2018)	Road transport
Gonzalez et al. (2023)	Road transport and sustainable cities

Source: Author work

Secondly, for validation purposes, expert advice and guidance were sought. The professionals were invited to contribute to developing and validating the structural hierarchy performance taxonomy diagram developed. Industrial experts were selected from Europe and the UK, including individuals with different types of expertise related to IWT, companies in the transport chain, intermodal transport, actors already using inland waterways for freight transportation and academicians to help validate and explore other potential indicators that might have been omitted. In this research, the experts are chosen based on their professional expertise, job position, and qualifications related to the research topic.

Experts' specialisation and years of experience are the primary inclusion criteria. A wide range of experts working in various disciplines of inland waterway transport were selected. The experience of experts involved in this survey ranged from ten to forty-five years, thus providing the required blend of experience and ingenuity (Jasti and Ram, 2019). Christensen (2021) defines an expert as someone with broad and deep competence in or knowledge of an issue at an appropriate level of detail and who can communicate their knowledge easily. Expert judgments have also been called expert opinions or subjective judgments. Informed opinion based on an expert's training and experience is routine and necessary for the analysis of key performance indicators. In general, experts' judgment varies widely in terms of conceptual understanding and comprehension of performance indicators. In this thesis, identifying and validating these key performance indicators requires different knowledge to be obtained from highly experienced experts who are both knowledgeable and experienced in their related fields. Experts' specialisation and years of experience are the primary inclusion criteria. A wide range of experts working in various disciplines of inland waterway transport were selected. The experience of experts involved in this survey ranged from ten to forty-five years, thus providing the required blend of experience and ingenuity (Jasti and Ram, 2019).

Subsequently, ethical approval was sought and acquired to authenticate the questionnaire's content and ensure participant consent. The research progressed to test the comprehensiveness of the identified performance factors while ensuring that none were excluded, as well as to construct an accurate structural IWT hierarchy performance taxonomy diagram. A sample of the final draft of this questionnaire survey can be seen in Appendix I

The primary objective of the survey at this stage was to examine and ascertain the performance factors that influence the sustainable growth of the transport network, using the expertise and perspective of subject matter experts. At the same time, the survey was to pre-test the questionnaire, ensuring that the questionnaire was free from any potential mistake and was well-presented to targeted participants for easy understanding before being field-tested on a larger sample. Furthermore, the study also employed the use of a questionnaire to create and validate the taxonomy diagram of the structural hierarchy of the IWT performance. A number of professionals were consulted to finalise the questionnaire survey. However, out of the total questionnaires sent out to participants, only eleven were received. Among these, two were deemed unsuitable for the research due to either being incomplete or not meeting the inclusion criteria of the research.

Furthermore, observation and site visits were conducted. Establishing a connection between academic study and tangible reality is crucial (Fix et al., 2022). In this study, a correlation was established. Observation is employed in social science as a methodology for gathering data about individuals, phenomena, and societies. Richer (2017) refers to direct observation as the act of closely observing and monitoring events, activities or behaviours in real-time. Walshe et al. (2012) highlighted that researchers frequently focus so much on creating questionnaires to gather information from experts that they fail to recognise the significant amount of data that may be obtained through observation. According to Mazhar et al. (2021), observation allows for documenting activities, conduct, and physical aspects without relying on individuals' willingness to answer the question. The ST4W study day/seminar, hosted by the Port of London Authority (PLA) in London provided an opportunity for a site visit. This study allowed for direct observation to be made.

The ST4W proposed facilitating a modal shift from road transport to waterways for shippers in North-West Europe, focusing on Small and Medium Enterprises (SMEs) posting palletised freight characterised by small volumes with partners in both the UK and Europe. The study was conducted and attended by several prominent personalities in Northwest European inland waterway transport and logistics, inland port officials, government officials, transport professionals and Cory environmental partners (Cory environmental: a London-based recycling and waste management company that uses waterways for the transportation of waste product). A round table discussion was held during the seminar, after which a site visit to the river Thames was observed as part of the study day activities. This presented a distinct opportunity to directly address certain issues revealed by this research with two professionals (Cory environmental and ST4W Interreg EU project partner) in the IWT domain through a direct face-to-face interview.

Additional Interviews with three more experts were conducted, including one professional who works for both the Commercial Boat Operators Association (CBOA) and the Canal and River Trust (CRT) in the UK, another expert from the Peel Port group and lastly, a professional from the academic background, who is from the intermodal transport and logistics background, a project partner of Inland Waterway Transport Solution Interreg North Sea region (#IWTS 2.0) and also a member of professional research bodies the Chartered Institute of Logistics and

Transport (CILT) was also carried out to assist the questionnaire in building a clearer picture of the question asked (See Appendix II). All of these experts have years of work experience in the related field. In-depth details on the experts' profiles and the sample selection procedure are provided in Chapter 5.

Andrade (2020) highlighted that a modest sample size is sufficient for research as long as the sample consists of knowledgeable professionals or experts. Professionals within a specific field frequently possess comparable beliefs and understandings (Nanjudesweraswamy and Divakar, 2021). The survey comprises 48 questionnaires, and experts were asked to indicate their level of importance or unimportance using a seven-point Likert scale in the questionnaire (i.e.,1= Highly Unimportant; 2=Slightly Unimportant; 3=Unimportant; 4=Neutral; 5=Important; 6=Slightly Important; 7=Highly Important).

According to Sullivan and Artino (2013), the seven-point Likert scale is a highly regarded measurement technique commonly employed to quantify data in survey research. A Likert scale enables individuals to articulate their level of agreement or disagreement with a specific topic (Jebb et al., 2021).This study has utilised the seven-point Likert scale to facilitate data analysis and maintain the respondents' attention on the survey questions. Given the seven-point Likert scale used in this survey, some indicators that scored below 5 "Important" on the ranked mean and weighted average were excluded from the final questionnaire at the end of the analysis. The results have led to identifying vital performance factors in the domain of IWT. A structural hierarchy performance taxonomy diagram has also been developed to create a comprehensive performance measurement database for inland waterway transport and logistics.

3.8.1.2 Data collection methods for the assessment of indicators

The study continues with data collection through survey questionnaires. A structured survey questionnaire B was further designed to elicit experts' opinions on the identified indicators regarding their weight priority and inter-relationship. The perception of the significance and weight of indicators and evaluators varies from person to person, as this is considered a subjective judgement (Jasti and Ram, 2019). Hence, a range of expert opinions with knowledge, experience, and ideas was sought to complete the questionnaires. An initial version of the fuzzy AHP questionnaire was developed and submitted to the supervisory team for evaluation and endorsement. After considering the comments and suggestions from the team, several adjustments were implemented, resulting in the completion of a final questionnaire (see Appendix III).

Subsequently, the formulated questionnaire (refer to Appendix III) was distributed to a range of knowledgeable professionals in the IWT domain who possess vast years of practical expertise. Experts from the UK and the four European case study countries were chosen for this survey. Chapter six of this research explains and discusses the complete procedure used for the questionnaire in more detail.

3.8.1.3 Data collection methods for performance rating

A performance rating benchmarking method was conducted for the UK IWT sector, along with four other prominent European market leaders. The model is validated by comparing five existing IWT networks in Europe and testing the developed proposition. This is the final phase of the IWT performance measuring procedure. In order to finalise this stage, the research employed an empirical method.

Firstly, the critical success factors for the IWT performance network have been identified from the literature, structured questionnaires, semi-structured interviews, and further priorities using fuzzy AHP. Subsequently, utilising the outcome of the procedure above, the study formulated and created a questionnaire based on the TOPSIS methodology (see Appendix IV). This questionnaire aimed to assess and rank the current case study in terms of critical success factors compared to the chosen European market leaders. The questionnaire was initially developed and distributed to the supervisory teams in order to guarantee the accuracy and clarity of the questions.

Finally, a conclusive version was created and disseminated to the chosen professionals. The appendix part contains this questionnaire. A comprehensive explanation of the ranking procedure is provided in Chapter 6.

3.8.2 Data analysis methods

Data analysis is crucial to every research (Simpson, 2015; Popenon et al., 2021). Data analysis involves the process of summarising the data that has been collected (Hamed, 2022). Data interpretation entails the analysis of information collected by analytical and logical reasoning to identify patterns, correlations, or trends. Various procedures and methods are essential for data analysis to guarantee trustworthiness and reliable outcomes derived from the collected data (Ali and Bhaska, 2016). When conducting research, it is essential to create accurate and clear methods that incorporate appropriate analytical techniques to accomplish the study's objectives. This study uses a mixed-method research methodology, as was previously mentioned. Fuzzy-AHP is first used in the study to examine the responses to the questionnaire created for the performance assessment stage. Afterwards, the questionnaire survey rating stage was analysed using TOPSIS.

3.8.2.1. Fuzzy set theory

The analytic hierarchy process (AHP) is a reliable method for solving complex decisions by determining the relative importance of a cluster of activities in a problem. The AHP is a problem decomposition method, where a complex multi-criteria decision problem can be decomposed into various sub-problems in a hierarchical structure. Each level represents a set of attributes related or interrelated to each sub-problem. Starting with the goal located at the very top, followed by criteria and sub-criteria, potential solutions are at the end of the hierarchy . This is explained in more detail by Saaty (1990). According to Saaty (2008), the AHP method is a measurement theory dealing with comparing pairs and relying on experts' opinions to devise the priority scale. Using the AHP, the importance of several attributes is obtained from a paired comparison process. Also, the relevance of attributes or categories of drivers of intangible assets are matched two-on-two in a hierarchic structure. In traditional AHP methods, a crisp number (e.g., 1-9) has been used by several experts to determine the importance of criteria, which has led to an unrealistic solution to a problem.

Nevertheless, several studies have indicated that the conventional AHP method, as developed by Saaty (1980), has some shortcomings. In their study, Peng et al. (2021) pointed out that the traditional methods used in nearly crisp-information decision applications; develop and deal with a highly unbalanced judgment scale and the uncertainty linked with the process applied is usually not considered. The traditional methods exhibit a subjective nature, and the perception of significance varies from person to person as this appears to be a subjective human judgement. To a large extent, the conventional AHP method cannot guarantee that the decisions are true or accurate. In numerous real-world situations, more than crisp numbered data is needed to model real-world scenarios to deal with the vagueness and uncertainty in decision-making, imprecise information, and human thought (Shen et al., 2013; Coffey and Claudio, 2021). Several researchers integrate fuzzy theory with AHP to overcome these problems and improve uncertainty. This study used fuzzy methods to replace the conventional

AHP method to manage the ambiguities in MCDM problems due to personal judgments and uncertainty arising from imprecision or vagueness. Some terms for articulating opinions can often be heard in real or daily life. Ill-posed questions, ambiguity in data representation, imprecision in computation and specific terms for communicating opinions, such as “neither agree nor disagree” and “nearly equal importance”, build uncertainties into the decision-making process. Researchers have widely used various research techniques to deal with uncertainties, including possibility, probability, and fuzzy set theory (FST). It is acknowledged generally that the fuzzy set theory can model decision-making methods based on imprecise and vague information, such as the decision maker’s judgment (Zadeh, 1965).

Zadeh (1965) introduced fuzzy set theory, which was oriented to the rationality of uncertainty based on imprecision or vagueness to deal with the vagueness of the subjective human nature of thought and judgment. According to Xu and Liao (2014), a fuzzy set is a class of objects characterized by the function of belonging. Each object gets a degree of membership within a specific interval belonging to the interval (0,1). FST operates on membership functions for a series of actions or steps to achieve a particular end while reaching a precise conclusion based on incomplete, imprecise, or uncertain information. Fuzzy sets generally use triangular and trapezoidal fuzzy numbers, which convert uncertain fuzzy numbers. A significant benefit of FST is its ability to represent incomplete/insufficient data. The theory further applies mathematical operators and programming to the fuzzy domain. It can capture experts’ uncertain, imprecise human judgments by taking linguistic variables (Patil and Kant, 2014; Aliyev et al., 2020). Instead of precise numbers, the fuzzy methods permit the use of fuzzy numbers, which can be designated to express the relative importance of the attributes. In solving various uncertain decision-making conditions and problems in the real world, fuzzy numbers are consistent. Chang presented the fuzzy AHP approach (1996), where the fuzzy triangular numbers (TFNs) are preferred for the pairwise comparison scale of fuzzy AHP. Figure 3.5. below shows a triangular fuzzy number.

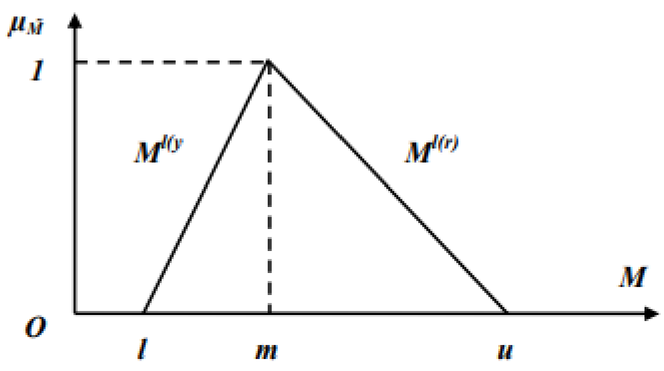

Figure 3-4: Triangular fuzzy number

Following the system described Chang (1996), different elements have been considered to create a closed gap for an established fuzzy number.

This is represented as follows:

I) There exists $x0 \epsilon R$ such that $\mu M\ (x0) = 1$

II) for any $a \epsilon [0,1]$

$$Aa = [x, \mu A(x) \geq a]$$

The fuzzy number will be denoted simply by: $M \epsilon F(R)$

In this case, all fuzzy sets are defined by F(R), while the set of real numbers is denoted by R. A fuzzy number $M\ on\ R$ will be a *TFN* if its membership function $\mu M\ (x): R \longrightarrow [0, 1]$is equivalent to the following Eq. (3.1):

$$\mu(x \setminus \tilde{M}) = \begin{cases} 0 & x < l \\ (x-l)/(m-l) & l \leq x \leq m \\ (u-x)/(u-m) & m \leq x \leq u \\ 0 & x > u. \end{cases} \tag{3.1}$$

From Eq. (1) above, $l, m, u,$ define the smallest possible value, the most favourable value, and the most considered most possible, respectively. In this case, *u* and *l* represent the individual lower, and upper bounds of the fuzzy number M, and m refers to the modal value of M and $l \leq m \leq u$ (as shown in Eq. 3.1 above). Thus, TFN can be represented by $M = (l, m, u)$.

A non-fuzzy number is recognised by convention in cases where $l = m = u$.

A fuzzy number with its related representation (left and right) of each range of membership is as below:

$$M = (M^{l(y)}, M^{l(r)})$$

$$= (l + (m - l)y, u + (m - u)y), y \epsilon [0, 1] \quad (3.2)$$

In this case, the fuzzy number denotes the right-side representation $l(y)$

and $l(r)$denote the left side.

Assume that $M_1$and M_2, M_1 = $(l_{1,}\ m_{1,}\ u_1)$ and M_2 = $(l_1\ m_2\ u_2)$ are to be two TFNs then the distance measurement of $d\ (M_1)$ is comparable to the Euclidean distance. The operational laws of the TFN $M_1 = (l_1\ m_1\ u_1)$ and $M_2 = (l_2\ m_2\ u_2)$ can be depicted as follows:

Addition of the fuzzy number ⊕

$$M_1 \oplus M_2 = (l_1\ m_1\ u_1) \oplus (l_2\ m_2\ u_2)$$

$$= \left(l_1 + l_{2,} + m_1 + m_2\ u_1 + u_2\right) \quad (3.3)$$

Multiplication of the fuzzy number ⊗

$$M_1 \otimes M_2 = (l_1\ m_1\ u_1) \otimes (l_2\ m_2\ u_2)$$

$$=(l_1\ l_2\ m_1\ m_2\ u_1\ u_2) \quad (3.4)$$

Subtraction of the fuzzy number Θ

$M_1 \ominus M_2 = (l_1\ m_1\ u_1) \ominus (l_2\ m_2\ u_2)$

$$= (l_1 - l_2,\ m_1 - m_2, u_1 - u_2) \quad (3.5)$$

Division of a fuzzy number Ø

$M_1 \varnothing M_2 = (l_{1,}\ m_{1,}\ u_1) \varnothing (l_{2,}\ m_{2,}\ u_2)$

$$M^{-1} = (l_1, m_1, u_1)^{-1} = (1/u_{1,}\ 1/m_1,\ 1/l_1) \quad (3.6)$$

$$\lambda \otimes M_1 = (\lambda l_{1,}\ \lambda m_{1,}\ \lambda u_1) \quad \text{Where } \lambda > 0, \lambda \in R \quad (3.7)$$

Reciprocal of the fuzzy number

$$M_1^{-1} = \frac{l}{l_1}, \frac{l}{m_1}, \frac{l}{u_1} \quad (3.8)$$

As developed by Zadeh (1965), the FST was introduced instead of the crisp set theory to deal with ambiguity and uncertainty in human cognition judgements. It is acknowledged that AHP shows drawbacks owing to its use of exact crisp numbers (i.e., 1-9) to rate the importance of criteria (Prascevic and Zivojin, 2017). The AHP employs precise criteria for making judgments. In certain instances, human emotions can be challenging to understand, and leaders may struggle to assign precise numerical values to their assessment judgments. In this particular scenario, the AHP is not relevant or applicable. It is important to note that the AHP can only consider independent criteria when doing pairwise comparisons. It is unable to account for uncertainty and risk in decision-making, as the natural world is inherently unpredictable. Therefore, decisions made using AHP are based only on the current situation and the intuition of the decision-maker (Karthikeyan et al., 2016; Ozgur, 2023). Although AHP has several limitations, it is nevertheless a valuable tool for decision-making and can be improved by combining it with other approaches and techniques. The fuzzy theory and its AHP extension aim to overcome the drawbacks of the traditional AHP. The significant aspect of the FST is that it deals with imprecise information and organises the problems' ambiguities based on individual judgment (Marimon Viadiu et al., 2006; Erdebilli et al., 2023). Bellman and Zadeh (1970) devised the FST to analyse decision-making problems. The FST uses linguistic terms to represent the decision makers' selections by extending the crisp set theory. Typically, the decision maker (experts in this case) feels more confident in making interverbal judgements instead of expressing their opinion in single numeric values. Many studies have shown that academic researchers have used integrated fuzzy theory with conventional AHP to solve hierarchical fuzzy problems and improve uncertainty (Lima and Carpinetti, 2019; Chen and Huang, 2022).

The academic study of Van Laarhoven and Pedrycz (1983), which compared fuzzy ratios defined by triangular membership functions, is one of the earliest works in which fuzzy AHP appeared. Further, Buckerly (1985) determined fuzzy priorities of comparison ratios with trapezoidal fuzzy numbers. In their work, Stam et al. (1996) determined or approximated the preference rating in AHP. The studies all utilised imprecise or fuzzy ratio-scale preference judgements. A new method for managing fuzzy AHP, using fuzzy triangular numbers for pairwise comparison scales, was presented by Chang (1996) using extended analysis. As set up by Chang, the new extended analysis method uses the extended analysis technique for the synthetic extent values of paired comparisons. Cheng (1997) proposes a new algorithm for evaluating a missile system by the fuzzy AHP based on the grade value of the membership function. The evaluation of diverse production cycle alternatives was also presented by Weck et al. (1997), which introduced fuzzy logic mathematics.

Kahraman et al. (1998) initially used the objective and subjective extended fuzzy AHP method to obtain the weights from the AHP while evaluating a fuzzy weight. Given that all these ideas aimed to accomplish global consistency and to accommodate the fuzzy nature of the proposed techniques based on stochastic optimisation were further introduced. Based on the linguistic variable weight of the AHP, a new method for evaluating weapon systems was proposed by Cheng et al. (1999). Zuh et al. (1999) examined the extent analysis procedure and the applications of fuzzy AHP. The study by Ulutas (2019) quantifies tangible and intangible benefits when proposing a technology selection algorithm in a fuzzy environment. Their work defines an application of the FST to hierarchical structure analysis and economic evaluations. The preferential weight of each alternative technology is found by aggregating the hierarchy.

The generally acknowledged fuzzy AHP method is presented by Chang (1992, 1996) as its extended analysis method uses the extended analysis technique for the synthetic extent values of pairwise comparisons. According to Chang's technique of extended analysis, an extended goal analysis is created for each object as extended goal analysis is created. The methodology proposed by Chang uses linguistic variables to describe the relative judgements given by experts. Suppose that $X = \{x1, x2, \ldots \ldots, xn\}$ be an object set and $U = \{u1, u2, \ldots \ldots um\}$ is the number of aims. An individual object $xi,$ is assumed, and an extended analysis is achieved for each goal, g_i. Therefore "m" for an individual object can be represented as follows:

$$M_{gi,}^{1},\ M_{gi}^{2},\ldots\ldots M_{gi,}^{m} \qquad i = 1,2, \ldots, n \tag{3.9}$$

In the FTN whose parameters are depicted as follows:

$$M_{gi,}^{j} \quad (j = 1,2, \ldots, m)$$

The least, most and considered most possible values are represented as (l, m, u).

The method follows the steps described by Chang's expanded analysis (1996), which includes the following steps (Kahraman et al., 2003, 2004; Kabir et al., 2011; Sequeira et al., 2020):

(I). Compute the value of the fuzzy synthetic extent for the ith object with according to Eq. (3.10)

$$s_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} \tag{3.10}$$

Where $\sum_{j=1}^{m} M_{gi}^{j}$ is obtained by performing the fuzzy addition operation of m extent analysis values for a particular matrix such that:

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=0}^{m} l_{gi}, \sum_{j=1}^{m} m_{j}, \sum_{j=1}^{m} u_{j}\right), \qquad (3.11)$$

and to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$ perform the fuzzy addition operation of M_{gi}^{j} $(j = 1, 2, \dots m)$ values such that:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} \left(\sum_{i=1}^{n} l_{i}, \sum_{i=1}^{n} m_{i}, \sum_{i=1}^{n} c_{i}\right) \qquad (3.12)$$

and then compute the inverse of vector the in Eq. (3.12) such that:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_{i}}, \frac{1}{\sum_{i=1}^{n} m_{i}}, \frac{1}{\sum_{i=1}^{n} l_{i}}\right) \qquad (3.13)$$

(II). In computing the degree of possibility, two fuzzy synthetic extents are considered for comparisons, which entails choosing the largest or smallest number's fuzzy value. The degree of possibility of M_2 $(l_2 m_2 u_2) \geq M_1$ = $(l_1 m_1 u_1)$ is defined as follows:

$$V\ (M_2 \geq M_1) = \sup\ [\ \min\ (\mu_{M1}\ (x)\ ,\ \mu_{M2}\ (x))\ ] \qquad (3.14)$$

an equivalently defined as follows:

$$V\ (M_2 \geq M_1) = \begin{cases} 1 & \\ 0 & Otherwise \quad \begin{matrix} if\ m_2 \geq m_1 \\ if\ l_1 \geq u_2 \end{matrix} \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \end{cases} \qquad (3.15)$$

Eq. 3.12 shows where d is the ordinate of the highest intersection point D between μM_1 and μM_2 as illustrated in Figure 3.6 below. To compare M_1 and M_2, it requires both the values of $V(M_1 \geq M_2)$" and $V(M_2 \geq M_1)$.

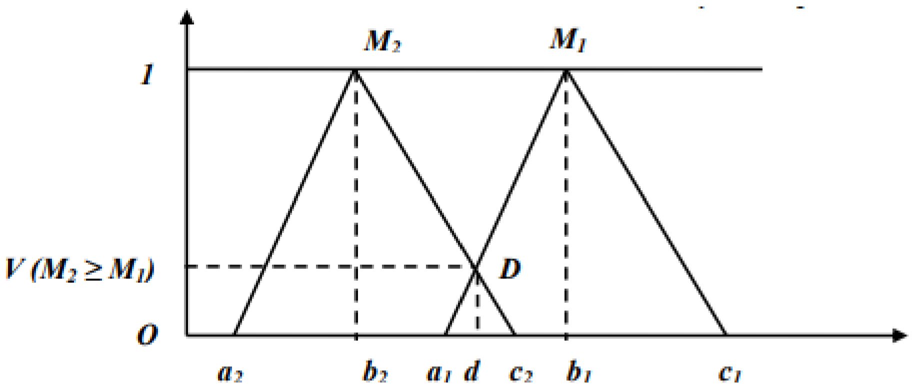

Figure 3-5: The intersection between $\boldsymbol{M_1}$ and $\boldsymbol{M_2}$

(III). To compute the degree of possibility for a convex fuzzy number to be greater than k we use convex fuzzy numbers M_i $(i = 1, 2, \dots, k)$. These can be defined according to Eq. (3.16).

V (M $\geq M_1, M_2 \dots, M_k$) = V [($M \geq M_1$) and ($M \geq$ M) and … ($M \geq M_k$)]

= min V (M $\geq M$), $(i = 1, 2, 3, \dots k)$. (3.16)

Assuming that

d' (A_1) = min V $(S_i \geq S_k)$ (3.17)

for k = $1, 2, 3, \dots, n; k \neq i$. Then the weight vector is given by W' = ($d'(A_1)$,

$d'(A_2)$,…., d' $(A_n))^T$ (3.18)

Where Ai = $(i = 1, 2, 3, \dots n)$ are n elements

(VI). By normalising, the normalised weight vectors are

$$W = (d(A_1), d'(A_2), \ldots d'(A_n))^T \quad (3.19)$$

Where W does not represent a fuzzy number.

Chang's fuzzy-AHP approach, TFN, is preferred for the pairwise comparison scale of fuzzy AHP. Since this approach is widely accepted, the extent analysis method was used for the synthetic extent value of the pairwise comparison. Hence, the fuzzy set theory has been selected in this thesis chapter to deal with the uncertainty of experts' judgment. Experts normally express their opinion by using the linguistic variable to appraise the significance of one criterion over the other or sometimes to rank the alternatives concerning different criteria. Thus, the fuzzy-AHP process determines each criterion's priority and sub criteria weight.

Determining the linguistic variables takes on values representing the terms set: its linguistic terms. A *variable* whose values are expressions in words and sentences in the natural or unnatural language is defined as a linguistic variable. Basic linguistic terms include *"Just Equal", "Equally important", Weakly important", Strongly important", "Very strongly important", and "Extremely important".* Table 3.5 - illustrates the linguistic scale together with the corresponding triangular fuzzy scale.

Table 3.5. Linguistic variable describing weights of the criteria and values of ratings

Linguistic scale for importance	**Fuzzy numbers**	**Membership function**	**Domain**	**Triangular fuzzy scale** (l, m, u)
Just equal	$\tilde{1}$			$(1, 1, 1)$
Equally important		$\mu_M(x)$ = (3-x) / (3-1)	$1 \le x \le 3$	$(1, 1, 3)$
Weakly important	$\tilde{3}$	$\mu_M(x)$ = (1-x) / (3-1)	$1 \le x \le 3$	$(1, 3, 5)$
		$\mu_M(x)$ = (5-x) / (5-3)	$3 \le x \le 5$	
Essential or strongly	$\tilde{5}$	$\mu_M(x)$ = (x-3) / (5-3)	$3 \le x \le 5$	

Important		$\mu_M\ (x)$ = (7-x) / (7-5)	$5 \le x \le 7$	(3,5,7)
Very strongly	$\tilde{7}$	$\mu_M\ (x)$ = (x-5) / (7-5)	$5 \le x \le 7$	(5,7,9)
Important		$\mu_M\ (x)$ = (9-x) / (9-7)	$7 \le x \le 9$	
Extremely important	$\tilde{9}$	$\mu_M\ (x)$ = (x-7) / (9-7)	$7 \le x \le 9$	(7,9,9)

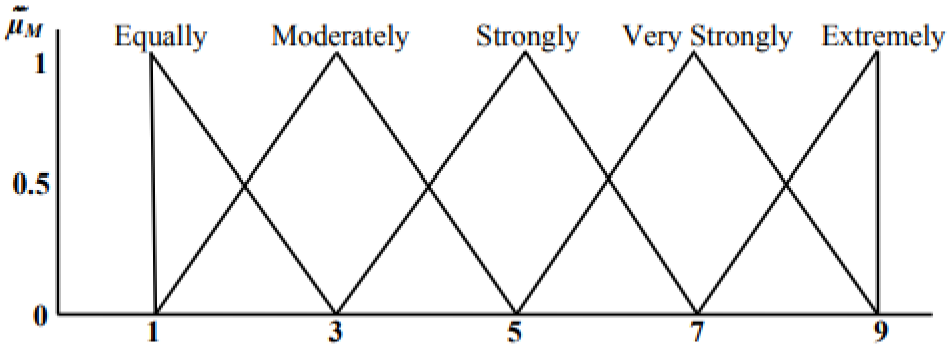

Figure 3-6: Linguistic variables for the importance weight of each criterion

From Table 3.5 above, if factor i has one of the above numbers allocated to it corresponding to factor j, then j has the same value as i.

Reciprocals of above

M_1^{-1} = $({}^{1}/_{u_{1,}}\ {}^{1}/_{m_{1,}}\ {}^{1}/_{l_{1}})$

TFNs are primarily used in applications because of their ease of computation and elements (Xu and Xu, 2020). Triangular and trapezoidal fuzzy numbers have been acknowledged as widely used methods (Kahraman, 2008; Kumar et al., 2023). In this chapter, the relative weight of various criteria has been considered a linguistic variable and represented by TFNs.

3.8.2.2. TOPSIS method

Hwang and Yoon (1981) developed TOPSIS as one of the classic MCDM methods widely used for ranking problems. The TOPSIS method is established on a simple and intuitive concept that a chosen alternative should contain the shortest distance from the positive-ideal solution (PIS) and the farthest from the negative-ideal solution (NIS) (Wang and Lee, 2007; Lin et al., 2008; Zyoud et al., 2016; Chakraborty, 2022). In other words, the positive-ideal solution has the most benefits and lowest cost of all alternatives (achieving minimal gaps in each criterion). The negative-ideal solution has the lowest and highest costs (achieving the maximal levels in each criterion). The positive-ideal solution comprises all the best values attainable to the criteria, whereas the negative-ideal solution comprises all the worst values attainable to the criteria (Zulqarnain et al., 2020).

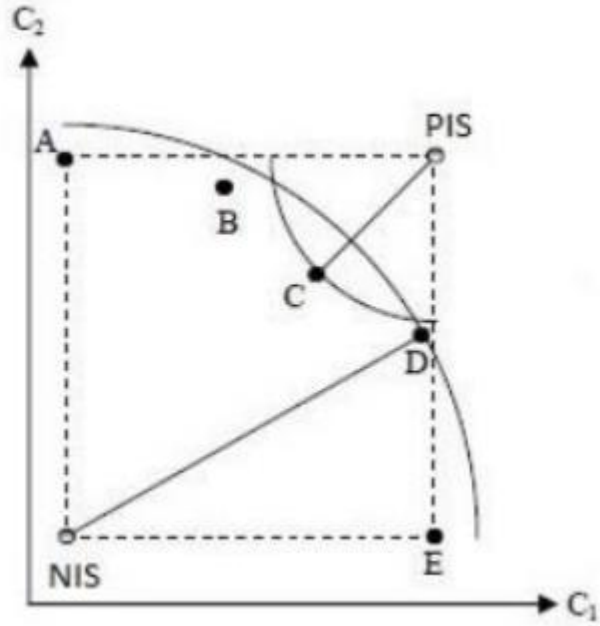

Figure 3-7: Ranking alternative through their Euclidean distance to the PIS and NIS
Source: Redrawn from Hodgett, (2014)

3.8.2.2.1Identify the decision-making alternative (Step 1)

Incorporating IWT actors in the logistics chain in countries like the Netherlands, Belgium, Germany, and France has resulted in the growing inclusion of waterborne transport in a more complex organisational structure, where its cost, capacity and regularity benefits are utilised. In this context, the IWT in these countries demonstrates greater flexibility and versatility compared to the rail system. Also, these different waterway corridors in the country above share similar features of river-sea connectivity.

3.8.2.2.2. Identify the criteria that will be used to assess the alternative (Step 2)

Maintaining a coherent procedure for analysing the decision-making process model is necessary. The work carried out in this section leads to the results from work undertaken in the earlier part of this chapter. Following this, the same criteria used to apply for the FAHP in the earlier section of this chapter will also be used to determine the performance ratings of the chosen decision alternatives.

3.8.2.2.3. Gathering data through the use of TOPSIS survey (Step 3)

A questionnaire was used to solicit an expert opinion survey in order to decide the chosen alternative. The quality of expert judgement is established through their expertise, capability, experience, and knowledge. The experts consisted of industry practitioners, academicians, and professionals employed in IWT agencies who possess knowledge and experience in the relevant field.

3.8.2.2.4. TOPSIS survey (Step 4)

TOPSIS requires the collection of pertinent data for analysis. In order to obtain the opinions of experts in the IWT or transport-related sectors, it is necessary to complete a questionnaire that was created in step 3. When reaching out to the relevant experts, the same procedures were followed as those employed for the fuzzy AHP in the previous section of this chapter.

3.8.2.2.5. Alternative ranking using the accumulated data (Step 5)

The procedure followed for the TOPSIS is as the follows:

I. Establish a decision matrix.
II. Construct normalised decision matrix.

III. Determine the weighted normalised decision matrix.
IV. Determine the positive ideal and negative ideal solutions.
V. Calculate the relative closeness to the idea solution.
VI. Calculate the separation measures for each alternative.
VII. Calculate the relative closeness to the idea solution CC_i
VIII. Rank the alternatives.

3.8.2.3. Choosing the appropriate rating values for alternatives with regards to the criteria

Experts were consulted to develop an evaluation matrix using the subjective judgement scale outlined in Table 3.6. The study employs the primary preference towards this study: The performance ratings are as follows: Low (L), Below average (BA), Average (A), Good (G), and Excellent (E). The judgement scale quantifies the performance of the specified criteria. Table 3.6 presents the evaluation matrix.

Table 3-6: Judgment scale of the rating

Low (L)	1
Below average (BA)	2
Average (A)	3
Good (G)	4
Excellent (E)	5

3.8.2.3.1. Case study to determine the ranking of alternative.

The method adopted for the fuzzy AHP has already been established previous section of this chapter. In this case, the subjective knowledge and judgement of experts in the field provide data for analysis through a combination of FAHP and TOPSIS. With this in mind, the following section gives a detailed explanation of the TOPSIS-based approach.

3.8.2.3.2. Utilise the collected data to establish the ranking of alternative.

Once the data has been collected, it was used to rank the priority order of the selected alternatives. This was done by utilising the TOPSIS methodology. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is used to rank the priority order of several alternatives. It can be realised as outlined in Chen (2011).

To follow this approach, the formula contains seven stages as follow.

I). Construct normalised decision matrix.

Various attribute dimensions are transformed in this step into non-dimensional attributes, allowing comparisons over criteria. Normalise scores or data as follows:

r_{ij} = x_{ij} / ($\sum x^2$ for i = 1, …, $m; j = 1, \dots, n$ (6.20)

(II). Construct the weighted normalised decision matrix.

Assuming that we have a set of weights for each criterion w_j for $j = 1, \dots, n$. Each column of the normalised decision matrix is multiplied by its associated weight. The new matrix element is:

v_{ij} = w_j = r_{ij} , for $i, \dots, m; j = 1, \dots, n$ (6.21)

(III). Determine the positive ideal and negative ideal solutions.

Where the positive ideal solution is:

A' = $\{v_1{}^*, \dots, v_n{}^*\}$, $where\ v_j{}^* = \{max(v_{ij})\ if\ j \in J\ ; min\ (v_{ij})\ if\ j \in J'\}$ (6.22)

And where negative ideal solution is:

A' = $\{v_1', \ldots, v_n'\}$, $where\ v' = \{\min\ (v_{ij})\ if\ j \in J\ ; max\ (v_{ij})\ if\ j \in J'\}$ (6.23)

(IV). Calculate the separation measures for each alternative.

The separation from the ideal alternative is:

D_i^* = $[\ \sum(v_j^* - v_{ij})^2\ ]^{1/2}$ $\quad i = 1, \ldots, m$ (6.24)

The separation from the negative ideal alternative is similar as:

D' = $[\ \sum(v_j' - v_{ij})^2\ ]^{1/2}$ $\quad i = 1, \ldots, m$ (6.25)

(V). Calculate the relative closeness to the idea solution $\mathrm{CC_i} *$

CCi^* = $S'_i\ /\ (S_I * + S'_I)$, $\quad 0 < CCi * < 1$ (6.26)

(VI). By comparing $\boldsymbol{CCi}$ values, the ranking alternatives are determined.

3.9 Chapter Summary

This chapter presents a comprehensive overview of the research concept, approach, design, data collection, and analysis methodologies. An in-depth analysis of each layer of the research onion allows for a thorough comprehension and valuable insight into the selection of the research methodology. This study's research topic and purpose support the use of a mixed methods design and an abductive research strategy, as previously discussed and justified. The choices chosen regarding the data collection and analysis techniques in this study align with the aim and objectives. The chapter describes the data collection and analysis methods used for this study. Questionnaires and semi-structured interview questions were the main instruments and methods used for primary data collection. The technique used to analyse the industrial survey is based on the combination of fuzzy AHP and the TOPSIS method, which has been discussed in detail.

The final research methodology used in this attempt to close the research gap identified by conducting relevant and suitable research in the domain of IWT using empirical methods. This research involves gathering data through appropriate empirical methods, such as surveys, to gain a better understanding of all the relevant aspects and factors that define the performance in the field of IWT, which are comprehensively captured and modelled.

Chapter 4: Research Setting: Identification of Sustainable Network of Inland Navigation Gateway Case Studies for Benchmarking

4.1 Introduction

Gateways represent the fundamental structural interface between regional and global transport systems (Notteboom et al., 2020). This chapter sets the scene for this study. The first two parts discuss a general overview of the maritime gateways, particularly in Europe and other parts of the world, where waterborne transportation is essential to these gateway domestic logistics systems.

This chapter presents an overview of continental European maritime gateways with regional inland waterways by examining the transport geography of this study, as depicted in the diagram in Figure 4.1.

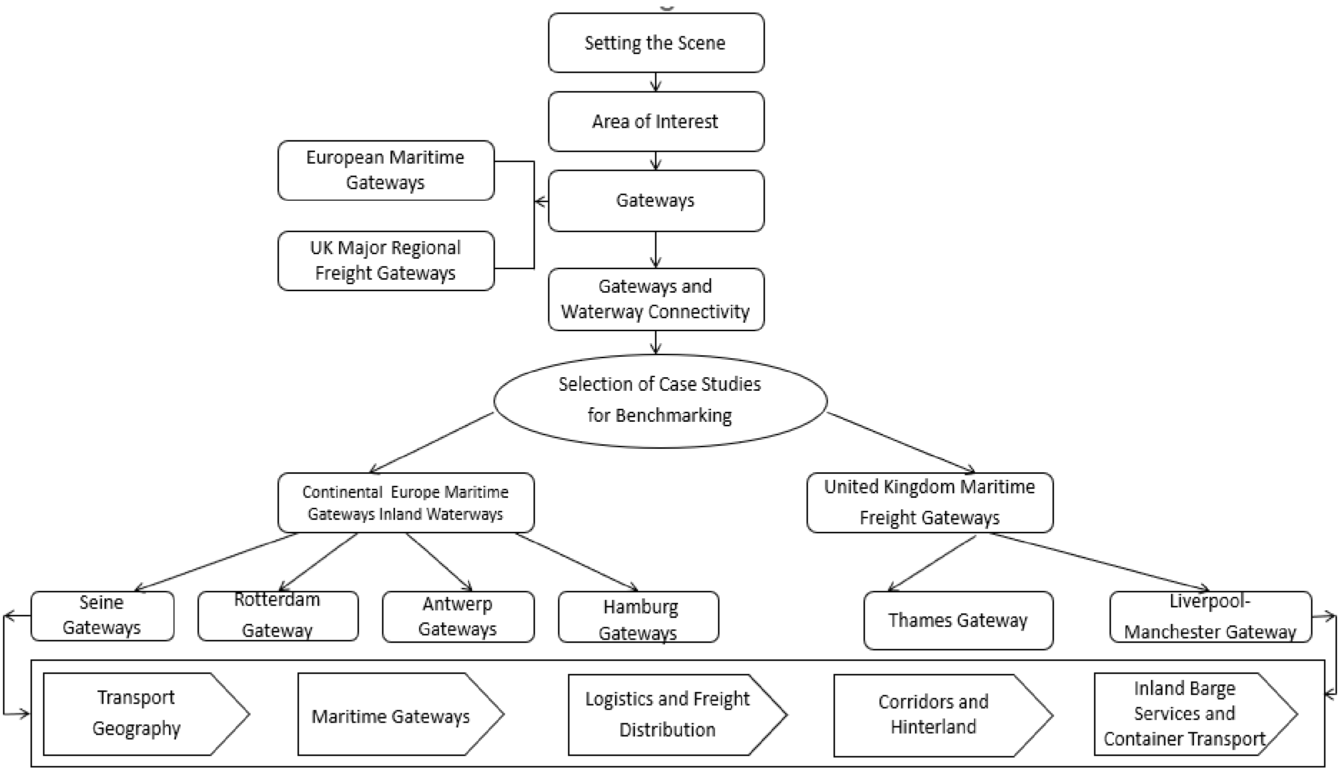

Figure 4-1: Identification of the research setting

Source: Author work

The research described in this chapter focuses on measuring the performance of inland waterway transport and logistics within these geographical boundaries. The gateway approach used in this research is based on key European and UK freight transport axis where modal transport changes could take place, using inland waterways and railways. This chapter's selection of these maritime gateways study serves Chapter Five for transport service performance analysis executed through an industrial survey established within the considered geographical region. The study's gateways are geographically located between maritime and terrestrial flows within the considered geographical region. Each gateway has a different level of maturity and qualities to enhance the development and use of inland waterways in its domestic freight logistics system. The main aim is to highlight best practices from this regional and national maritime freight gateway to improve the service performance of inland waterway transportation industry within the UK.

4.2. Maritime Freight Gateways

4.2.1 Overview of maritime gateways and inland waterway connectivity around the world

The freight transportation geography evolves at various scales. Still, it is a known fact that acknowledged that freight flows occurring at the local level result from both global and regional economic processes (Golini et al., 2018). As a results of the growth in world trade, transportation is changing at an accelerating pace, making the sector the pacesetter of the national economy and social development. Globalisation has increased the demand for local and international transport, which has expanded the complexity of the business environment (Dobre, et al., 2021). This development has grown alongside the quantity of freight shipment, complicating supply and distribution chains on the other hand, Containerisation has become an essential feature of the throughput shipped in many of maritime seaports in the past years (Rodrigues et al., 2023).

Research studies have acknowledged that containerisation has expanded the hinterland reach of the seaport (Konings, 2007; Kotowska et al., 2018; Totakura et al., 2020). For this reason, most seaports, especially in Europe, carrying out these containerisation services now act as gateways to often extensive inland networks. Gateways for international cargo interact with national, regional, and local hubs to articulate international and domestic flows of goods. Academic studies of gateways acknowledge that these maritime gateways are important transport nodes facilitating the movement of goods, extending among continents where international trade flows are being transhipped onto continental axes and vice versa (Fleming and Hayuth, 1994; Van Klink et al., 1998; Naima et al.,2022). As facilities that allow smooth interchange between trade inflow and outflow, maritime gateways worldwide contain and offer various value-added activities, including transportation, external logistic operations, modal and intermodal transportation services and integration with other supply chain actors. Nonetheless, other gateways focus their activities mainly on acting as transhipment nodes providing an interface between the maritime transport leg and the inland transport system.

Given the growing volume of container transport transhipped via maritime ports, gateways now play a significant role in intermodal transportation, facilitating the concentration of cargo and distribution by different forms of transport, offering both transit and transhipment services to their hinterlands. The growing volume of container currently being handled by seaport has made the capacity and performance of hinterland transportation an essential element within the port (Wide et al., 2021). Hinterland transportation has gained a new dynamic interface with the increasing share of intermodal transport. It has helped improve port accessibility by transfering cargo from congested roadways onto railways and waterways. The network of quality inland waterway routes and their associated barge transport has contributed to the development and performance of port activities (Behdani et al., 2021).

The development of intermodal transport has resulted in a hinterland structured along transport corridors. The development of hinterland coverage development and the related shift from the fundamental hinterland where the market is closest to the terminal to a competitive hinterland where there is more intensive competition with other businesses has made the port markets into a more competitive area (Ambra, et al., 2019). Thus, gateways link geographical areas by providing a transport infrastructure system of national and regional importance for both domestic and international trade.

Gateways are connected to transport/transit corridors by their roles and functions. These transport corridors are mostly transport routes on which freight is moved between specific areas, countries, and even regions. The maritime gateway primarily serves as a container sea terminal interface between the intercontinental/maritime transport leg and inland circulation systems. Intramodality and its associated transport corridors have led to an array of barge terminals linked with major deep-sea container terminals with scheduled barge services, giving deeper access and penetration between the seaport container terminal to the hinterland (Cesar et al., 2022).

Major ports, such as Shanghai and Nanjing are considered gateway ports in China. Shanghai port is unique, and it is strategically located as a coastal port connected to inland China by the Yangtze River. The port presents considerable international and national transhipment of maritime containers, primarily because it is a gateway to the Yangtze River basin. The location of gateway seaports are primarily areas close to major economic centres and intermodal corridors (Ducruet and Wang, 2019). According to Mou et al. (2018) location is key to load centring while also giving credence to the significance of the strategic location of the gateway port.

Shanghai port is located amongst China's most economically developed cities, situated along major transportation corridors with excellent geographical location and a sound transportation network system which comprises inland ports connecting inland waterways transport with other modes of transport. The port of Shanghai is a vital hub for inland shipping, generating a high volume of domestic transhipment while also constituting a gateway to the Yangtze River. (Sun et al., 2023). Integration of deep-sea volumes and large intermodal transport corridors have allowed load centres to enlarge contestable hinterland areas and intrude into the natural hinterland of rival ports (Veenstra and Notheboom, 2011).

In the United States, Gateways tend to be the dominant market, and this is true for the two prominent maritime facades, the East and the West coasts (Lavissiere and Rodrigue, 2017). However, the role and function of freight gateways and their corridors vary according to their geographical setting, impacting modal and operational considerations. In North America, economic activities are mostly positioned along coastal lines (East and West coast), with significant resource and manufacturing hinterlands (Rodrigue and Notteboom, 2010). The position of IWT along transport corridors depends on corresponding seaports, as well as waterway conditions and inland terminal density in their hinterland. Container ports located in a delta of navigable waterways generally strive to develop inland river services as a competitive transport mode, to serve local and distant hinterland regions (Notteboom and Rodrigue, 2023). In China and Europe, container barge services link seaports with their hinterland. Major European seaports, with good waterway links and a high-quality network of inland terminals, lead to above-average IWT shares in the hinterland of these Western European seaports.

4.2.2 European maritime gateways and transport corridors

Freight flows are the consequence of global and regional economic activities (Gerlitz and Meyer, 2021). European maritime port serves as the main gateway to the trans-European network and have been successful pioneers for interconnecting different transport modes. As there are generally characterized, gateways serve as a nodal point with an excellent intermodal connection that links various facilities in a transportation network. At the European level, most European container ports are considered gateway ports due to their superb transportation network with facilities like the inland terminal, distribution centres, warehousing, and servicing a hinterland and catchment area beyond their local, national borders (Cesar, 2022).The history of intermodal transport and containerization has pointed towards a higher level of intermodal integration (Van-Ham and Van-Duin, 2001; Notteboom and Haralambides, 2020).The evolution of intermodal transport has reinforced the roles and functions of a gateway port as a gateway that can play a significant role in intermodal transport by providing transhipment services, thereby enhancing the efficiency of shipment of cargo from the point of origin to their final destination. The growing volume of maritime container activity at the port has allowed intermodal transport to strengthen its position in the transport chain (Van-Klink and Van Den, 1998; Notteboom and Lam 2018). Figure 4.2 illustrates a typical map of the Rhine corridor with waterway connectivity used to transport intermodal containers.

In Europe, most intermodal networks serving hinterlands operate within transport corridors, linking two or more nodes together. The European barge network has always been primarily focused on maritime container flows through gateway ports, according to studies of port gateway performance conducted by Tongzon and Oum in 2019. Their studies highlighted some specific determinants and characteristics that allow the gateway to function effectively, which entails a strategic location with adequate infrastructure, connectivity, and a more comprehensive range of port services.

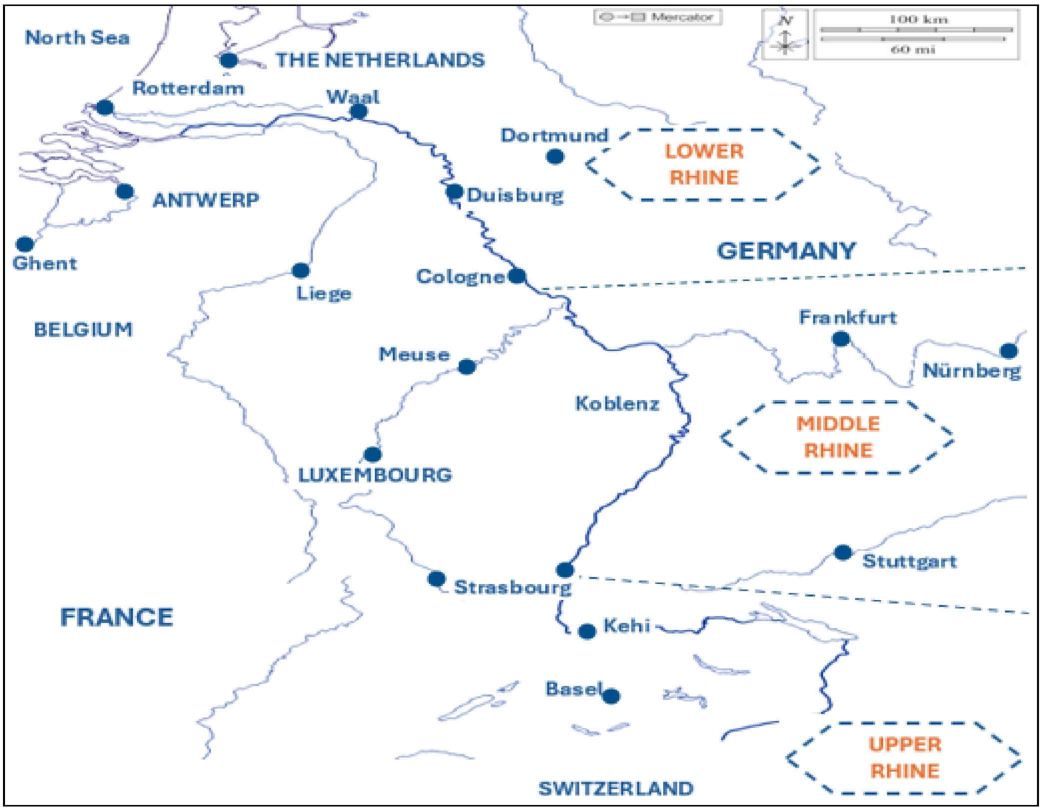

Figure 4.2: Map of the Rhine corridor
Sources: Author work

The transportation of containers via barges in Europe has its origins between Antwerp, Rotterdam, and the Rhine River basin. This development has risen dramatically along the north-south axis in the last decade, stretching between Belgium and northern France (Parola et al., 2020).

Currently, inland shipping plays a vital role in the hinterland transport connectivity of the research setting due to its exceptional geographic location at mouth of the large European rivers like the Rhine. The region's economic success is often associated with the Rhine, which was described as the “bearer of prosperity" within the Mannheim convention in 1868. Presently, three-quarters of European inland shipping takes place on the river Rhine, which shows the importance of this inland waterway for the European economy and transport sector. The Rhine remains the main artery and gateway to Europe in goods transport via waterways. Its network of rivers and channels enables the inland shipping sector to cover a large part of Europe (Psaraftis, 2021). Via the Rhine and its adjacent navigable waterways and canals, the industrial areas of North and South Germany and Northeast France are within reach for large inland vessels, while smaller inland vessels can reach other industrial areas in France (INS, 2018).

Traditionally, Northwest Europe and Western Europe are trade regions due to their geographic position on the coast and in the deltas of large European rivers. Their position at the heart of Europe's trading routes has contributed significantly to the economic development of these regions but also led to the large flows of physically processed freight of European origin and destination through the ports positioned within these geographical boundaries, observed explicitly in the ports of the Hamburg – Le Havre range, including Rotterdam and Antwerp (Parola et al., 2018). The share of barging for hinterland transportation from Western European container seaports has substantially increased. Rotterdam, Antwerp, and Hamburg handle approximately 94% of container transportation flow in Europe (Eurostat, 2022). The volume of marine containers transported via inland waterways to and from these ports makes apparent the significance of these Western European countries as hosts for major transit ports (Rotterdam and Antwerp) or as significant sources of container movements (Hamburg). However, the ports of Rotterdam and Antwerp have achieved a considerable share of rail and barge freight over a short distance of 100km for capacity and environmental reasons. On the other hand, the main challenge for these seaports is to increase the modal shift of hinterland container transport by rail and barges over distance between 100 to 400km (Malchow, 2014; Shobayo and Van-Hassel, 2020).

4.3. Intramodality and hinterland reach in European container port

In Europe, intermodal transport has undergone a significant revolution (Van Klink and Van Den Berg, 1998; Notteboom et al., 2018). The development of intermodal transport has resulted in major container ports structuring their hinterland along transport corridors (Ben-Japp et al., 2007; Parola et al., 2020). This development which enables large-scale transport, has become significant in keeping the port accessible by relieving congested roads and shifting cargo movement away to the railways and waterways. In recent times, the transport system has become a dominant factor of change in international and regional freight transportation, with enhanced efficiency in distribution (Rodrigue, 1999; DeWitt and Clinger, 2001; Rodrigue, 2004; Notteboom, and Rodrigue, 2023).

The seaport's competitive position depends not only on its location and ability to service larger vessels but more on its connections with the hinterland. Major European container ports have generated scale economies in operating intermodal transport that is effective to numerous destinations at reliable cost and high frequency. The emergence of intermodal rail and barge corridors has extended the geographical reach of the gateway port. In such a way, seaports stimulated intermodal transport and opened new markets beyond their traditional hinterland (Ambra et al., 2019). The development of intramodality has not only given ports incentives to expand their hinterland reach, but it has also resulted in a discontinuous hinterland, significantly beyond the immediate hinterland of the port (Cesar, 2022). Intramodality in Europe owes its growth to hinterland expansion and various transhipment operations at intermediate ports. Hinterland extension has led to more overlap among seaport hinterlands, and thus stronger competition between them. This is the case, especially for major Western European ports (Antwerp, Le Havre, Rotterdam and Hamburg), which compete to serve interior areas where the distance of the ports to major cargo generating areas is not a distinguishing factor (Visser et al., 2007).

However, road haulage remains pre-eminently the primary hinterland transport system in most European seaports. Nevertheless, intermodal rail and barge transportation have proven effective and competitive on many high-density traffic corridors in Europe. Examples of this can be seen in the Rhine Delta axis and some Alpine routes. Although the transport system cannot serve as a comprehensive European alternative to road transportation mode, to some considerable extent, intermodal solutions based on rail and barges serve specific European niche markets. In Western European countries, the port hinterland is not only situated along the coastline where the river flows directly into the sea, also includes interior areas; an example of this is the Rhine River delta system and its tributaries, Hesse in Germany (Main and Neckar), various economic zones in northern Italy (e.g., Milan,) and in the UK, the Liverpool-Manchester as well as Leeds-Humber belt (Zolfaghari et al., 2019; Gerlitz and Meyer, 2021).

4.3.1 European barge transport

Transportation by barge is predominantly serves freight movement between seaports and their hinterland. Because of an extensive river network, the barge transport system is ideal for carrying sea-borne freight on the next leg of its inland destination journey. Although the importance of barge transport varies from continent to continent, barge transport is directly but strongly used for large worldwide cargo transportation in the case of dry bulk (grain and ore), liquid cargo (crude oil) and maritime containers. In Europe, freight transportation by barge is growing modestly (Shobayo and Van-Hassel, 2020), while for to capacity and environmental reasons, its share has substantially increased in some parts of the continent. For example, in North-Western Europe (The Netherlands, Belgium, Germany and France), freight transportation by barge has evolved over the last decade. The roles and function of barge transport on this axis have been mainly attributed to the network of large, high-capacity rivers such as the Rhine, with excellent links to seaports.

As the merits of barge transport are its sustainability and less congestive operational approach while also offering large-scale operations at low unit transport costs, Western European ports are now prioritizing barge transportation in their transport chain. In recent times Eastern European countries like Poland and Romania have shown plenty of potential for barge transport. With ever-increasing demand for transport in Europe, the barge transport sector has been able to cater to shippers' demands serving as a leading mode of transport over a short distance along major river transport corridors and opening new geographical markets in these areas (Bu and Natchmann, 2022).

4.3.2. Inland barge services and container transport

In many European seaports, road transport remains the dominant mode of transport for inland services to and from seaports for technical, economic, and social reasons. However, rail and inland barge transport have a considerable advantage over road haulage as a high-capacity transport mode (Raza et al., 2020). European barge container services have primarily been developed between the seaports of the Netherlands, Rotterdam, Antwerp, Belgium, and Germany's hinterland. Geographically, container barge transport is dictated by the high-quality waterway network situation. Rotterdam has a strong position for barge traffic from and to the Lower Rhine and Middle Rhine, whereas Antwerp and Rotterdam have robust connectivity at the upper reaches of the Rhine (see Figure 4.2). The advantageous natural conditions of these seaports, located at the estuary of the Rhine River, have been a significant asset for the strong development of hinterland barge transportation in these areas.

Hinterland transportation enables maritime ports to collect or distribute many containers taken on or dropped off by large seagoing vessels. The movement of maritime containers via inland barge has gained a significant share in the hinterland modal split of the seaports. A seaport that integrates intensive maritime services with high-capacity inland services becomes a principal load centre in its port range due to its control of a more extensive hinterland (Robinson, 2002; Notteboom, 2004). In the port of Rotterdam and Antwerp, the movement of maritime containers via inland shuttle barges has gained a significant share in the hinterland modal split for the seaport. Container barge transport has become a competitive alternative to road and rail transport due to its ability to offer cheap and reliable transport services. Traditionally, low-cost operations formed the competitive edge of barge transport over the road. By exploiting these comparative advantages, the barge transportation sector has achieved a substantial market share in container transport.

4.4. A closer look at the port of Rotterdam container barge services

Several European ports constitute major gateways for intercontinental and continental freight, but the port of Rotterdam is the most prominent and busiest in Europe. The port of Rotterdam is one of the central, largest logistics and industrial transhipment hubs in Europe. The seaport serves as the gateway to more than 350 million consumers of the European market (Port of Rotterdam Authority, 2011). Theoretical models on gateway port development have indicated that large seaports which supported and invested heavily in early container infrastructure have attracted more container traffic (Notteboom, 2007a). The resulting port concentration has prompted increasing container throughput in these large ports, raised capacity issues, and the quality of hinterland accessibility.

The increasing throughput volume of maritime containers has resulted in pressure on terminal and hinterland performance. Container throughput was more than 14.3 million TUE in 2020 (POR, 2020). Container activities are laid out in three spatial clusters of terminals, with a maximum distance of 40km each; the Maasvlakte area, directly besidethe ocean, provides accessibility for significant contemporary container vessels into the Botlek and Eem/Waalhaven interior area. The port has extensive intermodal transport connections (road, rail, and inland barge). Currently, in the domestic hinterland container modal split, barge transport has approximately 38%, while rail and road account for 10% and 52%, respectively (POR, 2020). Road transport has remained the dominant transportation mode for the hinterland of the port of Rotterdam. For various reasons, including capacity, the share of rail in the hinterland transportation chain has remained low, subjecting rail transport to a modest role in hinterland container traffic. Container traffic by rail is mostly international traffic covering a distance ranging from 150km (to Antwerp and Belgium) and 1100km to Northern Italy.

Intermodal barge transport has played an essential role in hinterland transport. Freight transportation by inland barge has increased significantly and gained a significant share of the modal split of hinterland transport. Container barging has been of utmost importance in the port of Rotterdam in keeping the port accessible, given ever-increasing container volumes and road traffic congestion. The success of container barging transport services was due to high-quality waterways and relatively low prices made possible by the lower-cost operation (Notteboom et al., 2020). It explains the significant growth in the container barging sector since the mid-eighties.

However, they have a considerable share in the hinterland modal split of container transport by barge in Rotterdam port, several challenges have harmed the efficiency of barge operations. Despite spectacular growth in container barge transport over recent decades, the transport system has proved efficient and provides evidence that its performance can still be increased. The rising volume in the transport network presents opportunities for efficiency improvement (Magnan and Horst, 2020).

4.4.1. Characteristics of barge hinterland services in Rotterdam

Port of Rotterdam's competitive position depends not only on its strategic geographical location and service of bigger maritime vessels but more on its hinterland connectivity. The development of hinterland transport services enabling large-scale transport is gaining importance to keep the port accessible by shifting cargo from congested roadways to other modes of transportation, like the railways and waterways. The quality of hinterland access is essential for seaport competitiveness as it has become the source of port accessibility, enhancing port performance, especially in the container market. Connectivity to inland waterways has played a pivotal role in the hinterland connectivity of the Port of Rotterdam. Container transport by barge has been developed between the port of Rotterdam, Amsterdam, and the hinterland along the Rhine River. Hinterland transportation via shuttle barges has become a significant mode of transport in these busiest European maritime ports. It serves as an efficient and reliable mode of transport compared with other modes, enhances turnover in seaports, and reduces congestion in land infrastructure.

In the barge hinterland, transportation to and from Rotterdam, major markets or trades have been identified (A&S Management, 2003; Konings, 2007; Notteboom et al., 2018):

- *Rhine river trade*: Inland container barge transportation between the port of Rotterdam and areas of industrial concentration in Germany and associated areas in France and Switzerland, providing safe and reliable services.
- *Rotterdam-Antwerp trade:* There has been a rising volume of inland shipping on the link between Rotterdam and Antwerp. The Rotterdam and Antwerp depend heavily on barges to reach hinterland regions linked by water.
- *Domestic trade:* Transportation of containers via inland barges between the port of Rotterdam and the interior inland areas of the Netherlands

Although these inland barge trade routes have different supply and demand characteristics as well as geographical orientations, which has resulted in various operational features, frequent barge shuttle services are provided in the three markets above. Figure 4.3 illustrates a typical barge transport operation pattern in the Rhine River hinterland transport chain.

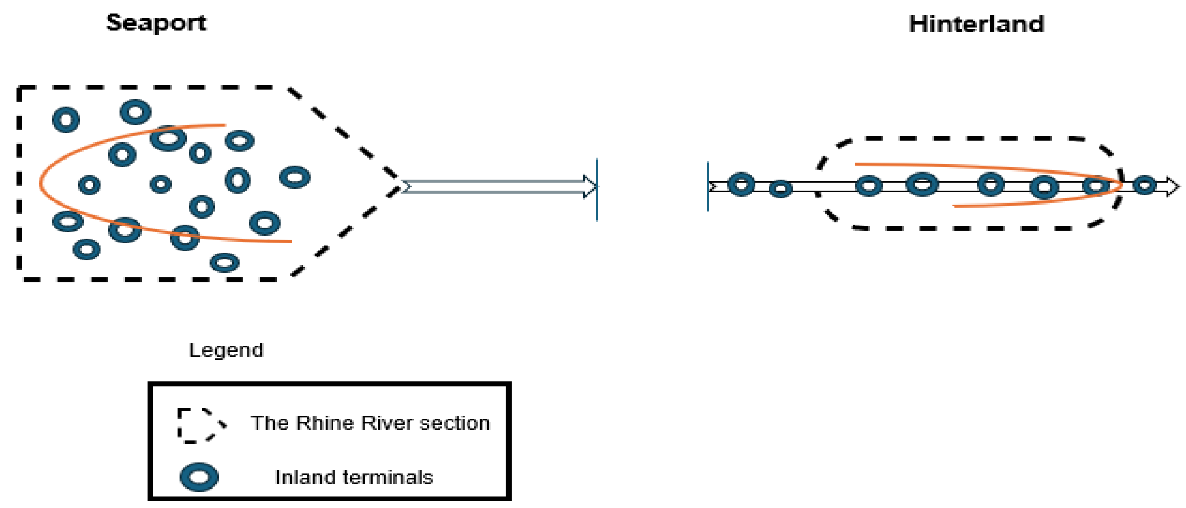

Figure 4-2: A typical barge transport operation pattern in the Rhine River hinterland transport chain.
Source: Author work

The features of the barge transport network services are largely similar to both the Rhine River trade and Rotterdam-Antwerp trade. The similarities are modest number of barge operators; availability of large inland barges; daily barge shuttle services; customers shipping and forwarders lines. However, in operation, features of the domestic barge trade in the Netherlands differ, barge operator and inland terminal operator, medium and small inland barges).

4.4.2. Network design

4.4.2.1.The Hub-and-spoke concept.

International traffic flows have set the scene for the barge transportation market, and due to the increasing container flows, new geographical market have emerged in the recent decades. The creation of these new geographical markets has made it vital to expand transport services the existing line and point-to-point inland barge services. Hub-and-spoke services offer an exciting combination of cargo bundling and various modes of transport (barge and rail) in one system. It has been acknowledged that hub-and-spoke services would transform the seaport's situation, which is characterised by collection and distribution, into a pattern where inland barges may only visit a single terminal (Pels, 2021). In the hub-and-spoke concept, the so-called hub terminal would accomplish the transformation pattern, where classification would be made on a hinterland container barge reaching the hub and transferring to their terminal destination.

As introduced by the port of Rotterdam, the hub-and-spoke network is a strategy that would manage and promote the use of barges in an effective way. Although container barge services in Rotterdam and Antwerp remain closely connected with point-to-point services and line bundling services to and from large load centres, one of the merits of the hub-and-spoke concept is that inland barges can deliver better cost-performance. This cost performance is because the cost saved by a reduction in navigating, terminal handling, and terminal waiting time is more significant than the additional cost of navigating the push boat between hub and port and handling cost in the hub (Konings, et al., 2013; Green et al., 2021).

4.4.3. Interface between seaport and inland waterway transport

The transportation sector is a substantial factor in economic and regional balanced development and has significantly influenced national integration into the world economic order. Currently, the inland shipping sector has reinforced its dependence on maritime access according to the demands and the rhythms of globalised flows; the interface between seaport with and IWT is being redefined. Links between inland ports are numerous and very varied in scope and intensity. More co-operation is starting to emerge between ports (Zweers et al., 2019). This trend is gaining momentum to express the need for upscaling the high-quality performance of IWT. These developments have pushed the IWT sector to open up and redefine itself in terms of logistics services operations, cargo information sharing and strategic positioning. As a direct implication, the seamless integration of IWT into contemporary modern industrial supply chains is emerging due to fierce competition among other transportation modes, increasing economic conjecture, growth of markets, and economic, social, and environmental sustainability factors (Roso et al., 2020).

4.5. Selection of European regional inland waterway transport and logistics gateway case studies for benchmarking.

4.5.1 Le – Havre - Seine – Paris corridor

Regional development emphasises the role of transport in the economic development of cities Lemke and Piotrowski (2016 cited in Wysokiński et al., 2012, p. 631). The geographical dimensions and components, the modern French ports, and the rapid expansion of combined waterway-road services at Le Havre - Marseille prompted a more in-depth analysis of primary data for benchmarking. Le Havre is a trade-enabling gateway for cargo entering the French consumer markets, ranked as the second French port and the ninth in Europe, with 66 million tons handled in 2017, including 2.8 million TEUs (Eurostat 2019). The Le Havre gateway has been a dynamic freight transport backbone axis, connecting sea, roads, inland waterways and railway routes from Le Havre, a coastal city, into the capital city of France, Paris. Le Havre is connected to Paris via the Seine River as an entry port. This area is one region in North-Western Europe where modal transport changes could occur, using rail and waterways more globally. The Seine River Estuary is the end of one of the largest navigable French rivers. It is the country's principal waterway artery.

Moreover, other navigable rivers flow into the Seine including, the Yonne, Loing, Marne and Oise, these four rivers form a route connection via a waterway network to the north, east and south of France. The Seine route goes through Paris and flows into the English Channel, an arm of the Atlantic Ocean separating northern France and southern England. The Seine gateway, as shown in Figure 4.3, the AURH atlas map, is located at the heart of North-Western European freight flows, connecting Le Havre -Seine – Paris – Ile-De-France through waterway routes capable of handling substantial flows and serving national and European hinterlands. The Seine corridor serves via natural routes, a consumer catchment area (Paris and its surrounding region) with approximately twenty-five million people – the largest in France and the second largest in Europe.

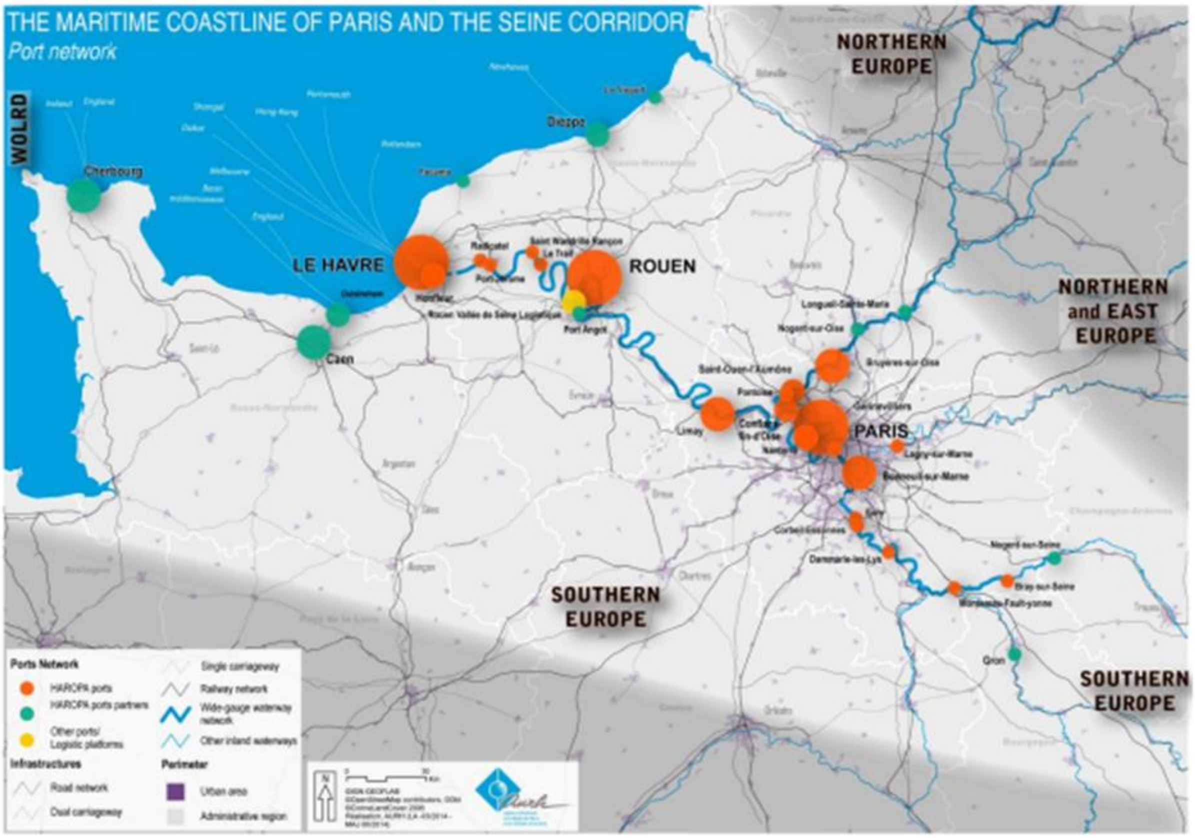

Figure 4-3: Maritime gateway of Paris and the Seine River Corridor

Source: AURH (2016)

Paris to Le Havre remains France's busiest waterway and is navigated by a substantial fleet of high-capacity barges and push-tows. This inland waterway route is a crucial asset for Le Havre and the Seine River valley (Pradana et al., 2019). This Normandy coastline allows Paris to take advantage of a high-quality area in its natural geographical continuation. The approach of a gateway on the Seine River approach was conceived by generating added value from freight flows. The gateway is based on a high-performing supply chain serving ports and industries. From an economic point of view, the Seine River valley is characterised by the Le Havre-Rouen industrial and port hubs, highly concentrated on the Le Havre industrial zones. The gateway allows these economic activities to expand along these routes.

4.5.2 Rotterdam, Hamburg, and Antwerp gateways

The situation of IWT along corridors depends on corresponding seaports and waterway conditions and the density of inland terminals in their hinterland. Vital seaports, good waterway links and a high-quality network of inland terminals lead to above-average IWT shares in the hinterland of Western European seaports. The Netherlands, Germany and Belgium account for more than 93% of the total EU flow of full containers on IWW (Eurostat, 2019). Netherlands and Germany have the largest share of IWT within the EU due to both countries' extensive inland waterway networks. The inland waterways and rivers link together hundreds of key towns and areas of industrial concentration, which are already providing safe and reliable services to freight businesses. These Western European countries have been selected for this research because the waterway shows similar features of river-sea connectivity, and the waterways transport network in these countries is connected to major ports such as Rotterdam and Hamburg, which forms vital hubs for imports and exports from other parts of Europe. For example, in the Netherlands, the IWW capacity is embedded in the transport system and utilized largely. This port owes its leading position to its outstanding accessibility for sea-going vessels and intermodal connections. The Netherlands and Belgium contain tight mazes of navigable waterway networks, unlocking all industrial areas, and the same holds for the north of Germany. The IWT in this region plays an essential role in their national transport systems.

The port of Rotterdam has continued to pay attention to its extensive network of intermodal transport connections (rail, inland shipping, and road) with the hinterland. Inland navigation plays a central role in providing principal transport axes towards hinterland shipper zones in these regions. Inland hubs have been constructed along waterways due to congestion and lack of space in the port areas providing reliable connections with other transport modes. These inland terminals offer additional services, including value-added activities that complete the transfer function, such as customs clearance, empty container depots, and distribution centres attracting regional or global distribution (Caris et al., 2014). A significant aspect of this network is that vertical integration and collaborative agreements appear in the hinterland transport chains, aiming to increase the geographical scope or offer door-to-door transport services (Notteboom, 2007b; Notteboom et al., 2020). The Dutch concept of synchro-modality also highlights the integration of inland shipping within the larger supply chain (Sakti et al., 2023).

On the other hand, with Antwerp's seaports, Flanders has perfect sea-going gateways for fast handling of all kinds of goods to and from any part of the world. Flanders' transport infrastructure features one of the world's densest road networks, which connects directly with France, the Netherlands, Germany and Luxembourg, and the UK by ferry or the channel tunnel. Logistics operators move cargoes from Flanders to most major European markets by road within a day. In Belgium and the Flanders region, inland shipping is gaining popularity as a reliable and cost-effective means of moving bulk goods over longer distances (Kaup et al., 2021). The recent attention to inland navigation in this region is due to its connection to

Europe's most important markets; Flanders is the starting point for significant freight transport via inland waterways. Flanders' river and canal networks are among the densest globally, extending over 1,357 kilometres.

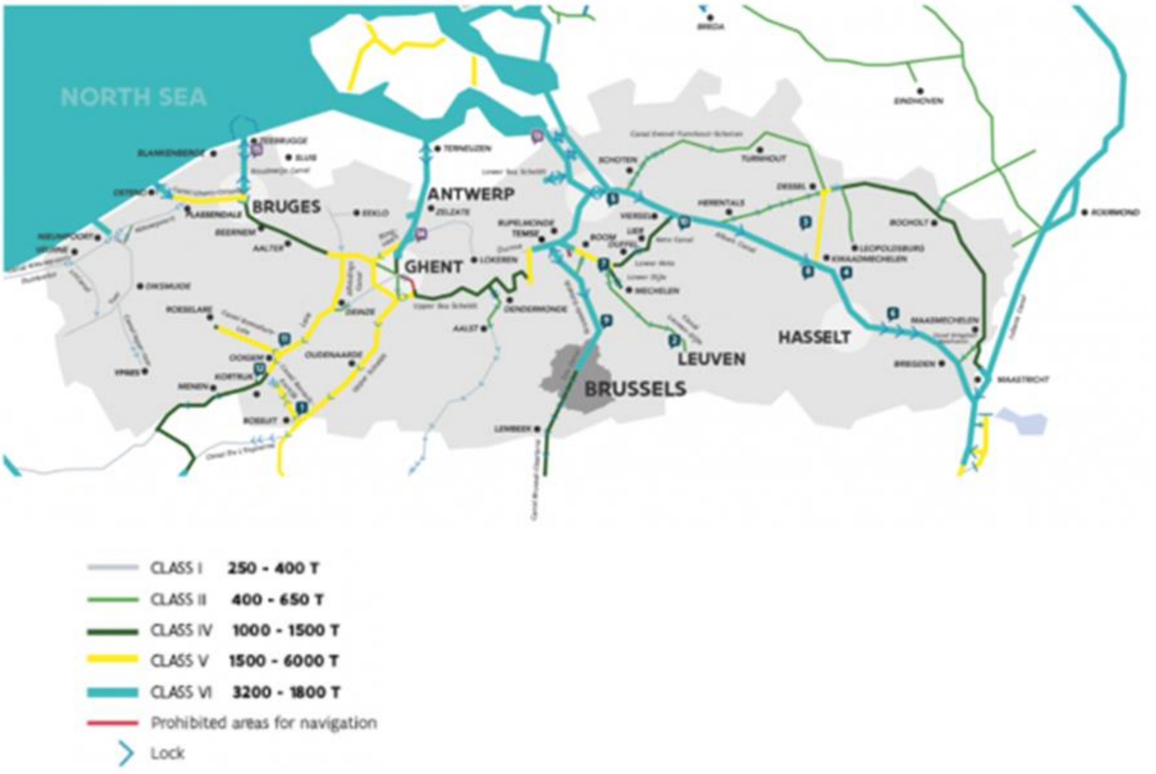

Figure 4-4: Inland container terminals in Flanders

Source: Flanders logistics ecosystem (2021)

Flanders is home to an impressive total of nearly 800 European Distribution Centres (EDCs), in which 80% of all companies are located fewer than 10 kilometres from a navigable waterway. Inland navigation is an essential mode of transport in these areas. The sector's strengths are its relatively low energy consumption, low costs for infrastructure and transport, and a high degree of reliability. With more companies trying to find a greener solution to their supply chain, the use of IWT is undoubtedly the way forward in reducing emissions and relieving transport congestion.

4.5.2.1. Inland shipping serving the hinterland of the selected European gateway sea-port

International transport dominates domestic and transit traffic volume in most container shipping transported via inland waterways. It constitutes over half of the containers transported via this transport network yearly. European countries use inland navigation to a variable extent in their freight transportation systems. As an integral part of the European transport network, in 2020, 505 million tonnes of goods were transported via European waterways, and inland container shipment represented 10% of total IWT in the EU (Eurostat, 2021). According to Eurostat data for 2019, Germany, and the Netherlands, contributed most to IWT container performance (TEU-km), and to a large extent, Belgium also played a significant role. This shows the importance of these European countries as major gateway ports for transit or as sources for hinterland destinations for inland containers.

Table 4-1: Selected European gateway seaports in the context of IWT

Port	Antwerp	Rotterdam	Hamburg	Marseilles-Fos-Sur-Mer
Primary information regarding linkages within inland waterways	Situated on the northern sea, this port is one of the largest in Europe and serves as a major hub for containers. Its advantageous position in the Scheldt-Meuse-Rhine delta allows it to be connected to a vast network of inland waterways spanning 1500km across Europe. Additionally, it has access to over 75 inland ports throughout Europe, some of which function as dry ports.	The largest port in Europe is located in the estuary of the Rhine and Meuse rivers, which connect Rotterdam with inland ports in the Netherlands, Germany, Belgium, France, Switzerland, and Austria. Additionally, it is connected to ports in central and eastern Europe through the Rhine-Main-Danube Canal. This port serves as a major container hub.	Hamburg is located 130km away from the open sea, on the Elbe River. The middle section of the Elbe River and the Elbe lateral canal connect the Hamburg port with important German business centres such as Hanover, Braunschweig, Salzgitter, Wolfsburg, and the Ruhr district. It is Germany's third largest inland port, surpassed only by the ports in Duisburg (52 million tonnes) and Cologne (911 million tonnes).	Situated on the Rhone River, Marseille is well-connected to prominent cities in southern France, such as Lyon, as well as other ports in the Rhone-Alpes and Burgundy regions. It serves as a container hub for the southern part of the country.
Annual turnover	Approximately 200 million tonnes, 60% of which consists of general cargo primarily in containerised form.	Approximately 500 million metric tonnes of cargo, with nearly 70% consisting of bulk cargoes, while	Approximately 150 million tonnes, with two-thirds consisting of general cargo, primarily in containerised form. A	Approximately 80 million tonnes of cargo are transported annually, with over half of them consisting of oil and its derivatives. Containerised

		the remaining 30% primarily consists of containerised freight.	significant portion of the cargo originates from or is destined for Eastern European nations.	cargoes account for 11 million tonnes.

Source: Author work based on Kotowska et al. (2018); Notteboom and Haralambides (2020); Rokicki et al. (2021); Santen et al. (2021); Rodrigues et al. (2023).

4.5.3 Thames gateway and the Liverpool/Manchester regional gateway

The role of a gateway, a much more complex approach, dramatically exceeds that of ports, transport infrastructures, and supply chain activities alone. Besides its use as a network that plays the role of an entranceway and an exit towards other networks, it links logistical development to all components associated with urban planning. These extended geographical components centre on innovating and generating a competitive difference. They are based on a proper added value supply chain economic system, leading to synergism between the supply chain, distribution, industries, trade, and other territorial activities (Duszynski et al., 2015). The Thames Gateway is an excellent example of an enriching territorial gateway in the UK that federates the zones between London and the high sea in terms of services and coordinated territorial development, which includes constructing a new deep-water port at the head of the Thames estuary by DP World. Figures 4.6 and 4.7 depict the River Thames and the Manchester Ship Canal/River Mersey, along with the boundaries of the inland waterway, ports and wharves used for transporting goods between rivers and seas.

The Thames gateway helps decongest London whilst ensuring a steering development between the state, municipalities, and private partners (Wiegmans, 2018).

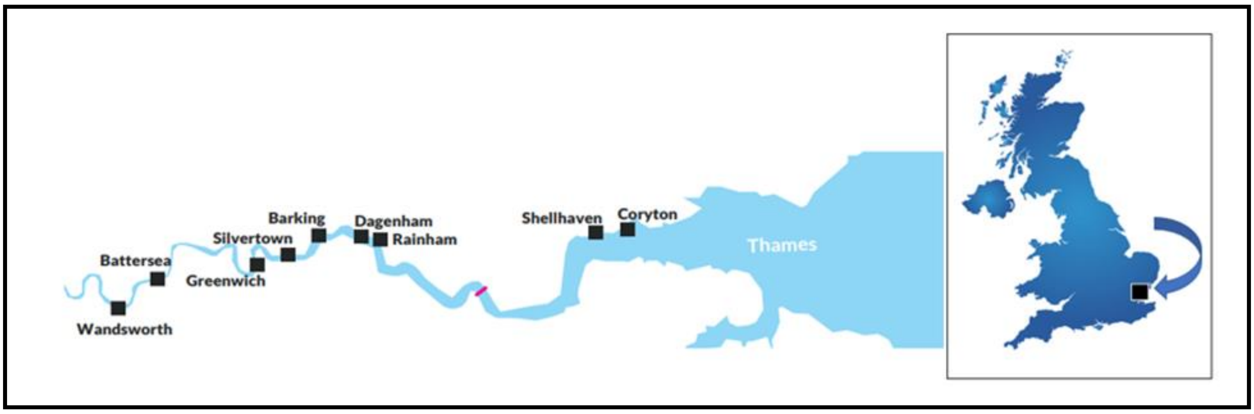

Figure 4-5: River Thames with inland waterway boundary, ports, and wharves for river-sea transport.

Source: Author (Redesigned from Department for Transport (2020) and CCNR (2020).

The port of Liverpool, on the other hand, was the fourth central maritime hub in terms of tonnage arriving in the UK in 2020, behind London, Grimsby and Immingham, and Milford Haven (Department for Transport, 2021). The port is a regional and national gateway in northwest England. An integral part of this gateway's connectivity and a significant influence in its strategic geographical location relates to the Port of Liverpool and the Manchester Ship Canal, linking the two industrial cities. The port has been of crucial economic significance to the Liverpool City region and the Northwest of England in general. According to Statista (2021), the volume of freight entering the port amounted to approximately 23 million metric tons in 2020. The port has expanded with the development of facilities to serve the largest container ships (post-Panamax), which will benefit the UK via a single stop at Liverpool rather than using one of the ports in the greater southeast. This development is the case of the new Liverpool 2 deep-water port which has opened the capability of providing direct service to Liverpool for Panamax vessels. This development is expected to increase the national distribution potential of the port. Moreover, the expected increase in the port's national distribution will increase the average haul length, creating more significant economies in favour of rail distribution.

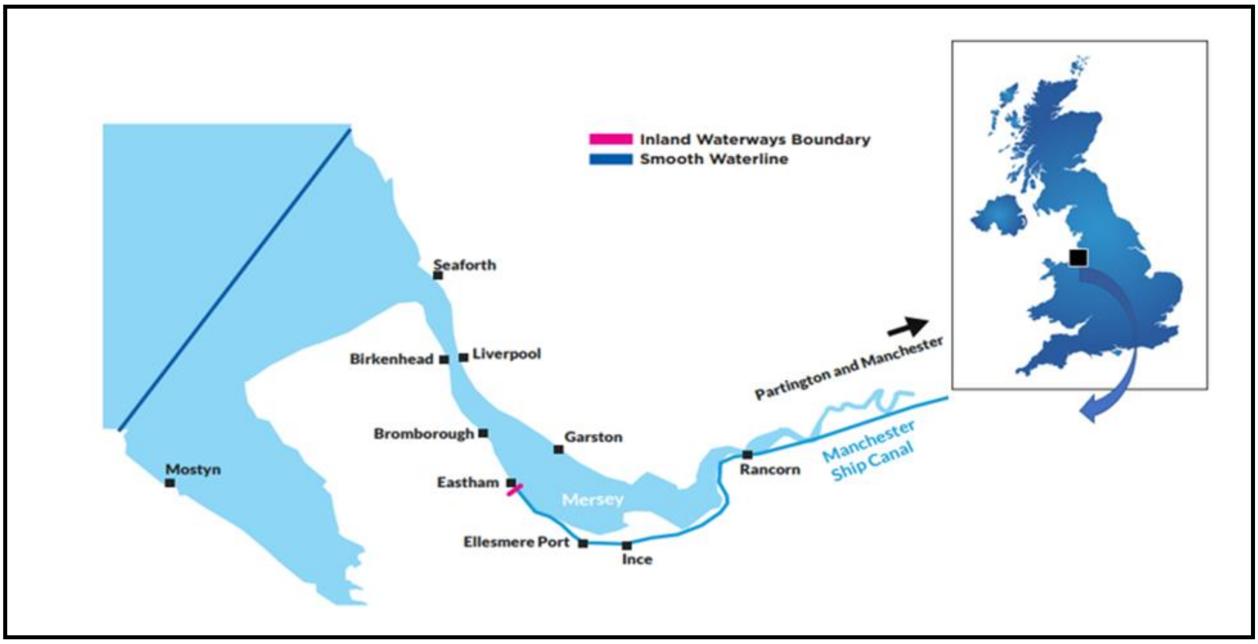

Figure 4-6: Manchester Ship Canal/River Mersey with inland waterway boundary, ports, and wharves for river-sea transport

Source: Author (Redesigned from Department for Transport (2020) and CCNR (2020).

Nevertheless, the potential for greater use of waterways in distributing freight in this region is feasible. The city region already has a substantial array of ports along the canal to Manchester and closer proximity to a several traditional industrial hubs, including Leeds.

4.6. Selection of Two Regional Maritime Gateways in the United Kingdom for Benchmarking

Each gateway has a different level of maturity and qualities to enhance the development of a sustainable transport system. The grid of links a gateway has to its hinterlands, and links between the closest hinterland terminal and the farthest, define an efficient and functional gateway along a structural corridor. Although each gateway acts differently, they are strategic tools, all sharing the peculiarity of going beyond an individual site to introduce connectivity and flows.

In the UK, there are several strong similarities between the Seine Gateways and the Thames Gateway in terms of freight movement and logistics activities, including port hub logic with the creation of a new freight container terminal by DP World, London’s relationship to its river, and the quality of rail and road links for cargo movement, among others. The increasing overload of capacity on the road and rail transportation networks forces the country to understand and integrate inland navigation as a potential alternative to freight transportation. This increased flow of goods and road transport emphasises inland navigation's vital role to match future demands and meet economic and ecological needs. In order to understand the dynamics of England's inland waterway situation (River Thames and Liverpool/Manchester Ship Canal) more clearly for freight transport, attention must be broadened to include competing European inland waterways. Four case studies have been selected in this study, namely Rotterdam (The Netherlands), the Le – Havre - the Seine – Paris corridor (France) Antwerp-Flanders (Belgium), and Hamburg (Germany) to benchmark the selected case study in England (River Thames and Liverpool/Manchester Ship Canal). Due to limited available resources for this research, some EU projects promoting IWT as a sustainable transport system in Europe were identified based on industry experts' judgements and their willingness to participate in the survey for Chapter Six.

4.7 Chapter Summary

This chapter determines the primary research setting for this study IWT in Europe, specifically the Netherlands, Germany, Belgium and France. Two case studies, the Thames Gateway and the Liverpool/Manchester regional gateway, are highlighted within major research settings in the United Kingdom. The identification of this regional logistics gateway case study facilitates the examination of how the IWT network performs within a regional maritime gateway by identifying and analysing the key performance metric based on stakeholders' perceptions within the inland waterway freight transport industry in the next chapter.

Chapter 5: Identification of an Integrated Set of Indicators for Assessing Inland Waterway Transport Performance

5.1 Introduction

The recent boost in the world's economic growth and industrial competition recognises improving quality and best practices in products and services. Improved competitiveness is an essential component in every industrial sector, often propelled by the desire for improved performance and increasing demand for high-quality services. The transport sector has heavily discerned the continuously growing pressure from globalised markets. The phenomenon of globalisation has significantly increased the demand for continental, regional and local freight transportation, and logistics; this has expanded the complexity of the business environment. As IWT has reinforced its reliance on maritime access connectivity, it has continued to play an essential economic role in bringing goods from Europe's busy seaport to its final destination. Gateway seaports connect and interact with inland shipping according to the rhythms of globalised flows. As a result, inland shipping has continued to be increasingly integrated into the modern industrial logistics chain due to these seaports' high volume of goods. In line with the EU's strategic ambition of "shifting 30% of freight transported by road, due to the unsustainable and congested road network, to an environmentally friendlier alternative that has lower societal impact, such as waterborne and rail transport" (Ambra et al., 2019).

This development has compelled the sector to re-evaluate its freight flow management, logistics process and strategic positioning. As such, efficient stimulation of IWT as part of a fully operational intermodal transport chain entails that the transport sector must enhance its quality, reliability, flexibility, planning capability and operation traceability so that these features are comparable with other transport modes (Posset et al., 2009; Caris et al., 2014; Totakura et al., 2020). These criteria serve as critical factors in today's freight transport industry. A reference or measurement standard from successful key industry players that have achieved and accomplished a certain level of success over a long period is required for internal and external comparison to ascertain adequate progress. Inadequate data limit the identification and subsequent performance analysis against objective and evaluation achievement for decision-making criteria, especially for inland shipping. Consequently, new perspective methods and acceptable standardised tools for measurements of IWT are needed.

Performance indicators are fundamental to the significant assessment of individual or organisational activity (Isoraite, 2005). They allow effectively and practically accepted techniques to support decision-making procedures by successfully identifying the cause and effects in a manner that directly and indirectly impacts the achievement of goals and corresponding results (Landeghem and Persons, 2001). In the transport industry, indicators may often be used individually to improve service quality and benchmarks. The idea is to proffer a comparator and tool for ensuring performance levels for analysis. However, this involves challenges in developing good performance indicators specific to IWT that are internationally applicable and accepted to support better decision-making and enhance the transport sector's competitiveness.

This chapter aims to develop a mode-specific benchmarking framework to ascertain sustainable benchmarking of IWT by capturing and modelling relevant aspects and factors that determine and influence the perception of performance in the context of IWT (See Table 2.4. for articles highlighting performance measurement in the IWT domain identified in the literature in Europe and other countries). It highlights prevailing guidelines, local policies and best practices from continental Europe and contributes these to improving the area of interest in the UK's IWT industry. This chapter describes the identified performance indicators in the IWT transport domain selected to capture and verify these performance indicators through an expert opinion survey. A questionnaire was designed, and an experts' opinion survey was conducted to determine the weights of the identified indicators/sub-indicator group and to explore any other remaining performance indicators/sub-indicators yet to be explored by the study.

5.2. Approach

The efficient utilisation of different transport modes and resources entails the comprehension of options and alternatives. The comparison of transport performance between different transport modes of a given country and other countries' transportation systems indicates areas where this potential for improvement. The body of literature shows that inland waterways still have the necessary transport capacities in Europe and the UK. However, the prerequisite for effective utilisation to enable multimodal transport entails effective transport planning and the availability of quality infrastructure connecting economic regions. Insufficient quality infrastructure at critical parts of the network can hamper the efficiency and competitiveness of the transport system. Unfortunately, to a certain extent, this is an aspect over which the stakeholders have little or no power or influence on their own.

The concept of performance measurement is often used to enhance business and agencies' performance transparency. IWT as a sustainable and alternative transport solution has continually become unsatisfactory in its performance, mainly due to the absence of transparency or inadequately chosen indicators. The sector suffers setbacks from lack of cooperation and information exchange between authorities and shippers, especially in the cross-national context. An essential aspect of modal improvement includes enhancing cooperation between relevant stakeholders, including the supply chain actors and public administrations (cities, regions, and customs authorities) (Shobayo et al., 2019; Alias et al., 2022). This key element facilitates sharing of their resources, bundling their transportation volumes and synchronising their operations; all these measures contribute to smoothing the functioning of the transport system (Specht et al., 2020). Currently, the transport system can provide only a restricted amount of factual data to assist in logistical transport operations. Insufficient documentation in the logistics sector is causing difficulties for logistics operators and cargo owners, making the sector unappealing to users.

However, at present, performance indicators are available only at the company level, which means they can only be used on an individual basis for quality improvement and benchmarking purposes (Posset et al., 2009; Farazi et al., 2021). Therefore, new industry-wide techniques and performance measurement tools are needed for IWT. The end goal is to have a shared understanding of standard definitions and measurements to promote the adoption of best practices.

This chapter describes the indicators and sub-indicators that can be undertaken to capture and verify issues, as identified through an expert opinion questionnaire survey. A decomposition method was applied to categorise the unstructured indicators into different indicators/sub-indicator groups. Figure 5.1 illustrates the proposed methodology used to identify indicators/sub-indicators for this study.

Phase 1 of this approach explores the integrated set of indicators and sub-indicators for assessing IWT. Various IWT performance indicators, sub-indicators and alternatives are identified from literature sources and industry reports. A survey of experts' opinions was then carried out to select suitable industrial experts and IWT project partners across Europe and the UK to test the proposed approach empirically in this phase. Empirical studies were conducted first through a pre-testing survey using a semi-structured questionnaire to confirm all the integrated indicators and sub-indicators derived from literature sources and industrial reports. Next, a final set of semi-structured questionnaires was sent and received after the consulting experts commented on the final results. Initial construction of a structured model diagram in a three-tier hierarchical structure is formed with goals, criteria, and sub-criteria at each level. The second phase is the confirmation of the IWT performance indicators and sub-indicators. Phase III is the validation of the initially developed diagram. In this phase, the weights (importance rating) of various IWT performance criteria and sub-criteria are first determined using a seven-point Likert scale questionnaire. This is then followed by evaluating and determining the final rank using the statistical test reliability method, as presented in Table 5.4.

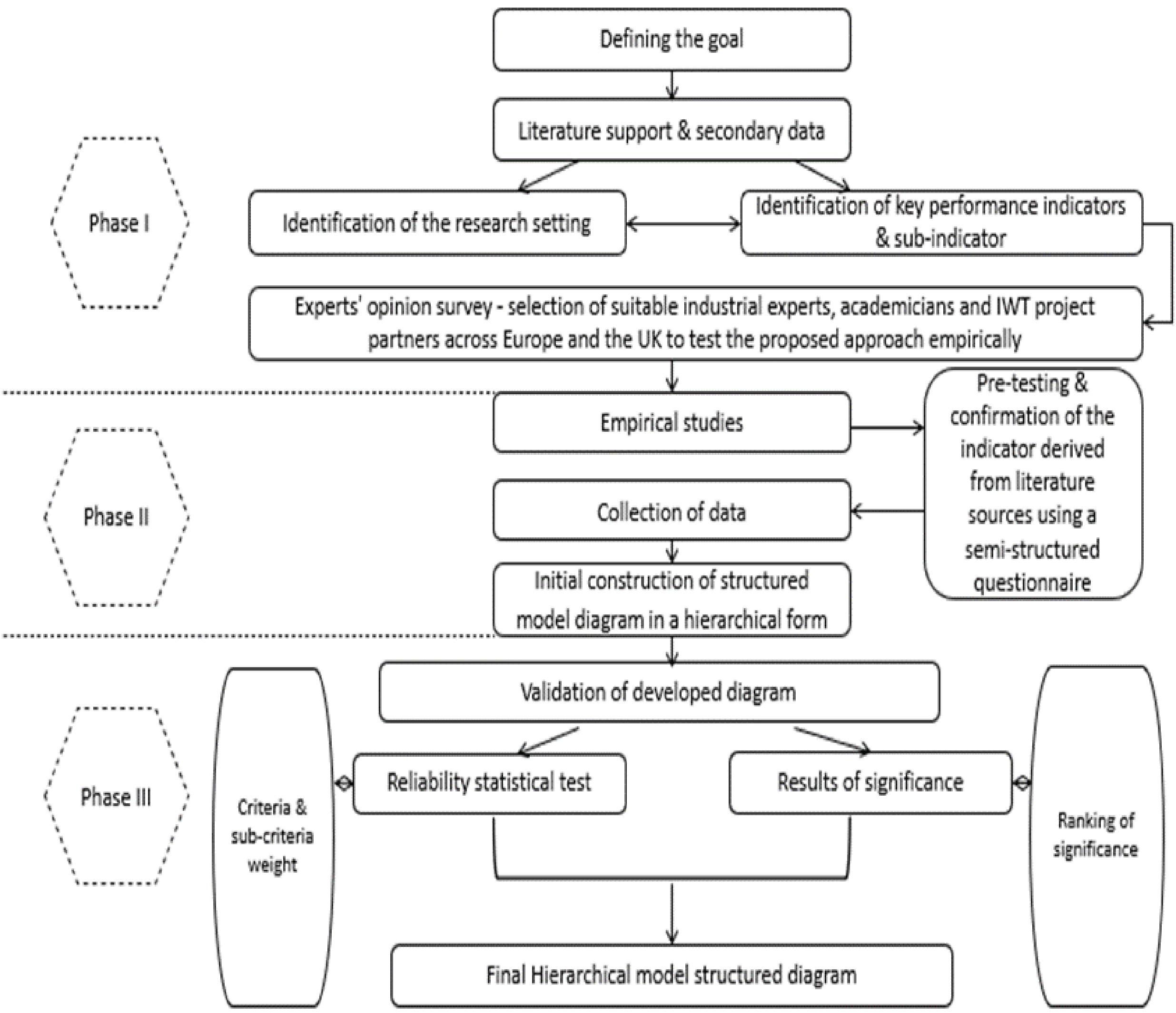

Figure 5-1: Proposed methodology used to identify indicators/sub-indicators for this study
Source: Author work

5.3 Case study selection on regional inland waterway transport within major maritime logistics gateways for benchmarking

It is commonly accepted that the transportation industry is one of the fundamental drivers of trade and economic growth. In all European countries and inside the EU member states, the transportation sector is one of the crucial sectors of the economy. As such, European projects and official reports reveal the substantial focus by the EU on the freight transportation industry as a factor contributing to its prosperity. At the same time, the sector is one of the most significant contributors to the EU's GHGs (European Barge Union, 2018). Both theory and practice have shown that the transport industry is the most significant energy consumer and pollutes the environment to a major extent (Ivanovic et al., 2009). In Europe, most freight is transported by road which has remained Europe's most popular and preferred choice of freight transport. The road has continued to be the leading freight transport mode and has carried three-quarters of freight in the EU for over a decade.

"The EU's share of road transport freight globally is constantly at approximately 75%". Rail and inland waterways transport represent only 17% and 6% of the total inland freight transported in 2020 (Eurostat, 2021). However, a remarkably higher share of freight carried by inland waterways can be observed at the country level in the Netherlands, Romania, Germany, Belgium, and Bulgaria due to access to quality river systems with good infrastructures. Aside from central Europe (Danube River), where considerable freight is transported via waterways, the hinterland reaches some north-western European seaports like Rotterdam, Hamburg, Antwerp, and Marseilles-Fos-Sur-Mer via good waterway connectivity. Connectivity is well-developed, with waterborne transport into the logistic chain (Kotoswska et al. (2018); Barrow et al., 2022). Although cargo transported by road is considered essential for economic development, it has also been widely recognised as a highly unsustainable form of transportation due to its danger to human health and high external costs caused by air pollution and congestion (Beila and Putz, 2023). With worldwide concerns about environmental issues and global warming, logistics services providers are now paying more attention to the negative externalities of their operations activities. These negative externalities include some of the following:

- Environmental pollution (Grondys, 2018; Vichova et al., 2021; Paddeu and Denby, 2022).
- The unsustainable and already congested road network (Pasidis, 2019; Nugmanova et al. 2019; Li and Lansenby, 2022).

- Traffic safety (road accidents result in many fatalities) (Wegman, 2017; Russo and Comi, 2017; Olmez et al., 2021).
- Risk of climate change (atmospheric changes and climate disruptions) (Moretti and Loprencipe, 2018; Wang et al., 2020; Mulholland and Feyen, 2021)
- Deterioration of land use (Colonna et al., 2012; Eckersten and Balfors 2023; Alipour and Dia, 2023).
- Noise pollution (Wrótny and Bohatkiewicz, 2021; Jephcote et al., 2023; Welch et al., 2023).

Sustainability has become a significant drive to promote the use of inland waterways for freight transportation. The decongestion and decarbonisation of the sectors require sustainable transport policies. Until recently, transport policies and linked investments in Europe were often more focused on road and rail transportation. To meet these challenges and issues, shifting freight from roadways to waterborne transport has become a key route to a sustainable transport sector. European transport policy in recent years has made remarkable efforts. However, globally, shifting freight from road transport to inland waterways is supported by an increased number of priority projects primarily financed by institutions keen to develop waterways for freight transportation and are often focused on developing the frameworks necessary for modal shift. European policymakers have taken several measures and established policies on the critical issues of improving the economic and environmental performance of the IWT industry, including:

- Proposal, policies, and promotion of sustainable IWT in Europe (PLATINA I-III and the NAIADES I -III)
- Regional policy for better use of inland navigation to relieve heavily congested transport corridors
- Research and best practices to improve technical, economic performance, environmental issues, and transport safety
- Robust pre-normative research and innovation-rewarding legislation
- Support through cohesion funds and cohesion instruments of the European Regional Development Fund (ERDF) and by a financial institution by means provided for developing the TEN-T
- Supporting freight transportation on waterways through other funding and financing programmes Connecting European Facility (CEF), Horizon2020, and the EU structural and investment funds. (Funding of projects with advanced plans to eliminate bottlenecks)

- Research on the introduction of modern concepts, advance information and communication technologies, cooperation, and information exchange to improve the performance of IWT through better cooperation between national authorities and improved information exchange between authorities and transport users
- Other local financial funding and policy supported by the national government of a few European countries (Netherlands, Belgium, France, and Germany) to help develop the use of waterborne transport as a viable hinterland transport mode connected to their major gateway ports

Compared with other land-based modes of transport, IWT is sustainable considering its energy consumption, gas emissions and traffic congestion, as explained in the EU NAIADES II program 2014 roadmap. With numerous European firms looking to boost their green credentials, inland navigation and river-sea shipping can play a vital role and offer positive results. However, with its spare network capacity, the waterway industry must enhance its service quality to further gain from the growing European demands for transport. The general preference for road freight transportation and its market share in Europe is due to its quality services, flexibility, reliability, planning ability and operational traceability. The underlying reason for the failure of inland shipping to meet the overall customers' requirements is unsatisfactory service quality, which is one of the main reasons this transport mode has little relevance in the modal split (Machairs and Nocera 2019). Although several factors determine the competitiveness of inland IWT, to a large extent, the competitiveness of inland shipping depends on waterway infrastructure standards. One of the basic requirements to enable the seamless integration of inland navigation into modern industrial supply chains is the availability of infrastructure connecting economic regions. The existence of waterways routes and their sufficient capacity alone cannot guarantee the successful operation of the transport sector, but it also needs to offer high quality.

In an era of an increase in the significance of sustainable transport, the use of inland navigation as a sustainable alternative mode of transport at major European gateway ports is growing. Due to emerging IWT markets in the EU, some member states have adequate administrative structures for inland navigation. Another contributing factor influencing utilisation of this transport mode is its political importance (through - economic geography and the infrastructure of waterway). In countries like the Netherlands, Belgium and Germany, several actions at the national level have resulted in establishing an institutional and strategic framework for inland navigation as a supportive alternative transport network. IWT corridors linked to these major European gateway ports have contributed considerably to maintaining and keeping the main port accessible.

5.4 Identification and classification of performance indicators of inland waterway transport and logistics

The primary task usually carried out when a sector's performance is under critical observation or examination is to reach a consensus on indicator choice. As a rule, productivity/efficiency and price change are among the first indicators that economists usually look out for when assessing a sector (OECD, 2002). On the other hand, others are more inclined towards financial returns (i.e., financial analysts), security and safety, or environmental performance. Thus, all of the indicators mentioned above appeared to be valid. When a singular or precise indicator is being determined as a choice among other elements, the stated objectives and data availability are paramount. However, the selection of possible indicators set in the transportation industry can be immense. To deal with such situations in the transport sector is to ensure that the objective of the benchmarking practices is clear to the analysts. The second order of business is to ensure the chosen indicator's availability and reliability. The choice of potential indicators should not be based on data collection alone but, preferably what is that essential is the selection represents the likelihood or possibility of being able to deliver the most precise and useful information regarding the status of the observed practices (Yun et al., 2011). Litman (2007) proposed that transport indicators should be accessible, transparent, straightforward, scientifically sound, verifiable, and reproducible.

Inland shipping has always remained the mainstay of maritime transportation and has played a significant role in global and domestic freight flows. The IWT system has become one of the primary modes of freight transportation from European gateway seaports due to the rapid advancement of the global supply chain (Weigmans et al., 2014). The performance measurement of inland waterways transport and logistics is quite complex, due to the various components and their operational activities, ranging from economic to technical and environmental sustainability. This research chapter aims to develop a comprehensive set of IWT performance indicators, measurement tools, identification, and classification strategies within the context of inland waterway transport and logistics for benchmarking purposes (Bozuwa et al., 2012) and assist businesses and agencies in identifying possible barriers to performance improvement. The method applied in the benchmarking includes examining practical and established metrics where practical applications are explained as the processes utilised, and the resulting institution practices as quantified metrics (Suita et al., 2020).

According to OECD (2002), the use of indicators remains not only essential in highlighting key issues and objectives for sustainable growth alone but also helps firms to have a clear idea of how their business practices affect their efficiency and competitiveness as well as a broader objective for the environment, society, and economy. Thus, IWT performance indicators that sufficiently reflect the actual condition of the modern industrial supply chain are captured and modelled.

Developing suitable performance indicators constitutes a detailed transport system model, and an appropriate performance measurement system for all categories of inland waterways within the research setting. Within this approach, the system consists of the following.

- A structured mapping to capture all the physical and operational processes involved in freight transportation on waterways
- The physical waterway infrastructure components and other related infrastructure needed for a successful freight movement
- Available resources (fleet, vehicles, ICT, and human resources)
- Safety, security, and traffic conditions impacting the transport performance
- Stakeholders and roles (various categories of actors relating to IWT)

5.5. A strategic indicator-based approach with relevant industrial stakeholders involved in inland waterway freight transportation to explore and confirm the indicators and sub-indicators derived from literature support and secondary data – an industrial case study approach

The planning, execution, and control of IWT at the national, regional, and international levels involves various stakeholders. This diversity of stakeholders plays a critical role differently in the transport and logistics processes. The transport system exhibits a high degree of complexity due to the numerous and diverse stakeholders influencing its performance due to their decision-making processes. De Blic et al. (2020) categorise groups as the potential stakeholders involved in the transport chain. De Blic et al. (2020) re-grouped the stakeholders into four different classes, as Wagenaar proposed earlier in 1992.

- Commercial group – shipper, consignee
- Organising group – forwarders
- Physical group – pre-carrier operators, terminal operators, and their links to other modalities, stevedore’s companies, barge operators/skipper
- Authorising group – customs, port authority and inspectorates

These various stakeholder groups generally influence, promote, and initiate the different processes involved in IWT. To understand the multiple processes involved in assessing the significant components of the system for benchmarking, a comprehensive overview of academic literature associated with different aspects of IWT was carried out. An initial version of a complete list of popular and underrepresented indicators that influence IWT performance from previous from was identified and prioritised previous studies. Vital data are often converted into practical or applicable information to assist policymakers in decision-making processes (Balanchandra and Reddy, 2013). In this way, indicators can facilitate a complicated and extensive information base. Thus, indicators help present a “synthesis” view of an existing situation (Isoraite, 2005; Balanchandra and Reddy, 2013).

Accurate and time-sensitive information helps stakeholders improve decision-making processes (Posset et al., 2009; Specht et al., 2020). The approach used by this present study for the selections of criteria used for structuring the individual indicators includes elements which are established based on facts instead of intuition. Factors considered include transparency, robustness, scientifically proven evidence, quality, and to a certain degree, which of these are interrelated. Primarily, the measures are planned for stakeholders to understand the indicators easily. The evaluators consulted assessed the significance of each indicator in the current IWT freight industry as a pre-testing measure before carefully designing a survey questionnaire based on their input. However, various regions are influenced by their geographical infrastructure constraint (e.g., bottlenecks and missing links). It is essential to Include all the system elements when assessing the IWT system. Identifying the most critical factors when evaluating and benchmarking IWT with other regions or countries is key to comprehending the transport network’s perception.

Mobility and Reliability (MR)

Mobility is an essential resource since it involves moving people, goods, and services between different socio-spatial environments. Undoubtedly, mobility is significantly affected by the accessibility of all kinds of transport. Meeting society’s needs to access transportation, move people, trade, and establish a relationship with other regions is considered an essential factor in how effectively the transport system functions (Bell and Morse, 2008). *“Mobility”* is related to the ability to move people and goods from one place to another, whilst “Reliability” relates to the degree of certainty and predictability of travel times on a transport network. Inland navigation provides an advantage in terms of *Reliability* because it does not suffer from congestion problems that currently restrict road and rail. Although some unpredicted traffic constraints occur due to ice, accident, floods, and low waters, especially in Western and South-Eastern Europe it is increasingly recognised that IWT represent a reliable mode of transport (Christodoulou et al., 2020). The performance *indicators "Mobility and Reliability"* entail sub-indicators of *Transit time (MR1). Transit time (MR1)* – is an essential criterion in factors influencing mode choice (Brogan et al., 2013; Tafidis et al., 2017; Bury et al., 2017). Shippers and logistics providers consider time a critical factor when purchasing freight transport services, especially for just-in-time logistics operations, which mainly depend on timely and predictable freight. In inland navigation, a vessel's time in different ports (including waiting times by dockside before loading and after unloading on the way to its destination is referred to as transit time, trip time or waiting time. The second sub-indicator under this dimension is *Navigability (MR2).* Navigable waterways are transport corridors connecting inland ports with the global supply chain. When waterways are not dredging, inland barges have to carry a lighter load. Dredging the inland waterway route becomes very important for inland ports when the minimum fairway parameters are not achieved to maintain the desired water depth in their channels. To a large extent, the depth of water availability in the fairway determines the number of tons of goods inland barges can carry at a particular time. Fairway depths and widths are thus, considered critical for freight movement on waterways as they also influence their competitiveness (Sorin, 2016; Beyer, 2018).

Another important sub-indicator identified under this dimension is *Availability and access to multimodal transport information (MR3).* The utmost goal of most freight transportation is "access" - shippers ability to reach the desired location with goods, services, and activities. Continuous information on the current status of the fairway, infrastructures and port services to transport users is weighted significantly. A lack and of availability or transparency in the flow of freight information make it highly challenging to plan, thus hampering the success of multimodal hinterland transportation (Punzo et al., 2022).

The fourth sub-indicator in this dimension is he *Carriage capacity (MR4).* One of the inherent advantages of inland navigation is its cargo capacity. For example, one modern inland waterway vessel (length: 110m, width: 11.45m) can replace 150 trucks (Leijer et al., 2015). Abnormal and oversized cargo traffic makes road freight unreliable but may be suitable for shipment via waterways (Zolfaghari et al., 2020).

Handling performance (MR5) is related to how the transport system responds to the many demands of the shipper and logistics services providers. The transportation market operates in response to the shippers' needs and handling is considered one of the significant aspects of performance (Brogan et al., 2013).

The sub-indicator under this dimension is the *Quality level of traffic services (MR6)*, which can easily be summarised as traffic-based measurements, which include various aspects of the number of barge trips, traffic speed, and the level of services provided by the waterway. (Nanxi and Kum, 2022).

The last vital sub-indicator identified under this category is the *Availability of transport infrastructure such as river ports and multimodal connectivity (MR7).* River ports are crucial in IWT, serving as operational and logistical hubs for efficient goods movement and connecting various modes of transportation (Zhuang et al. 2023). They handle transhipment, cargo and customs clearance and facilitate economic expansion. Ports that function efficiently reduce congestion, waiting times, and operational costs, promoting regional development and economic growth, while poor conditions can result in delays and higher costs (Maslennikov, 2021; Notteboom et al., 2020).

<u>Efficiency and Profitability (EP2)</u>

An *Efficient* freight transport system makes it possible to reduce time, cost and energy use while moving freight from origin to destination. Freight transport efficiency is essential because it significantly affects several economic and environmental factors (Bell and Morse, 2008; Wang et al., 2020). Freight transportation by inland barge is considered *Profitable* at a distance of 60km, and some intermodal terminals are situated within 15km of the major gateway and logistics port (Gobebiowski, 2016).

The sub-indicator *Total cost and expense of river freight (EP8)* indicates one of the most significant factors in decision making among modes of transport. Researchers have included cost as a criterion influencing modal choice decision-making since the 1970s (Dial, 1979; Bu and Nachtmann, 2020). This criterion can be taken to indicate transportation and logistics cost, length of haul and in-transit carrying cost, risk mitigation or compliance cost and any other resulting from the movement of the freight. Using inland waterways for freight movement offers value to customers because of its efficient operations and low cost. However, as the unit cost decreases over a long distance (Karttunen et al., 2012; Wiegmans and Konings, 2015).

The sub-indicator *Energy efficiency (EP9):* is used to denote an aspect of an eco-efficient transport system for economic and environmental sustainability. *Energy efficiency* issues arise when considering the distance that a given route covers. In Europe, freight transport by inland waterway contributes to the goal of the low-carbon economy as set out in the EU's Transport Policy White Paper (European Commission, 2011; Kalajdzic et al., 2022). As the most energy and carbon-efficient transport, for most bulk transport operations, inland barges can transport one tonne of cargo for almost one to two times less than rail and three to four times less than an HGV using the same energy consumption (Santén et al., 2021). One of the reasons for its energy efficiency is that the barge utilises the natural flow of water with its engine power to provide effective propulsion. However, this mode of transport has experienced a decrease in both the utilisation and fuel efficiency over the past decades (Rogerson et al., 2020; Golaka et al., 2022).

Another sub-indicator is the *Attractiveness of the transport system (EP10):* The transport systems efficiency in terms of safety, reliability, affordable cost, and environmental friendliness remains the primary asset of the transport sector (Martinez-Moya, and Feo-Valero, 2020; Prus and Sikora, 2021).The inland navigation system's effectiveness and efficiency contribute substantially to its competitiveness and attractiveness. To a large extent, this contributes to the economic well-being of a country (Karttunen et al., 2012). *Price alternative (EP11) (e.g., road and rail):* In transport sourcing and mode choice decisions, the price has a significant impact. Price is a primary consideration for shippers when buying freight transport services and economists measure the change in modal demand as a change in freight transport prices (Borgan et al., 2013). Scientific research studies confirm prices remain a primary criterion in decision-making for modes choice (Danielis and Marcucci, 2007; Bergantino et al., 2013; Brusselaers and Momens (2022). Economies of scale are more significant and more to attainable in inland navigation than rail and more competitive in cost performance compared to road transport (Caris et al., 2014).

Transhipment cost in seaport (EP12) refers to the charges incurred during cargo switching between modes of transportation inside the port areas, including handling charges, storage fees, labour, port dues, equipment, and administrative expenses (Matsuda et al., 2020). Understanding transhipment costs is crucial for efficient supply chain management and ensuring seamless transportation through seaports, ensuring smooth flow from origin to market (Bu and Nachtmann, 2020).

Environmental Impact and Decarbonisation (ED)

The freight transport industry is essential to a country or region's economy. Previous research has identified the sector as an indicator of economic welfare and success (Ali et al., 2018). Sadly, the environment is negatively impacted by the activities of the freight transportation industry in terms of emissions caused particularly by road transport using fossil fuels. *Environmental impact and decarbonisation (ED)* relate to environmental considerations and the negative consequences of freight transportation in terms of atmospheric change, climate disruption, noise, and health risks. The transport sector is accountable for around a quarter of GHG emissions in both the UK and EU because most trucks operate on diesel engines, which are significant sources of emissions, i.e., carbon dioxide (CO_2), nitrogen oxide (N_2O) and particulate matter (PM) (Eurostat, 2023; Department for Transport, 2020; Grosso et al., 2021). Compared with other modes of transportation, inland navigation is the most environmentally friendly in terms of its energy consumption and gas emissions. However, the sector will lose a comparative environmental advantage to road transport if no significant actions are made to reduce air pollution further (Bouckaert, 2016; Barrow et al., 2022).

The sub-indicator *Emission reduction (ED13)* is concerned with environmental pollution from burning fossil fuels which causes atmospheric changes, and climate disruption which is recognised and perceived as harmful to both the natural and built environments and public health (Rigo et al., 2007; Christodoulou et al., 2020; Mako et al., 2021). Global concern about climate change and the environment has led many shippers and logistics services providers to pay more attention to their operations' negative externalities. Environmental performance is considered critical when assessing gateway port sustainability using different transport modes. Alternative freight transport systems like river-sea shipping are considered sustainable since it can offer green transport. (Barrow et al., 2022).

The sub-indicator *Renewable and alternative energy (ED14)* is concerned with low carbon solutions to the existing state of transport by greening fleets, using alternative fuels to reduce pollution, and energy consumption reducing the carbon footprint and air pollutant emissions (Kortsari et al., 2022). Using alternative fuels for inland barges along a major logistics gateway corridor has proven to reduce local air pollution whilst contributing to a greener IWT (EIBIP, 2018). The sub-indicator explores the viability of low carbon and renewable energies and considers the economic, environmental, and socio-economic benefits.

In Europe, the environmental argument has strongly favoured the utilisation of inland navigation along gateway ports as an alternative freight transport system, especially for the significant reductions in CO_2 and NO_x. *Emission reduction funding (ED15)* is concerned with promoting and encouraging businesses along the logistics gateway to become greener by reducing their emissions such as by funding new technologies, including hybrid marine engines (Camarago-Diaz et al., 2022). From the transportation and users' perspective the financial support instruments in place are needed for investment, and adequate incentive funds (made available by local/national authorities, government, and even private sector) available to the general public for the promotion and encouragement of freight transport, are also essential elements.

Similar to this is the sub-indicator *Enforcement/Monitoring (ED16),* which is concerned with compliance with the relevant aspects of the legislation across the sector as well as transport users, involving both safety-related and non-safety-related (Xing et al., 2013; Wang et al., 2020). Also, the sub-indicator *Noise (ED17)* is a critical sub-indicator in assessing the ecological efficiency of transport systems related to pollutant and noise emissions. The transport industry is the most significant source of air and noise pollution in the EU and the UK. The undesirable effects of transport operation are degradation of health and the environment (Grey et al. (2021). Under this sub-indicator, the assessment aims to define the costs of counteracting the adverse effects of its transport operations connected with this gateway port. Although the majority of the total external costs of transport are associated with road transportation, the inclusion of the expenses of negative influence is usually assumed or claimed to be a factor in developing a transport system conforming to environmental and health aspects (Marianna et al., 2017).

Infrastructure Condition (IC)

Infrastructure Condition (IC) remains a crucial indicator for transport users. Infrastructure standards and quality define the level of gateway accessibility since freight gateways are inherently dependent on the quality of their infrastructure to ensure efficiency. The efficiency and competitiveness of inland navigation are influenced by sufficient quality infrastructure at critical parts of the transport network. The maintenance/availability of infrastructure according to the demand at competitive prices directly influence its users in various ways. The sub-indicator *Connectivity (C18)* (road and rail interchange) is a significant prerequisite that shows quality infrastructure with reliable and well-connected intermodal links ensuring a good transport status. Transport links (i.e., waterway and rail) associated with the gateway port must be good, as well as the quality of the transfer options. (Hossain et al., 2019).

Another important sub-indicator in this dimension is *Transhipment facilities for integration (IC19);* these indicators are considered critically important as they play a vital role in freight handling, enabling smooth transfer within and between modes, as well as the flow of logistical activity and port performance. Cargo transfer at an intermodal exchange by modern and efficient transhipment facilities keeps up the quality of the network, thus attracting more users (Saeedi et al. (2022). The availability of infrastructure services and information streams is considered essential for integration into the multimodal logistic chain. Efficient intermodal transhipment facilities and terminals allow seamless road, rail, and waterborne transport integration according to the rhythm of the transport demand (Totakura et al., 2022).

Modern fleets for competitiveness (CI20) are a valuable indicator which shows the development and modernisation of the inland fleet for freight transport. This sub-indicator explores the increasing involvement of inland navigation in the multimodal transport chain by making the fleets more competitive, improving environmental performance, flexible operation and secure in the context of the multimodal transport chain by modernising the fleets (Hassel and Rashed, 2020).

Similarly, *Congestion-free transport system (IC21)* refers to the weighted sum of delays over representative transport corridors connected to the gateway port. It represents an element of the transport system's reliability on a particular freight gateway. Although IWT is slower than road and rail, it is generally acknowledged that inland navigation is a safe, reliable, and environmentally friendly mode of transport compared to other land-based transport, confronted with congestion (Konings, 2003; Alias et al., 2022). Thus, there is a significant capacity for increased exploitation.

Waterway infrastructure maintenance is considered vital to ensure a competitive transport system. *Infrastructure maintenance (IC22)* relates to preserving the existing transport network. This sub-indicator is considered a critical indicator of productivity (Vidal and López-Mesa, 2006; OECD, 2022), enhancing affordable and equitable market access for all while providing balanced regional economic development, promoting adequate mobility, and connecting transport corridors to gateway ports. To a large extent, the competitiveness of a transport system depends on infrastructure standards and maintenance (Beyer, 2018). As IWT is often border-crossing or multi-corridor transport, the weakest stretch of the route dramatically affects its overall competitiveness. Infrastructural quality has direct effects on the cost-efficiency and service quality of IWT. Fairway conditions and bottlenecks directly influence the degree of barge movement, load factors and service quality, such as the delivery speed and time reliability (Siedl and Schweighofer, 2014). Infrastructure maintenance is a significant prerequisite to ensuring a competitive transport system along the corridor.

Limited geographical expansion (IC23) denotes the natural spatial distribution and route directions of the inland waterways. To a significant degree, navigable waterways routes are mostly associated with a limited geographical scope. Naturally navigable rivers and their estuaries are mostly not interconnected, save for the tributaries. Making waterway routes navigable and building links via artificial watercourse networks (canals and locks) has huge financial implications (Defryna et al., 2021). The main cargo flow is often not covered by the available transport network; thus, costs arise for trans-loading and transfer from one mode (IWT) to other modes. Therefore, inland waterways are almost always singular routes. In the event of transport disruption along the main routes (bad weather conditions, accidents and extremely low or high waterway levels), alternative vessel transport routes are very unusual, significantly impacting the reliability of transport (Department for Transport, 2004; Zolfaghari et al., 2020).

The sub-indicator *Spatial planning (IC24)* The process entails strategically allowing resources and infrastructure to enable effective and sustainable distribution of goods. This involves recognising important freight routes, creating logistics centres, and enforcing regulations to control truck movement and minimise traffic congestion (Konings, 2003; Totakura et al., 2022).

Safety and Security (SS)

For freight transportation systems, the *Safety and Security (SS)* of a supply chain between origin and destination are paramount (Yu et al., 2020). The sub-indicator *Traffic condition (SS25)* is usually the amount of traffic a particular mode or route can carry. In the freight transportation industry, traffic congestion can have far-reaching, direct, and indirect effects on economic productivity and growth (Posset et al., 2009). Congestion issues can arise when carriers' demand higher prices from shippers because systems are near capacity, leading to increased travel time and fuel cost. Traffic conditions and transit speed remain essential considerations for transport users buying freight transportation services (Restrepo-Arias et al., 2022).

A similar sub-indicator in this dimension is *Navigation safety and route capacity (SS26);* safety is one of the main assets of waterborne transport. Safety of navigation on inland waterways is exceptionally high, partly due to moderately low traffic density compared with other surface transport types. Safety measures and practices taken by carriers to protect cargo from possible danger, including fire, grounding, fatalities, collisions, and accidents resulting from transportation shipment from origin to destination (Martin et al., 2004; Maras, 2008; Camp et al., 2010). This benefit is significant for barges carrying hazardous goods in large quantities for which safety is a priority. The measure of quality is the extent of safety margins, customer satisfaction with a product's characteristics (safety) and the characteristic features that make of a route suitable for shipment (e.g., physical facilities available to meet the shipper's needs). Good safety records add to the overall reliability of inland navigation for transport users (Vidan et al., 2012).

Vessel Identification (SS27) is concerned with detailed information on the location of vehicles and goods and accurate information on traffic and infrastructure conditions along the transport corridor. It refers to system-wide vessel identification within a precise waterway transport route

(Durajczyk and Piotr, 2022). EU has played an essential role in inland shipping information for navigation and operation, especially in Smart fairways and the RIS corridor management concept. A vital system for the case of inland navigation is the RIS, which gives harmonised and standardised information exchange based on AIS, comparable to that used by commercial ocean-going ships (Asborno et al., 2022). Another important sub-indicator is *Seaworthiness (SS28);* this indicates the vessel's condition and whether it is safe to sail. An inland barge or vessel must have the required degree of fitness for navigation in all respects at the commencement of her sail regarding all its probable circumstances (Meersman et al., 2020). Unlike other modes of transport like road, where minor errors can easily be adjusted, a centimetre of dissimilarity in the construction of inland barges can have devastating consequences (Jagannath, 2014). The issue of vessel seaworthiness is considered an essential element to guarantee safe passage and goods carriage through gateway ports (Dorsser et al., 2020).

The sub-indicator *Weather forecast (SS29)* usually represents seasonal weather conditions (low and high-water occurrence, movable and unmovable ice, windy weather, reduced visibility). In transport mode selection, the seasonal influence of weather conditions is very significant (Beuthe et al., 2014). Various weather phenomena influence navigation performance, which is significantly influenced by water level. Critical weather phenomena, like low and high water are phenomena with a significant influence on vessel speed (Schweighofer, 2014). In general, seasonal changes in weather conditions (e.g., dry season resulting in low water) influence travel time through the water level. Navigation operation along waterway transport corridors, including vessel speed, can differ dramatically according to the current water level, thus affecting fuel consumption. During navigation, a need suspension can sometimes arise due to high water conditions along transport routes which change the river’s morphology. Navigating some transport corridors may be subject to the current weather and hydrology conditions, which are very challenging to overcome even at relatively high costs (Radmilovic and Dragovic, 2007; Christodoulou et al., 2020). The cost-effectiveness and reliability of inland shipping may be unavoidably reduced due to severe weather outbreaks.

Innovative Transport Technology (ITT)

The emergence of Intelligent Transportation Systems (ITS) has paved the way for new innovative possibilities for improving the transportation system's safety, operation, and environmental impact. *Innovative Transport Technology (ITT)* focuses on successfully creating and implementing a new product, method, service, market, or any part of the existing operation to improve the present performance level. In the transport industry, changes such as innovation are driven explicitly by the supply conditions, such as innovation (Wiegmans, 2018).

The sub-indicator *Information and communication flow along the supply chain (IT30)* (Data exchange) is the performance attribute related to information exchange between authorities, shippers, and other transport users (Specht et al., 2020). This includes information from transport flows where flows and data are inextricably connected. However, among all the inland modes of transportation (road, rail, IWT), the overall innovation rate for IWT is low. The success of multimodal hinterland transport is hampered by lack of information exchange and collaborative planning results leading to long waiting times for barges at the seaport (Durajczyk and Piotr, 2022). Information and communication flow along the supply chain has an enormous influence on IWT freight transportation. These services increase navigation safety and improve the transport system's efficiency, reliability, and scheduling.

Shoreside data availability (AIS coverage) (IT31) is a vital sub-indicator that refers to the availability of a high-performance ICT infrastructure along the waterway route for stable and permanent data exchange (Restrepo-Arias et al., 2022). Another sub-indicator under this dimension is *Hierarchical tracking and tracing of data at the logistics unit level (IT32).* It indicates the ability to trace and track product information regarding the transaction (order, shipment, payment) and location (warehouse, traffic, inventory) through all freight shipments from origin to destination) (Asborno et al., 2022). One key element for modal transport shift is to improve cooperation between all stakeholders, including supply chain actors and public administrators enabling them to share their resources, bundle their transport volumes and synchronise their operations. Monitoring vessel operations, locations, and status along the transport corridor significantly boost the profitability and productivity fleet (route planning, reallocating fleet units if needed) (Specht et al., 2020). On the other hand, cargo tracking improves customer service with real-time tracking, location status and better-planned routes if needed.

The sub-indicator *Interoperability with customer systems (IT33),* explores the digitalisation and better integration of the transport system into the multimodal supply chain (Razak et al., 2021). The inland transport industry can provide unrestricted access and competitive services through Interoperability. The RIS facilitates standardised information exchanges for collaboration and cooperation between administrators and businesses, fully covering transport operations so that they can be optimised for inland navigation, enabling the creation and the efficient operation of intermodal logistics chains (Durajczyk and Piotr., 2022). In the IWT sector, implementing RIS in an efficient, expandable, and interoperable manner provides an interface with transport management systems and other commercial activities. Also, the sub-indicator

Voyage planning (IT34) is a vital sub-indicator under this dimension, indicating the ability to plan. Route and voyage planning and traffic management are critically important to support transport corridor management (Meersman et al., 2020; Niedzielski, 2022).

Tracking and tracing are considered crucial aspects of supply chain management (Liao et al., 2020; Li et al., 2022). The sub-indicator *tracking and tracing based on the GS1/EPCIS (IT35)* systems deals with improving IWT efficiency by utilising GS1 standard, EPCIS and a data model, enhancing monitoring tracing, real-time monitoring and supply chain management, thus increasing operational efficiency and resolving interoperability concerns (Niedzielski, 2022). Other sub-indicators identified in this category include the *RIS and VTS services (IT36),* which are essential metrics for evaluating IWT performance (Baldauf et al., 2020). The RIS system offers up-to-date information on the current state of waterways, weather conditions, and the position of vessels (Mekkaoui et al., 2023). On the other hand, the VTS system ensures the safe passage of vessels by providing traffic management services (Zhang et al., 2023). They assist stakeholders in making decisions, promote the exchange of information, and ensure the efficient execution of transportation procedures (Shakhnova et al., 2023).

Economic Development (ED)

The freight transportation industry is a crucial driver of economic growth and development. It is a vital indicator of the status of the economy. *Economic Development (ED)* is concerned with the gross value of the sector and the labour market. The *Aggregate added value (E37),* concept in transportation refers to the economic benefits and improvement attained by incorporating value-added activities and services, encompassing cost-effectiveness, efficiency, productivity, reliability, and customer satisfaction. Thus, these metrics give an insight into the overall competitiveness and attractiveness of the sector (Dinu et al., 2016; Hernández, 2022).

The sub-indicator *Development (ED 38)* (regional and local) is a valuable dimension that gives an insight into the overall competitiveness and attractiveness of IWT. It has the potential to bring new jobs and welfare to the region, resulting in a better multimodal network, thus, increasing the region's attractiveness (Mihic et al., 2012). As transportation has been identified as crucial to economic progress (Lenz et al., 2018; Šev˘ceko-Kozlovska and Cižiuniene, 2022), IWT has significantly contributed to economic growth and development in the regions it serves (Plotnikova et al., 2022).

Employment (direct and indirect) (E39) indicates the quality of employment directly and indirectly quality generated in a particular region during a specific period. The added value created from employment significantly impacts the overall performance of the country's economic development (Vidan et al., 2012; Tournave, 2022).

The sub-indicator *Marketing (ED40)* included social marketing and initiatives, e.g., customer information to promote climate-friendly purchase decisions. In the context of IWT, marketing entails recognising and comprehending the requirements and desires of clients in the industry, devising strategies to fulfil those demands, and efficiently advertising and selling services to specific audiences (Grzelakowski, 2019). With firms looking to boost "green credentials", inland navigation can offer positive results in terms of public and customer perception.

Policy Formulation and Implementation (PFI)

This indicator relates to creating and implementing specific rules, regulations, priorities, funding, and action programmes issued explicitly by a national, regional, or local political decision. In the transportation industry, a set of strategic planning measures aimed at the future developments of the transport system is usually referred to as a "Transport Masterplan", a long-term strategy with the overall target of creating a sustainable transport system (Mihic et al., 2012).

The first sub-indicator under this dimension is *administrative support for modal shift to inland waterways (PI 41).* This indicates that desired acceleration in achieving a modal shift to IWT requires administrative support, of which a financial support instrument is vital (Santen et al. (2021). Another sub-indicator is *Existing legislative framework for modal shift inland waterways (PI42) -* Shifting freight from the road to river-sea shipping is crucial to a sustainable transport sector. An increasing number of international and national projects often support the modal shift to IWT globally, supported by creating a framework necessary for shifting freight. At the European level, the EU has implemented several successful programs to promote and support the utilisation of IWT and intermodal transport in the supply chain (Mihic et al., 2011; Grzelakowski (2019).

Major logistic gateway ports with suitable inland waterway connectivity can be active in moderating and marketing projects, especially for containerisation on waterways and stimulation of a modal shift through *Incentives and grants (PI43).* The incentives and grants are designed to promote, encourage, and support the modal shift to IWT to generate environmental and broader social benefits. Although shifting freight from road to waterways can sometimes be costly, setting incentives and grants is intended to offset the additional costs of switching to a more environmentally friendly mode of freight transport (Kruse et al., 2014; Department for Transport, 2020). The drive is to seek time-limited support for the inception of new services involving quality of service, improved vessel specification, vessel sailing time, increased capacity, frequency of sailing, and voyage time, which enhances its competitiveness.

In the transportation industry, operators are keen to know how their performance corresponds to other companies operating similar activities. In an era of global competitiveness, environmental sustainability and social concerns, companies are increasingly interested in identifying, adopting, and implementing *Knowledge transfer and "best practices" (PI44).* This sub-indicator explores and compares the relative efficiency of a given sector to that of a reference sector. Good practice from market leaders is takes on increasing importance in the competitive market. The relative performance of transportation (cost, reliability, flexibility, service quality and transit time) are among the significant and essential considerations influencing the shippers' choice of transport services (Vidan et al., 2012; Santen et al., 2021).

The sub-indicator *Logistic clusters formulation and collaboration (PI45)* is concerned with interconnected geographical clusters of firms in the same industry that compete and cooperate, offering various services along this gateway, including logistics services and functions and logistics-intensive operations. Collaboration and value-added services are vital for firms situated within logistics clusters (Rivera et al., 2016).

Education and skill development is another vital sub-indicator under this category. By augmentation of technical knowledge, personnel can attain the requisite proficiency to handle and oversee the IWT network and manage logistics efficiently (Turcanu et al., 2021). Education and skill development (PI46) are essential for the progress of IWT. Education provides individuals with specialised knowledge, whereas skill development fosters cultivating leadership ability, safety consciousness and environmental awareness (Pyzhova et al., 2021; Turcanu et al., 2021). Effective initiative ensures a competent workforce, promoting sustainable practices and adjusting to changing patterns (Nguyen and Nguyen, 2020).

Integrated transport policy entails the synchronised and unified strategy for organising, executing, and overseeing various transport modes within an interconnected system (Bruzzone et al., 2021). The sub-indicator *Integrated transport policy* (PI47) is crucial in the context of IWT since it is vital in effectively managing and improving the performance of IWT through a comprehensive approach (Solomon et al., 2020). It involves coordinating various aspects, such as infrastructure planning and policy measures, to improve efficiency, safety, and sustainability. The goal is to optimise resource utilisation, reduce congestion, and minimise environmental impact (Barrow et al., 2022).

Achieving overall success in the IWT and logistic sector, primarily to a large extent, depends on the ability of necessary parties to coordinate effectively and collaborate towards shared goals (Rogerson et al., 2020). Enhancing the performance of IWT requires essential *cooperation and coordination (PI48)* among diverse stakeholders, such as shipping firms, port authorities, government agencies and industry groups (Kotowska et al., 2018). This involves sharing resources, best practices, and knowledge, implementing standardised procedures, identifying risks and expertise, leading to innovative solutions and fostering trust and transparency (Ilchenko et al., 2021). Collaboration additionally strengthens the sectors; bargaining power (Roso et al., 2020). Table 5.1 summarises all the performance indicators and sub-indicators and their target areas identified in the literature for the present study.

Table 5-1: Performance indicators and sub-indicators used for the present study

Performance Indicator	Sub indicators	Target area
Mobility and Reliability (MR)	**(MR1)** Transit time **(MR2)** Navigability **(MR3**) Availability and access to intermodal/multimodal transport information **(MR4)** Carriage capacity **(MR5)** Handling performance (MR6) Quality level of traffic services **(MR7)** Availability of transport infrastructure such as river port and multimodal connectivity	- Catchment area – time/distance - Services delivery level
Efficiency and Profitability (EP)	**(EP8)** Total cost and expense of river freight **(EP9)** Energy efficiency **(EP10)** Attractiveness of the transport system **(EP11)** Price alternative (e.g., road and rail) **(EP12)** Transhipment cost in seaport (time-cost saving)	- Travel efficiency - Affordability and cost

Environmental Impact and Decarbonisation (ED)	**(ED13)** Emission reduction **(ED14)** Renewable and alternative energy **(ED15)** Emission reduction funding **(ED16)** Enforcement/monitoring **(ED17)** Noise	- Environmental sustainability - Public health
Infrastructure Condition (IC)	**(IC18)** Connectivity (road and rail interchange) **(IC19)** Transhipment facilities for integration **(IC20)** Modern fleets for competitiveness **(IC21)** Congestion-free transport system **(IC22)** Maintenance of infrastructure **(IC23)** Limited geographical expansion **(IC24)** Spatial planning	- Intermodal/multimodal transport chain
Safety and Security (SS)	**(SS25)** Traffic condition **(SS26)** Navigation safety and route capacity **(SS27)** Vessel identification **(SS28)** Seaworthiness **(SS29)** Weather forecast	- Safety and security Social
Innovative Transport Technology (IT)	**(IT30)** Information and communication flow along the supply chain (Data exchange) **(IT31)** Shoreside data availability (AIS coverage) **(IT32)** Hierarchical tracking and tracing of data at logistics unit level **(IT33)** Interoperability with customers systems **(IT34)** Voyage planning	- Intelligent and Innovative transport technology

	(IT35) Tracking and tracing based on GS1/EPCIS **(IT36)** RIS and VTS services	
Economic Development (ED)	**(E37)** Aggregate added value (of transportation and infrastructure) **(E38)** Development (regional and local) **(E39)** Employment (direct and indirect) **(E40)** Marketing	- Employees in certain region - Development
Policy formulation and implementation (PI)	**(PI41)** Administrative support for modal shift to inland waterways **(PI42)** Existing legislative framework for modal shift inland waterways **(PI43)** Incentives and grants for modal shift **(PI44)** Knowledge transfer and best practise **(PI45)** Logistic clusters formulation and collaboration **(PI46)** Education and skill development **(PI47)** Integrated transport policy **(PI48)** Cooperation/collaboration	- Planning policy Regional/national transport strategy

Source: Author work

5.6 Hierarchically structured model for prioritization of key performance indicators

In today's competitive world, the transport industry, especially the IWT sector, must be capable of evaluating its objectives and its subjective performance in terms of service quality and customer satisfaction while setting up suitable strategies to reach its final goals. The idea of performance assessment measurements, particularly in a dynamic and complex environment, requires selection and ranking of critical performance indicators (Haddadi and Yaghoobi, 2014). The proposed research methodology, therefore, aims to define a method of improving the quality of prioritisation key performance indicators of IWT sector. As discussed earlier in Chapter 3 of this research study, the fuzzy-AHP-TOPSIS-based methodology is employed to support this thesis's entire benchmarking framework process.

5.6.1. Proposed framework - An empirical study

In the transport industry, information for improvement and development that may lead to performance improvement has been obtained through benchmarking. The benchmarking procedure has numerous defining features that differentiate it from performance measurement. However, the whole process involved in the benchmarking technique contains the critical elements of performance measurement, including vital themes of comparison, best practice identification, adoption of these practices' procedures, and strategies for performance improvement (Dattakumar and Jagadeesh, 2003; Geelings et al., 2006). For successful benchmarking of transport operation activities, the general bases remain the actuality of a suitable methodology within the research setting where this method will apply. Closely related to these is the design of appropriate indicators that help complete benchmarking (Szendro and Torok, 2014). In this study, the performance indicators were identified at the initial phase of the benchmarking process. The key performance indicators and sub-indicators were identified and synthesised based on an in-depth literature review and consultation with academicians and industrial experts across Europe and the UK. The creation of a comprehensive set of indicators was designed which links IWT and sustainable transport networks, which includes indicators of the following dimensions environmental sustainability, economic development, social, and institutional/governance. For the best and most unsuitable indicator values across the research, the database indicators and sub-indicators would enable the development of the benchmarked performance indicator template for comparison and evaluation. The evaluation of the areas of interest within the UK (River Thames and the Manchester Ship Canal) followed, using this template while also identifying gaps and deviations from the desired status.

The preliminary assessment of performance improvement regarding IWT resulted in eight broad groups of indicators. As most successful benchmarking starts with a focused area, this study uses field testing under a pilot study to confirm the identified indicator in a limited number of the study areas using a semi-structured questionnaire technique. The eight critical attributes identified on the underlying indicators include the following: mobility and reliability, efficiency and profitability, environmental impact and decarbonisation, infrastructural condition, safety and security, innovative transport technology, economic development, policy formulation and implementation. From the identified set of indicators, the respondents were asked via a pilot study what level of importance they think should be attributed to each indicator and sub-indicator and to suggest other indicators/sub-indicators they think should be considered. The pilot testing in this study serves as a starting point for the benchmarking indicator framework to be carried out. Eight indicators were considered fundamental for this study, as shown in Table 5.1.

5.6.2. Design and pre-testing of research instruments

A questionnaire survey strategy was used for this research study. The use of a survey questionnaire has been identified by existing literature as the most suitable instrument for data collection, especially for academic research (Kothari, 2004; Dionco-Adetayo, 2011). Hence, this study utilised self-administered questionnaires in order to achieve an understanding of the perspectives of various groups. As a method for information collection, the questionnaire employed for this study was created with a written set of carefully worded questions and instructions related to the problem. The survey questionnaire was developed according to a systematic plan to explore the feasibility of the initial hierarchical structured diagram and any additional criteria yet to be identified. Thus, identifying key performance indicators and their classification was based on the expertise of the constructed group.

After acquiring the data, content validity was achieved to enhance the developed questionnaire's clarity. The procedure for questionnaire design and pilot study employed the following steps:

- Select expert panel participant for validity purposes
- Implement a pilot study to confirm the shortlisted significant indicators and the modified hierarchy model.

Firstly, the initial questionnaire and cover letter were drafted. A covering note was attached at the beginning of the questionnaire describing the study's main aims and assuring the participants of the strict confidentiality and anonymity of the data supplied in the pilot questionnaire, which is safeguarded under the Liverpool John Moores University Ethical Guidelines. For validity purposes, ethical approval from the LJMU REC committee was first obtained to validate the questionnaire content and participant consent.

The pretesting questionnaire used for primary data collection (See Appendix I) is presented after completing the pilot study. For clarity and the standard of questions asked, the initial drafted version of the questionnaire was examined by two academicians and three industry professionals who better understand the practical scenario of IWT and the associated transport policies to comment on the appropriateness of the questions.

Only individuals with at least ten years of expertise in IWT operations, IWT projects, or intermodal transport/supply chain management were chosen as participants to review the questionnaire. Geographically, the participants were drawn from IWT actors operating on and along the Danube rivers in Europe, Netherlands, Germany, the River Thames, and the MSC, representing Manchester and Liverpool's main waterway hinterland links in the UK. Participants include those involved in IWT infrastructure, port authorities, administrative staff of IWT (Canal and River Trust - the Inland Waterway Authority for the UK), and academicians. See Table 5.2 for individual participant profiles. The primary emphasis was placed on infrastructure managers, port authorities, and transport officials in order to optimise adherence to IWT business organisation requirements, transport policies and regulations. Before the pilot study was conducted, the questionnaire was revisited based on their comments and feedback.

Table 5-2: Expert Participant Profile - Participants assigned to review the questionnaire

Participant Expert	Field of Expertise	Job Title	Experience (in yrs)	Country(ies) of Operation
Expert 1	Public, private port and terminal operator/ IWT projects partner	Marine operations	33+	Danube region
Expert 2	Intermodal transport /IWT projects coordinator	Projects coordinator	20+	Netherlands, Germany, and Belgium
Expert 3	Administrative staff of IWT (inland port official)	Sustainable marine operation	17+ yrs	UK
Expert 4	Academician from intermodal background	Senior lecturer	23+ yrs	Serbia
Expert 5	Academician from IWT/intermodal transport/supply chain management background	Senior lecturer	19 yrs	UK

Source: Author work

Furthermore, the questionnaires are structured into two sections; *Section A*, labelled "experts' profile", has five variables (See Appendix III); *Section B* presents the main pretesting questionnaire and has eight variables. All sections of the questionnaire used a Likert scale. Likert Scale questions form one of the most extensively used tools for popular opinion in social and educational research. The Likert scale was devised to measure 'attitude' in a scientifically accepted and validated manner (James and Thomas, 1990; Joshi et al., 2015). Since the advent of the Likert scale in 1932, the scale has been of significant importance in research studies because it can measure the extent to which a person agrees or disagree with a particular question or statement. The seven-point Likert scale was used in this study because it offers respondents seven choices connected to an agreement that are distinct and adequate without confusion. Although different names are often given to the varying states depending on the rating a particular researcher prefers (Brown, 2010). Specifically, the Likert scale adopted for this study is in the following format: *1=Highly Unimportant; 2=Slightly Unimportant; 3=Unimportant; 4=Neutral; 5=Important; 6=Slightly Important; 7=Highly Important.*

In drafting the questionnaire, extra caution was taken to design and present the questionnaire in order to escape confusion and ambiguity. Much effort was put into designing and structuring the questionnaire to make it attractive in a way that encouraged and did not impede the respondents from answering the questions conveniently. As piloting and pretesting questionnaires are essential, procedures are needed to be conducted to ensure the questionnaire is free from any possible errors or issues. The questionnaire in this study pre-assessed the accuracy, effectiveness, and clarity of communication through a pilot study by exploring different expert panels of judges.

This study aims to represent the different domains within the IWT that contribute to the performance of the transport sector within the European context. For the expert opinion survey, the questionnaires were circulated to a wide range of experts working in IWT, logistics, and academia in the education setting. In total, nine out of the thirty expert participants participated in the feedback process (see Table 5.5). The opinions of senior professionals from consulting companies like the ST4W Interreg North-west Europe were collected through direct interviews during the ST4W study day hosted by the Port of London Authority in November 2019. Other experts were interviewed at various times following a scheduled date and time.

5.6.3 Selection of participants in the expert panel for validity purposes

5.6.2.1 Expert panel

The quality of the expert judgment is based on their proficiency, capability, experience, and knowledge. Extant literature has shown the reliability of expert judgement (Rosqvist et al., 2003; Beecham, 2005; Alvarado-Valencia et al., 2017; Bolger and Wright, 2017). This study carefully selected experts to validate the identified indicators and sub-indicators. Before recruiting the expert participants, checks were made to ensure that they had equal interest, background, and relevant experience in the given field. This validation study illustrates the conclusive stage of the first phase of the survey. The expert opinion survey was conducted to ensure that the indicators were sufficiently accurate to measure content validity. The pre-testing survey questionnaire was conducted with nine experts from both the UK and Europe. The experts comprised industry practitioners, academicians and professionals working in IWT agencies with knowledge and experience in the relevant area. (four academicians from intermodal/multimodal transport backgrounds, two UK and EU IWT project partners, one port official, one legitimising agent and one consultant specialising in the field of supply chain and intermodal transport and logistics) (See Table 5.5 for expert opinion survey participant profile).

5.6.2.2 Expert panel demographics

This study targeted experts from different backgrounds within the transport sector. Two main sets of inclusion criteria were sought to select experts participating in the opinion survey. Individuals were required with equal interest, knowledgeable background, and a wealth of experience operating intermodal inland waterways transport and supply chains. In order to identify people with these attributes, firstly, the capability and applied experience of individuals participating in the opinion survey were required to range from five to forty years. The researchers also required participants from companies likely to operate logistical services using inland waterways or individuals from companies improving the accessibility of inland waterways through innovation within the research setting.

According to Briggs's (2000) domain experience, the capability to share views, ideas, own knowledge, and concepts are features of an expert. To seek the second inclusion criterion for participating individuals, the researcher required that participants come from an academic background. Academicians with years of experience in the educational setting (PhD or

Professor) or academicians whose professional career puts them directly in contact with various industry experts, infrastructural project partners, local companies or international companies who are already involved in freight transportation via inland waterways. Individuals who met the above inclusion criteria were selected to participate in the expert opinion survey and semi-structured interview. Tables 5.3 and 5.5 present the distribution of experts participating in the semi-structured interview and the expert opinion survey participant profile, including their background, years of experience, geographical location, and knowledge of their field. All these areas of expertise are represented to ensure that in the early phase of the survey questionnaire development, the industry practitioner's wealth of experience and researcher knowledge is fed back to model development.

Initially, twenty prospective industry and academic participants were contacted to participate in the feedback process by gauging their interest in participating in the expert opinion survey. Specifically, five were from the educational setting and fifteen from the industry with proven experience in various fields. Additionally, two industry experts were interviewed face to face during the ST4W Interreg study day in November 2019, hosted by the Port of London Authority, and three other professionals were interviewed on different dates according to a scheduled date and time. Although the researcher initially contacted eleven prospective experts for the experts' opinion survey (interview), eight of them did not respond to their emails even after a follow-up reminder was sent. Only three experts responded to the researcher's email invitation and agreed to participate in the survey. In total, only five experts were interviewed (see Table 5.3 for expert profiles), and nine completed survey questionnaires were received.

Table 5-3: Expert participant profile – semi structured interview

Expert	**Field of Expertise**	**Job Title**	**Experience (in yrs)**	**Countries of Operation**
1	Intermodal IWT/ inland port terminal operator	Quarry Officer	20+	UK
2	Multimodal transport and logistics	EU Project partner	26	Belgium, France, Netherlands, and the UK
3	Intermodal transport and supply chain management	Procurement manager	20+	UK
4	IWT (canal and river trust)	Administrative officer	18	UK

5	Inland waterway transport and short sea shipping	EU Project partner (#IWTS 2.0)	15	Germany, Netherland, and the UK

Source: Author work

Gumus et al. *(*2015) posited that selecting appropriate experts helps achieve the reliability of the study. Odu (2019) corroborated this in his work by highlighting the vital influence a qualified group of panellists has on the accuracy of group judgment. The weighting attributes and suitable explanation of each participant's expert evaluation criteria used in identifying prospective respondents of the expert opinion survey are presented in Table 5.4.

Table 5-4: Experts' respondent weighting criteria

Weight Value	**Relevance Level**	**Explanation (either-or)**
20%-30%	Highly Relevant	Expert respondents have many years of experience in intermodal IWT and supply chain management and have held a top management position in freight transport and logistics activities or are industry practitioners with years of experience or project delivery promoting the use of inland navigation. In academia, the respondents have a wealth of knowledge and in-depth studies that contribute to IWT or supply chain management.
10%-19%	Fairly Relevant	Expert respondents have at least 20 years of work experience in intermodal IWT, supply chain management, or similar work in the IWT transport industries. In academia, the respondents have sound knowledge of logistics and supply chain management or inland shipping and logistics or project delivery, promoting the use of inland navigation. They have an excellent understanding of the practical scenario of IWT and associated policies.
1%-9%	Relevant	Expert respondents have essential work experience in intermodal IWT, project delivery promoting the use of inland navigation, supply chain management, or similar work in the IWT transport industries. In academia, they have a general understanding of the status of the IWT transport sector and associated transport policies.
0%	Irrelevant	No experience or knowledge in relation to the research topic.

Source: Author work

Since the quality of judgment of experts is based upon their experience, knowledge and capability, this study carefully selected experts for the evaluation weighting criteria based on their wealth of experience and knowledge in the area of interest.

Table 5-5: Expert opinion survey participant profile

Participant Expert	Field of Expertise	Expert Weight	Job Tittle and Position	Experience (In yrs.)	Country(ies) of Operation
Expert 1	Academic and Practitioner	20%	Academic professor and expert for IWT	45 yrs.	Serbia and Danube countries
Expert 2	Legitimising agent (Waterway agency)	15%	Marketing/Corporate and public affaires	40+ yrs.	UK
Expert 3	Organisation Consultant	15%	Regional director (Freight transport)	40 yrs.	UK and worldwide
Expert 4	Academic	15%	Academic professor	36 yrs.	Malaysia
Expert 5	EU Project delivery and SME	10%	Senior project manager (International research project)	20+ yrs.	UK and international
Expert 6	Academic and research	10%	Senior lecturer	20+ yrs.	UK and international
Expert 7	Academic	5%	Head of project department/simulator	20 yrs.	The Netherlands/continental Europe
Expert 8	EU project delivery	5%	Project director	20 yrs.	UK and Belgium
Expert 9	Port and agencies	5%	Senior manager environment/planning	9+ yrs.	UK

Source : Author work

5.7 Data Analysis

These opinions survey further established the degree to which the identified indicators and sub-indicators are comprehensive to the study. Appropriately, the study conducted reliability and validity tests to affirm the research's quality. The reliability of a questionnaire survey is closely associated with its validity. A questionnaire survey must possess reliability in order to be considered valid. In various forms of research, Cronbach's Alpha has come to be recognised as the standard procedure for using multiple-item measurements of a concept or construct. This is due to the fact that the approach only needs to be administered once, making it far simpler to utilise than other estimates. Cronbach's Alpha was used to evaluate the content and validate the measures. It indicates the degree to which individual experts consider a respective attribute "essential" (Cortina, 1993; Cho and Kim, 2015). Cronbach's Alpha was adopted to assess the validity of this survey since it reveals whether received responses are consistent between items. The idea is that there should be high covariance among comparable items if the instrument is reliable (Collins et al., 2009). The individual response's reliability is examined by using the following equation and functions.

$$a = \left(\frac{k}{k-1}\right)(1 - \frac{\sum_{i=1}^{k} \sigma_{yi}^{2}}{\sigma_{x}^{2}})$$

Where k refers to the number of questions in the survey

σ_{yi}^{2} refers to the variance associated with the current question

σ_{x}^{2} refers to the variance associated with the observed total scores

The overall assessment of a measure's reliability of by Cronbach's alpha typically ranges from 0 to 1. Higher values denote higher accordance between items (Bujang, et al., 2018). Measures are reliable when there is consistency as they indicate the probability that the measured items have the same characteristics. Higher Cronbach's alpha values show more excellent scale reliability, whilst lower values imply that the set of items measured does not measure the same construct reliably (Taber, 2017). More significant values, near to 1.0, imply a more considerable consistency in measurement. Typically, in Cronbach's alpha, a value of 1.0 implies that all of the test scores variability is due to actual score differences without any mistake in measurement. Conversely, no reliable variance is associated with a value score of 0.0 and there are many measurement mistakes (no consistency) (Bonett and Wright, 2014).

The higher the value, the more appropriate the level of reliability. In practice, a coefficient between 0.65 and 0.8 is usually acceptable. However, the range of Cronbach's alpha coefficient has been put forward more succinctly by Sekaran and Bougie (2010) in Table 5.6 below.

Table 5-6: Rule of Thumb Cronbach's Coefficient Alpha

Cronbach's Coefficient Alpha (α)	**Reliability**
0.80 to 0.95	Excellent
0.70 to 0.80	Good
0.60 to 0.70	Fair
< 0.60	Poor

Source: Sekaran and Bougie (2010)

A total of 48 survey questions were tested for this pilot study. As shown in Table 5.5, a high-reliability level was achieved for the survey questionnaire. The overall Cronbach's alpha was 0.898. Based on the rule of thumb of Cronbach's coefficient alpha (α) as presented by Sekaran and Bougie (2010) in Table 5.6 above, the alpha coefficient of the 48 questions (0.889) indicates that the questions have relatively "excellent" internal consistency. Table 5.7 presents the reliability statistics test of the survey questionnaire.

Table 5-7: Survey questionnaire reliability statistics test

Reliability Statistics	
Cronbach's Alpha	Total Number of Questions
0.898	48

As shown in Table 5.8, the total sum, mean, weighted average and standard deviation were further calculated from the experts' judgments. Figure 5.2 shows a radar chart based on the mean and weighted average of the questionnaire results. From this radar chart below, the mean and weighted average lines appear to be much closer to each other, indicating the reliability of the experts' weighting scores. Furthermore, low weighted average values also reveal that the experts had similar concerns about precise indicators. In this study, experts were asked to indicate their level of importance or unimportance using a seven-point Likert scale in the questionnaire (i.e.,1= Highly Unimportant; 2=Slightly Unimportant; 3=Unimportant; 4=Neutral; 5=Important; 6=Slightly Important; 7=Highly Important).

Given the seven-point Likert scale used in this survey, some indicators that scored below 5 "Important" on the ranked mean and weighted average were excluded from the final questionnaire at the end of the analysis. Table 5.9 shows the ranked indicators in response to the question: "How significant are the identified indicators to the overall performance of river freight transport?"

Table 5-8: Total sum, mean, weighted average, and standard deviation

Identified Indicators		How important are the identified indicators to inland waterway transport and logistics?			
		Sum	Mean	Weighted Average	S. D
Mobility and Reliability	**(MR1)** Transit time	55	6.11	6.15	0.60
	(MR2) Navigability	61	6.78	6.85	0.44
	(MR3) Availability and access to multimodal transport information	57	6.33	6.3	0.5
	(MR4) Carriage capacity	52	5.78	5.95	0.66
	(MR5) Handling performance	55	6.11	6.15	0.78
	(MR6) Quality level of traffic services	47	5.22	5.3	0.44
	(MR7) Availability of transport infrastructure such as river port and multimodal connectivity	40	4.44	4.4	0.72
Efficiency and Profitability	**(EP8)** Total cost and expense of river freight	57	6.33	6.3	0.5
	(EP9) Energy efficiency	56	6.22	6.35	0.66
	(EP10) Attractiveness of the transport system	59	6.56	6.55	0.52
	(EP11) Price alternative (e.g., road and rail)	56	6.22	6.2	0.44

	(EP12) Transhipment cost in seaport (time-cost saving)	37	4.11	4.1	0.78
Environmental Impact and Decarbonisation	**(ED13)** Emission reduction	53	5.89	6	0.60
	(ED14) Renewable and alternative energy	51	5.67	5.7	0.5
	(ED15) Emission reduction funding	55	6.11	6.25	0.78
	(ED16) Enforcement/monitoring	51	5.67	5.8	0.70
	(ED17) Noise	52	5.78	5.95	0.97
Infrastructure Condition	**(IC18)** Connectivity (road and rail interchange)	52	5.78	5.9	0.66
	(IC19) Transhipment facilities for integration	53	5.89	5.9	0.60
	(IC20) Modern fleets for competitiveness	52	5.78	5.8	0.44
	(IC21) Congestion-free transport system	46	5.11	5.2	0.60
	(IC22) Maintenance of infrastructure	49	5.44	5.45	0.52
	(IC23) Limited geographical expansion	47	5.22	5.25	0.44
	(IC24) Spatial planning	54	6	6.2	0.70
Safety and Security	**(SS25)** Traffic condition	54	6	5.9	0.70
	(SS26) Navigation safety and route capacity	50	5.56	5.6	0.52
	(SS27) Vessel identification	50	5.56	5.55	0.52

	(SS28) Seaworthiness	53	5.89	6	0.60
	(SS29) Weather forecast	51	5.67	5.8	0.70
Innovative Transport Technology	**(IT30)** Information and communication flow along the supply chain (Data exchange)	52	5.78	5.9	0.66
	(IT31) Shoreside data availability (AIS coverage)	50	5.56	5.75	0.72
	(IT32) Hierarchical tracking and tracing of data at logistics unit level	51	5.67	5.8	0.5
	(IT33) Interoperability with customers systems	53	5.89	5.9	0.60
	(IT34) Voyage planning	49	5.44	5.55	0.52
	(IT35) Tracking and tracing based on GS1/EPCIS	26	2.89	3.1	0.92
	(IT36) VTS and RIS services	28	3.11	3.1	1.05
Economic Development	**(E37)** Aggregate added value (of transportation and infrastructure)	55	6.11	6.25	0.78
	(E38) Development (regional and local)	50	5.56	5.75	0.88
	(E39) Employment (direct and indirect)	52	5.78	6	0.66
	(E40) Marketing	50	5.56	5.75	0.88
	(PI41) Administrative support for modal shift to inland waterways	47	5.22	5.25	0.66
	(PI42) Existing legislative framework for modal shift inland waterways	45	5	5.15	0.70

Policy formulation and implementation	**(PI43)** Incentives and grants for modal shift	48	5.33	5.5	0.70
	(PI44) Knowledge transfer and best practise	51	5.67	5.7	0.70
	(PI45) Logistic clusters formulation and collaboration	50	5.56	5.65	0.5
	(PI46) Education and skill development	53	5.89	6.05	0.78
	(PI47) Integrated transport policy	54	6	6.05	0.86
	(PI48) Cooperation/collaboration	41	4.45	4.45	0.52

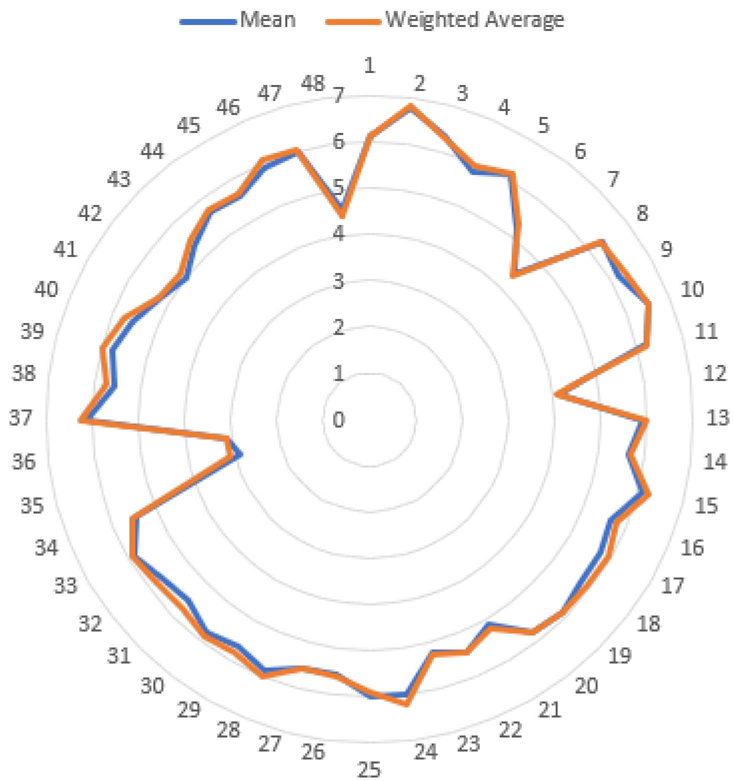

Figure 5-2: Radar chart based on mean and weighted average of the questionnaire results

Table 5-9: Questionnaire survey ranking

Indicators	Sum	Rank (Sum)	Mean	Rank (Mean)	Weighted Average	Rank (W.A)	S. D	Rank (S.D)
MR1	55	61	6.11	6.78	6.15	6.85	0.60	1.05
MR2	61	59	6.78	6.78	6.85	6.55	0.44	0.97
MR3	57	57	6.33	6.78	6.3	6.35	0.5	0.92
MR4	52	57	5.78	6.78	5.95	6.3	0.66	0.88
MR5	55	56	6.11	6.78	6.15	6.3	0.78	0.88
MR6	47	56	5.22	6.22	5.3	6.25	0.44	0.86
MR7	40	55	4.44	6.11	4.4	6.25	0.72	0.78
EP8	57	55	6.33	6.11	6.3	6.2	0.5	0.78
EP9	56	55	6.22	6.11	6.35	6.2	0.66	0.78
EP10	59	55	6.56	6.11	6.55	6.15	0.52	0.78
EP11	56	54	6.22	6	6.2	6.15	0.44	0.78
EP12	37	54	4.11	6	4.1	6.05	0.78	0.72
ED13	53	54	5.89	6	6	6.05	0.60	0.72
ED14	51	53	5.67	5.89	5.7	6	0.5	0.7
ED15	55	53	6.11	5.89	6.25	6	0.78	0.7
ED16	51	53	5.67	5.89	5.8	6	0.70	0.7
ED17	52	53	5.78	5.89	5.95	5.95	0.97	0.7
IC18	52	53	5.78	5.89	5.9	5.95	0.66	0.7
IC19	53	52	5.89	5.78	5.9	5.9	0.60	0.7

IC20	52	52	5.78	5.78	5.8	5.9	0.44	0.7
IC21	46	52	5.11	5.78	5.2	5.9	0.60	0.66
IC22	49	52	5.44	5.78	5.45	5.9	0.52	0.66
IC23	47	52	5.22	5.78	5.25	5.9	0.44	0.66
IC24	54	52	6	5.78	6.2	5.8	0.70	0.66
SS25	54	51	6	5.67	5.9	5.8	0.70	0.66
SS26	50	51	5.56	5.67	5.6	5.8	0.52	0.66
SS27	50	51	5.56	5.67	5.55	5.8	0.52	0.6
SS28	53	51	5.89	5.67	6	5.75	0.60	0.6
SS29	51	51	5.67	5.67	5.8	5.75	0.70	0.6
IT30	52	50	5.78	5.56	5.9	5.75	0.66	0.6
IT31	50	50	5.56	5.56	5.75	5.7	0.72	0.6
IT32	51	50	5.67	5.56	5.8	5.7	0.5	0.6
IT33	53	50	5.89	5.56	5.9	5.65	0.60	0.52
IT34	49	50	5.44	5.56	5.55	5.6	0.52	0.52
IT35	26	50	2.89	5.56	3.1	5.55	0.92	0.52
IT36	28	49	3.11	5.44	3.1	5.55	1.05	0.52
E37	55	49	6.11	5.44	6.25	5.5	0.78	0.52
E38	50	48	5.56	5.33	5.75	5.45	0.88	0.52
E39	52	47	5.78	5.22	6	5.3	0.66	0.5
E40	50	47	5.56	5.22	5.75	5.25	0.88	0.5
PI41	47	47	5.22	5.22	5.25	5.25	0.66	0.5
PI42	45	46	5	5.11	5.15	5.2	0.70	0.5

PI43	48	45	5.33	5	5.5	5.15	0.70	0.5
PI44	51	41	5.67	**4.45***	5.7	**4.45***	0.70	0.44
PI45	50	40	5.56	**4.44***	5.65	**4.4***	0.5	0.44
PI46	53	37	5.89	**4.11***	6.05	**4.1***	0.78	0.44
PI47	54	28	6	**3.11***	6.05	**3.1***	0.86	0.44
PI48	41	26	4.45	**2.89***	4.45	**3.1***	0.52	0.44

***Identified indicators with both mean and W.A below 5.0 are excluded**

From Table 5.9 above, the standard deviation ranged from 0.44 to 1.05. When standard deviation values are analysed, higher values signify that experts attribute a specific element of proportions value to extend to a range of multiple values.

A total of 48 questions were tested in this study. The sum, mean, weighted average, and standard deviation of the experts' responses were calculated. The analysis of survey results through the statistical means is illustrated in Tables 5.7, 5.8 and 5.9, respectively. Also, a comparison of the results based on the mean and the weighted average, as illustrated on the radar chart above (Figure 5.2), shows that the two lines are almost identical, demonstrating the reliability of the experts' weighting criteria.

To focus on the identified indicators/sub-indicators judged more important by the experts, those with a mean and weighted average below "5" were further excluded from this study. The sub-indicator availability of the transport infrastructure, such as *river port and multimodal connectivity, transhipment cost in seaport, tracking and tracing based on GS1/EPICS, RIS and VTS services, and cooperation and collaboration* were excluded in the modified hierarchical structure (See Figure 5.3). However, to further confirm the reliability and validity of the final hierarchical structure diagram developed, the identified indicator/sub-indicators for assessing the performance of IWT were ranked and categorised in a modified hierarchical structured diagram. The modified hierarchical structure diagram was again circulated to experts for validation. The opinions of the nine experts who participated in the initial experts' opinion survey were again sorted for final validation. Additionally, the opinion of one industry expert who was interviewed earlier was again sorted through a direct face-to-face interview. Of the nine experts who were re-contacted, eight agreed to the final structure diagram without modification, while no response was received from the remaining person. However, recommendations and informal advice were further given by a few experts on the conduct of this study. Figure 5.3 below presents the final hierarchical structure diagram.

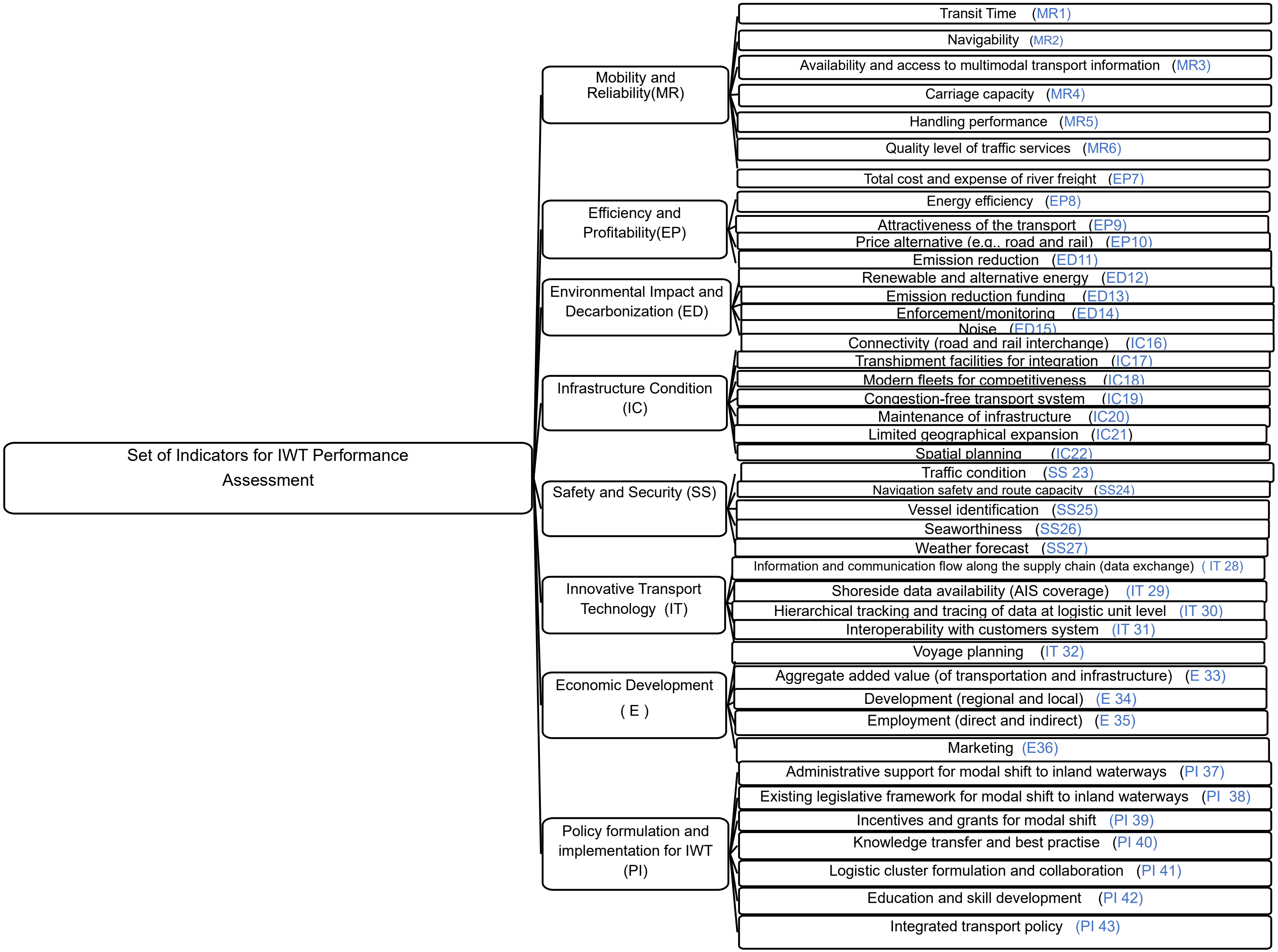
Set of Indicators for IWT Performance Assessment
Mobility and Reliability(MR)
Transit Time (MR1)
Navigability (MR2)
Availability and access to multimodal transport information (MR3)
Carriage capacity (MR4)
Handling performance (MR5)
Quality level of traffic services (MR6)
Efficiency and Profitability(EP)
Total cost and expense of river freight (EP7)
Energy efficiency (EP8)
Attractiveness of the transport (EP9)
Price alternative (e.g., road and rail) (EP10)
Environmental Impact and Decarbonization (ED)
Emission reduction (ED11)
Renewable and alternative energy (ED12)
Emission reduction funding (ED13)
Enforcement/monitoring (ED14)
Noise (ED15)
Infrastructure Condition (IC)
Connectivity (road and rail interchange) (IC16)
Transhipment facilities for integration (IC17)
Modern fleets for competitiveness (IC18)
Congestion-free transport system (IC19)
Maintenance of infrastructure (IC20)
Limited geographical expansion (IC21)
Spatial planning (IC22)
Safety and Security (SS)
Traffic condition (SS 23)
Navigation safety and route capacity (SS24)
Vessel identification (SS25)
Seaworthiness (SS26)
Weather forecast (SS27)
Innovative Transport Technology (IT)
Information and communication flow along the supply chain (data exchange) (IT 28)
Shoreside data availability (AIS coverage) (IT 29)
Hierarchical tracking and tracing of data at logistic unit level (IT 30)
Interoperability with customers system (IT 31)
Voyage planning (IT 32)
Economic Development (E)
Aggregate added value (of transportation and infrastructure) (E 33)
Development (regional and local) (E 34)
Employment (direct and indirect) (E 35)
Marketing (E36)
Policy formulation and implementation for IWT (PI)
Administrative support for modal shift to inland waterways (PI 37)
Existing legislative framework for modal shift to inland waterways (PI 38)
Incentives and grants for modal shift (PI 39)
Knowledge transfer and best practise (PI 40)
Logistic cluster formulation and collaboration (PI 41)
Education and skill development (PI 42)
Integrated transport policy (PI 43)

Figure 5-3: Final hierarchical structure

Source: Author work

5.8 Chapter Summary

This chapter recognises identification and categorisation of service performance indicators as an effective procedure for conducting efficient performance assessment. This study's literature review and survey questionnaire serve as a guide to strengthen the knowledge basis for identifying the performance indicators for inland waterway freight transportation. Extant works of literature were reviewed carefully to identify the performance indicators that have been addressed in the relevant literature. A decomposition method was then applied to categorise the unstructured indicators into different indicators and sub-indicator groups. A questionnaire was designed, and an experts' opinion survey was conducted to determine the weights of the identified indicators and sub-indicator groups and to explore any other remaining indicators/sub-indicators yet to be explored by the study through expert opinion.

This study carefully selected experts to validate the identified performance indicators and sub-indicators. Before recruiting the expert participants, checks were made to ensure that experts had equal interest, background, and relevant experience in the field and countries of interest. Data were collected by circulating the developed questionnaire by e-mails and face-to-face interviews. This thesis developed the hierarchical structure after reviewing the existing global practices, regional/local policies, and general guidelines, especially in the research setting. The study presents hierarchical performance assessment indicator groups consisting of eight different IWT categories (i.e., *Mobility and Reliability, Efficiency and Profitability, Environmental Impact and Decarbonisation, Infrastructure Condition, Safety and Security, Innovative Transport Technology, Economic Development and Policy Formulation and Implementation*). The perception of the significance and weights of the indicator groups among experts varies from person to person, the quality of the expert judgment is built based on their proficiency, capability, experience, and knowledge. Despite the wide range of experts selected from different countries, industry practitioners, consultants and academicians for the expert opinion survey, a consensus of their opinion was reflected in their findings, indicating substantial agreement. The next chapter of this thesis assesses the identified performance indicators by applying Fuzzy AHP and TOPSIS models to find their priorities and context relations.

Chapter 6: Assessment of Inland Waterways Freight Transport and Logistics Performance: Integrated Set of Indicators

6.1 Introduction

The challenge for implementing a performance measurement system that concentrates on a particular transportation mode is to document thoroughly the crucial processes of the specific mode of transportation. Within this activity are all the transport system's essential components, including defining actors and stakeholders involved in waterborne freight transport and their relevant physical and soft components. Factors that influence the general significance of the overall impact of transport performance are identified. Describing these vital processes provides a reasonable basis for evaluating the key performance indicators of the transport system. This chapter focuses on assessing the integrated indicators for inland waterway freight transport and logistics operations using fuzzy AHP methods to prioritise and detect the critical factors that influence the success of waterborne transport in the modern supply chain. The chapter aims to elucidate these factors and then evaluate and rate them by analysing the components using fuzzy AHP techniques and ranking the indicators for the UK based on their critical success factors among European competitors using the TOPSIS method. The study used empirical methods to collect primary data on the indicator weighting and their inter-relationship.

6.2. Methodology for the assessment of an integrated set of indicators for integrating waterborne transport into the modern logistic chain

Performance indicators serve as an approved method that provides an effective and practical approach to support decision-making by working out the causes and effects that directly and indirectly influence the attainment goals and corresponding results. These performance indicators are intended to help better understand the impacts of decisions within the whole IWT system. This study captures and models all relevant factors and attributes that influence the system's performance in the European and UK contexts. Based on the development of the system model, a generic fuzzy AHP and TOPSIS-based assessment model are proposed for determining and assessing the critical success factors and then the TOPSIS method for their subsequent ranking.

The proposed integrated fuzzy AHP-TOPSIS-based performance indicators framework will be implemented in the IWT sector during the performance assessment stage, and the following steps apply. Figure 6.1 presents the model's schematic diagram.

Phase I: Construction of a structured model diagram in a hierarchical form based on the identified indicators and sub-indicators. (Process already carried out in the previous chapter of this study).

Phase II: A structured fuzzy AHP-based questionnaire had been formulated, and data were collected to assess the professional judgement of experts or decision-making executives using the linguistic variable for pair-wise comparisons of criteria and sub-criteria. (see section 6.3.1 on fuzzy logic for a discussion of why linguistic variable are preferred to numeric values for such comparisons).

The expert opinions obtained were assigned to a group to form a fuzzy judgement matrix or decision matrix.

Phase III: The linguistic variable for pair-wise comparisons of criteria and sub-criteria then converted and represented into Triangular Fuzzy Numbers (TFNs).

Phase IV: After constructing a fuzzy pair-wise comparison matrix and obtaining a judgment matrix, the consistency of the obtained is checked before employing the sample to assess the degree of randomness in the judgement.

Phase V: Based on the pair-wise comparison matrices and the expert's judgments, the weight of these identified indicators was calculated.

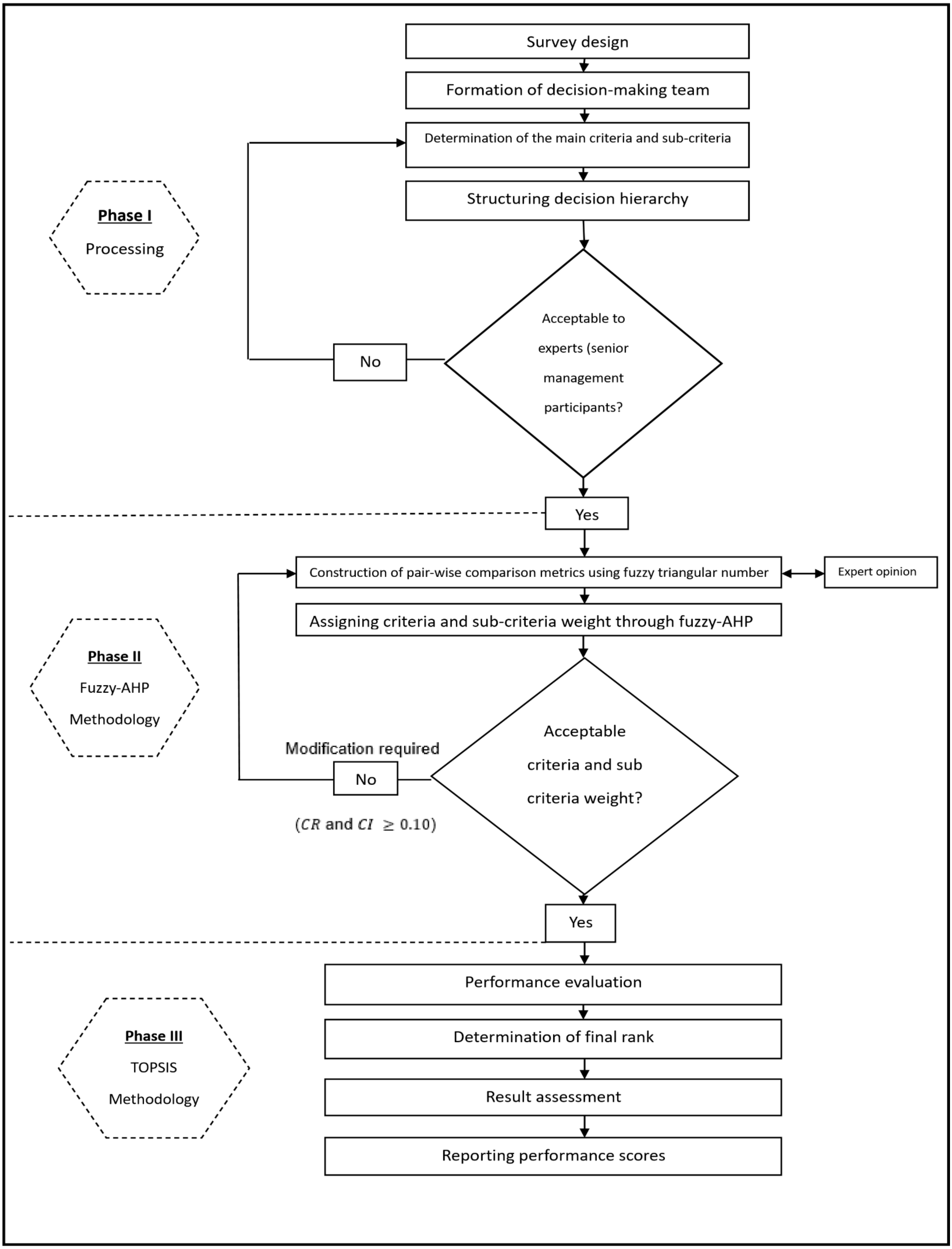

Figure 6-1: Schematic diagram of the proposed model for performance evaluation

Source: Author work

6.3. An Empirical Study

The essence of benchmarking is identifying the highest standards of the practically approved method for enhancing the quality of services or procedures and strategies and then making the improvements required to attain those standards, generally referred to as “best practices”. A fuzzy AHP model was developed in this study, and data were collected to assess the expert’s judgement and then the TOPSIS method for their subsequent ranking. The following were the various phases through which this study collected data:

(i) Questionnaire survey – This phase started with questionnaire development and design, pilot study and expert selection (Input to the system model was compiled by consulting experts).

(ii) Data collection, description, and analysis.

(iii) Checking the effectiveness of the proposed methodology.

(iv) The final phase was results and discussion.

6.3.1. The fuzzy AHP model-based survey questionnaire

A structured survey questionnaire was formulated for data collection. The questionnaire employed for this study was created with a written set of carefully worded questions and instructions related to the problem for respondents to answer. Before distributing the final questionnaire for data collection, this study performed content validity to ensure the questionnaire's relevance, simplicity and clarity (Ng, 2006; Hilton, 2017). At first, the completed questionnaire was submitted to the supervisory team for clarity, evaluation, and to receive any essential feedback. The questionnaire was modified and approved based on the teams' feedback. A cover note was drafted and attached at the beginning of the questionnaire describing the study's primary aim and assuring the participants of the strict confidentiality and anonymity of data supplied, which is safeguarded under the Liverpool John Moores University Ethical guideline in both the pilot questionnaire and the main survey.

Furthermore, the study obtained ethical approval from the LJMU REC committee to validate the questionnaire content and the participants' consent. A sample of the pretesting questionnaire used for primary data collection is shown in Appendix I. In drafting the questionnaire, extra caution was taken in designing and presenting the questionnaire in order to escape confusion and ambiguity. Much effort was put into designing and structuring the questionnaire to make it attractive, which encouraged and did not impede the respondents from answering the questions conveniently. As piloting and pretesting questionnaires are essential, procedures are needed to be conducted to ensure the questionnaire is free from possible errors or issues (Malmqvist et al., 2019). The questionnaire in this study pre-assessed the accuracy, effectiveness, and clarity of communication through a pilot study by exploring a panel of expert judges. Appendix II shows the final survey questionnaire used in this study.

The questionnaire is structured into two sections. Section A, labelled "Respondent profile", has five variables. These variables include experts' details to identify the type of organisation, country of operation, job title and position, whether the respondent is directly or indirectly involved with IWT and, finally, their years of experience in the field. Section B is further divided into parts A and B, with part A presenting the initial hierarchical structured diagram and key definitions of the main criteria. Part B presents the main fuzzy AHP model questionnaire using linguistic variables for pairwise comparisons of criteria and sub-criteria.

In the questionnaire, experts are asked to choose a pairwise comparison set to demonstrate the extent to which one indicator is more important than another in each pair. Section B's last part has matrices that must be appropriately marked to indicate the experts' judgements. The target sample comprises experts ranging from business development functions to individuals in the operational environment of IWT. A wide range of experts in the inland navigation/river-sea shipping domain were selected for the experts' survey. One of the main criteria for the experts' selection for this study was their expertise and contribution to the field concerned. The experts selected come from valuable logistics, freight and shipping companies that are likely to operate the waterways or transport their goods via waterways. The role of modern technology and innovation in making waterborne transport a viable option is significant. Hence, it was essential to circulate the questionnaire to expert personnel creating new technologies to enhance the use of inland navigation for adequate freight transportation (inland waterway technology companies).

The use of inland waterways for freight transportation is constantly driven by legitimising agents (waterway agencies, port agencies). This questionnaire was further disseminated to organisations such as the CRT and other specific waterway agencies such as the PLA and Peel Ports Group. The researcher also invited participants from academia in the education setting and members of professional research bodies like the Logistic Research Network (LRN) who understand the scenarios of river-sea transport and associated policies at the European and the UK level and also infrastructural project partners and consultants from leading business consulting firms in inland navigation. Finally, the other prominent experts recruited for this survey include stakeholders from European firms (companies/agencies from the Netherlands, Rhein and Danube (Rhein-Danube ports) and other Europeans already utilising inland shipping in their local freight transport chains. In these cases, investigating their main success drivers could help create recommendations for how best the system could be implemented.

Emails were sent out to the targeted respondents, seeking their willingness to participate in the survey. Afterwards, the developed questionnaire was circulated to 256 contacts via email on January 17th, 2022. Following the initial distribution of the survey questionnaire, the response rate remained low for six weeks. Thus, a subsequent reminder email was sent with the second wave questionnaire. In total, 33 respondents completed the questionnaire four months after the second wave was sent, including 27 valid and six invalid questionnaires, as the respondents answered only some of the questions in each category. After receiving the completed questionnaire, the supervisory team were notified of the returned questionnaire. The supervisory team checked to ascertain the respondents' expertise, job position, years of experience, and work region, all to establish the respondent's reliability. Most of the survey respondents held a position at or above the managerial level and had the authority to make decisions within their various operating organisations. The supervisory team approved the reliability of the response, and analyses were carried out. See Table 6.1. for the response rate.

Table 6-1: Total number of questionnaires administered and returned

Total no of questionnaire distributed	Returned Questionnaire	Valid Replies	Incomplete replies
256	33	27	6

The experience and field knowledge of the respondents participating in the survey ranged from five to forty years at a minimum. Participants were only contacted and selected if they had at least five years of experience in the inland shipping industry. The participants were decision-makers in their various domains of operation. From the returned questionnaire used for this study, the figure shows that approximately 50% of the respondents have more than 15 years of professional experience and knowledge in relevant intermodal transport, IWT, supply chain and logistics operations management. Thus, the survey provided the needed mix of experience and ingenuity, making this study reliable. The respondent profiles, as presented in Table 6.2, show that most respondents work or have worked in companies affiliated with IWT.

Table 6-2: Respondent profiles

		No
Type of Operating Organisation?	Head of Project/Managing authority	8
	Academicians	2
	Projects officer/Project partners	5
	Monitoring coordinator	1
	Head of supply chain consulting firm/logistics/warehousing/consolidators	3
	Head of marketing/Corporate/Public affairs	5
	Others	3
Country(ies)	France	3
	The Netherlands	6
	Germany	5
	Belgium	4
	UK	9
Job tittle and position (Expertise)	Consultants working in the supply chain and IWT	7
	Professional in inland navigation/intermodal transportation projects	8
	Academicians from transport and logistics background	2
	Inland waterways technology companies	4
	Value-added services (VAS) professional (warehousing and consolidators)	2
	Legitimising agents	4
	Others	0
Inland waterways you are familiar or indirectly involved with?	Le-Hare-Seine-Paris corridor	4
	Rotterdam, Hamburg, and Antwerp coastal gateways	7
	Rhine-Main-Danube corridor	9
	Thames and the Liverpool/Manchester regional gateway	6
	Others	1
	1 – 5 Years	0

Years of professional working experience	6 – 10 Years	4
	11 -15 Years	10
	16 – 19 Years	5
	20 Years above	8

Source: Author work

Industry practitioners, cargo consignors and consignees (shippers) forwarding agents, and shipping company representatives from the UK, France, the Netherlands, Belgium, and Germany top the survey respondents list. Following them are experts working on inland navigation/intermodal transportation projects in leading consulting companies in the area of interest. Academicians from transport and logistic backgrounds in the selected countries were second to the least of the respondents of this survey. Finally, the fewest least respondents were value-added services (VAS) professionals (warehousing, consolidators). The majority of the survey participants occupied a manager position or above and possessed the power to make choices inside their respective operating organisations.

6.3.2 Numerical illustration with the case study

The relative importance and the total weights of the identified indicators from the respondents' judgements were calculated using fuzzy AHP. The following steps show details of the data analysis.

Step I: Structure problem hierarchy.

This step evaluates the importance of the critical success factors. The success factors are structured into a hierarchy, as depicted in Figure 5.3. The general decision goal for the benchmarking analysis is presented at level one of the hierarchies with level two as the decision criteria and level three the sub-criteria.

Step II: Identifying the linguistic variables and developing a fuzzy conversion scale.

The conversion of linguistic values into fuzzy scales is achieved using the triangular fuzzy conversion scales and linguistic scales proposed by Gil et al. (2015). The process is illustrated in Table 3.4 and Figure 3.7.

Step III: Construction of pair-wise comparison matrices using fuzzy triangular numbers.

This study employed the average value technique to integrate different evaluators' vague judgment values regarding the exact evaluation measurement for individual evaluators with the same importance. According to their subjective judgment, the evaluators for this study assigned their range of linguistic variables. In order to assess their relative importance, participants were requested to compare each criterion at a level group of the hierarchy on a pair-wise basis. The experts' assessment has been expressed in linguistic terminology, and it's not appropriate for examination. During this analysis stage, the subjective phrase will be converted into triangular fuzzy numbers utilising the linguistic scales outlined in Table 3.5. Table 6.3 displays an expert's response segment to provide an example. Figure 6.2. shows the final objective hierarchy for assessing IWT performance.

In this study, as illustrated in Table 6.3, the decision matrix 'D', which consists of 8 x 8 elements, may be constructed to measure the relative degree of importance for each critical success factor based on the proposed methodology defined in section 6.3. SC_1, SC_2, SC_3, $SC_{4,}$ $SC_{5,}$ SC_6, $SC_{7,}$ SC_8 respectively, denote the different criteria.

Table 6-3: Fuzzy pair-wise comparison matrix

	MR	**EP**	**ED**	**IC**	**SS**	**IT**	**ED**	**PI**
MR	111	5/2, 3, 7/2	111	2/3, 1, 3/2	2/9, ¼, 2/7	3/2, 2, 5/2	2/3, 1, 3/2	7/2, 4, 9/2
EP	2/7, 1/3,2/5	111	3/2, 2, 5/2	3/2, 2, 5/2	111	3/2, 2, 5/2	3/2, 2, 5/2	2/3, 1, 3/2
ED	111	2/5, ½, 2/3	111	5/2, 3, 7/2	2/3, 1, 3/2	3/2, 2, 5/2	3/2, 2, 5/2	2/3, 1, 3/2
IC	2/3, 1, 3/2	3/2, 2, 5/2	2/7, 1/3, 2/5	111	3/2, 2, 5/2	3/2, 2, 5/2	7/2, 4, 9/2	5/2, 3, 7/2
SS	7/2,4, 9/2	111	2/3, 1, 3/2	2/5, ½, 2/3	111	2/3, 1, 3/2	2/3, 1, 3/2	5/2, 3, 7/2
IT	2/5, ½, 2/3	2/5, ½, 2/3	2/5, ½, 2/3	2/5, ½, 2/3	2/3, 1, 3/2	111	2/5, ½, 2/3	5/4, 3, 7/2
E	2/3, 1, 3/2	2/5, ½, 2/3	2/3, 1, 3/2	2/9, ¼, 2/7	2/3, 1, 3/2	3/2, 2, 5/2	111	3/2, 2, 5/2
PI	2/9, ¼, 2/7	2/3, 1, 3/2	2/9, ¼, 2/7	2/7,1/3,2/5	2/7,1/3,2/5	2/7,1/3,2/5	2/5, ½, 2/3	111

Sources: Author work

Step IIII: Construction of the aggregated matrix

The fuzzy combination of several separate elements formed the individual respondents' preferences. Each respondent's preferences were aggregated into a group preference for each indicator before the calculated fuzzy weight for each indicator was computed.

Table 6-4: The fuzzy pair-wise comparison matrix of eight criteria

	SC_1	**SC_2**	**SC_3**	**SC_4**	**SC_5**	**SC_6**	**SC_7**	**SC_8**
SC_1	(1.000,1.000,1.000)	(1.000,3.077,4.500)	(0.400,2.120,4.500)	(0.222,1.253,4.500)	(0.222,0.721,3.500)	(0.500,2.484,4.500)	(0.500,2.118,4.500)	(0.500,2.692,4.500)
SC_2	(0.222,0.325,1.000)	(1.000,1.000,1.000)	(0.222,0.465,2.000)	(0.222,0.694,2.500)	(0.667,1.000,2.000)	(0.400,0.990,3.500)	(0.286,0.759,2.500)	(0.286,0.855,3.500)
SC_3	(0.222,0.472,2.500)	(0.500,2.151,4.505)	(1.000,1.000,1.000)	(0.222,1.102,4.500)	(0.286,1.313,4.500)	(0.286,1.109,3.500)	(0.286,1.197,4.500)	(0.286,1.618,4.500)
SC_4	(0.222,0.798,4.505)	(0.400,1.441,4.505)	(0.222,0.907,4.505)	(1.000,1.000,1.000)	(0.286,1.338,4.500)	(0.400,1.113,4.500)	(0.286,1.355,4.500)	(0.400,2.265,4.500)
SC_5	(0.286,1.387,4.505)	(0.500,1.000,1.499)	(0.222,0.762,3.497)	(0.222,0.747,3.497)	(1.000,1.000,1.000)	(0.286,1.251,3.500)	(0.286,1.015,3.500)	(0.500,2.509,4.500)
SC_6	(0.222,0.403,2.000)	(0.286,1.010,2.500)	(0.286,0.902,3.497)	(0.222,0.898,2.500)	(0.286,0.799,3.497)	(1.000,1.000,1.000)	(0.222,0.997,4.500)	(0.400,2.294,4.500)
SC_7	(0.222,0.472,2.000)	(0.400,1.318,3.497)	(0.222,0.835,3.497)	(0.222,0.738,3.497)	(0.286,0.985,3.497)	(0.222,1.003,4.505)	(1.000,1.000,1.000)	(0.500,2.588,4.500)
SC_8	(0.222,0.371,2.000)	(0.286,1.170,3.497)	(0.222,0.618,3.497)	(0.222,0.442,2.500)	(0.222,0.399,2.000)	(0.222,0.436,2.500)	(0.222,0.386,2.000)	(1.000,1.000,1.000)

Source: Author work

Step IIII. Determining the consistency index and consistency ratio

The FAHP use a consistency ratio to verify the findings and guarantee that the pairwise comparison is consistent. If the consistency ratio is less than or equal to 0.1, the results of the combined pairwise comparison are considered reliable.

Step III. Calculate the fuzzy weights.

Chang's extent analysis method is a widely accepted methodology that several researchers have used for its comprehensibility. The extent analysis procedure proposed by Chang was used in this study to consider the extent of an object or criteria to satisfy the goal. In this step, the fuzzy synthetic extent values of eight criteria are determined in line with the rule of Chang's extent analysis method. In choosing the weight vectors of the criteria for the overall goal of this study, the numerical analysis of the received synthetic extent values of eight criteria by using Eq. 6.10 are as follows:

SC_1 = (4.34, 15.46, 31.50) ⊗ (1/206, 1/73.46, 1/25.87) = (0.021, 0.211, 1.218)

SC_2 = (3.31, 6.09, 18.0) ⊗ (1/206, 1/73.46, 1/25.87) = (0.016, 0.083, 0.696)

SC_3 = (3.09, 9.96, 29.51) ⊗ (1/206, 1/73.46, 1/25.87) = (0.015, 0.136, 1.140)

SC_4 = (3.22, 10.22, 32.52) ⊗ (1/206, 1/73.46, 1/25.87) = (0.016, 0.139, 1.257)

SC_5 = (3.30, 9.67, 25.50) ⊗ (1/206, 1/73.46, 1/25.87) = (0.016, 0.132, 0.986)

SC_6 = (2.92, 8.30, 23.99) ⊗ (1/206, 1/73.46, 1/25.87) = (0.014, 0.113, 0.927)

SC_7 = (3.07, 8.94, 25.99) ⊗ (1/206, 1/73.46, 1/25.87) = (0.015, 0.122, 0.999)

SC_8 = (2.62, 4.82, 18.99) ⊗ (1/206, 1/73.46, 1/25.87) = (0.013, 0.066, 0.743)

Eqs.6.15 and 6.16, respectively, can then be used to calculate the degree of possibility of the superiority of 1 which is denoted by V ($SC_1 \geq SC_2$). Therefore, the degree of possibility of the superiority for the requirement is calculated as

$V\ (SC_1 \geq SC_2)$ = 1 $V\ (SC_1 \geq SC_3)$ = 1 $V\ (SC_2 \geq SC_{4)}$ = 1

$V\ (SC_1 \geq S_5)$ = 1 $V\ (SC_1 \geq S_6)$ = 1 $V\ (SC_1 \geq\ S_7\ )$ = 1

$V\ (SC_1 \geq S_8)$ = 1

The value for the second requirement is calculated as:

$$V\ (SC_2 \geq SC_1) = \frac{0.021-0.696}{(0.083-0.696)-(0.211-0.021)} = \frac{-0.675}{-0.803} = 0.841$$

$V\ (SC_2 \geq SC_3)$ = 0.927 $V\ (SC_2 \geq S\ C_4\ )$ = 0.923 $V\ (SC_2 \geq S\ C_5)$ = 0.932

$V\ (SC_2 \geq\ SC_6)$ = 0.957 $V\ (SC_2 \geq SC_7)$ = 0.945 $V\ (SC_2 \geq SC_8)$ = 1

The value for the third requirement is calculated as:

$V\ (SC_3 \geq SC_1)$ = 0.937 $V\ (SC_3 \geq SC_2)$ = 1 $V\ (SC_3 \geq SC_4)$ = 0.997

$V\ (SC_3 \geq SC_5)$ = 1 $V\ (SC_3 \geq\ SC_6)$ =1 $V\ (SC_3 \geq SC_7)$ = 1

$V(SC_3 \geq\ SC_8)$ = 1

The value for the fourth requirement is calculated as:

$V\ (SC_4 \geq SC_1)$ = 0.944 $V\ (SC_4 \geq SC_2) = 1$ $V\ (SC_4\ \geq\ SC_3)$ = 1

$V(SC_4 \geq SC_5)$ = 1 $V\ (SC_4 \geq SC_6)$ = 1 $V\ (SC_4 \geq SC_7) = 1$

$V\ (SC_4\ \geq\ SC_8) = 1$

The value for the firth requirement is calculated as:

$V\ (SC_5 \geq SC_1)$ = 0.924 $V\ SC_5 \geq SC_2) = 1$ $V\ (SC_5 \geq SC_3) = 0.995$

$V(\ SC_5 \geq SC_4)$ = 0.992 $V\ (SC_5 \geq SC_6)$ = 1 $V\ (SC_5 \geq SC_7) = 1$

$V\ (SC_5 \geq SC_8) = 1$

The value for the sixth requirement is calculated as:

$V\ (SC_6 \geq SC_1) =$ 0.9023 $V\ (SC_6 \geq SC_2) = 1$ $V\ (SC_6 \geq SC_3)$ = 0.845

$V\ (SC_6 \geq SC_4) = 0.972$ $V\ (SC_6 \geq SC_5) = 0.979$ $V\ (SC_6 \geq SC_7)$ =0.990

$V\ (SC_6 \geq SC_8) = 1$

The value of the seventh requirement is calculated as:

$V\ (SC_7 \geq SC_1) =$ 0.916 $V\ (SC_7 \geq SC_2) = 1$ $V\ (SC_7\ \geq SC_3) =$ 0.985

$V\ (SC_7\ \geq SC_4) =$ 0.983 $V\ (SC_7 \geq SC_5) = 0.989$ $V\ (SC_7 \geq SC_6) =$ 1

$V\ (SC_7 \geq SC_8) = 1$

The value for the eight requirement is calculated as:

$V\ (SC_8 \geq SC_1) =\ 0.831$ $V\ (SC_8 \geq SC_2) = 0.976$ $V\ (SC_8 \geq SC_3) =$ 0.911

$V\ (SC_8 \geq SC_4) =\ 0.907$ $V\ (SC_8 \geq SC_5) =\ 0.915$ $V\ (SC_8 \geq SC_6) =$ 0.938

$V\ (SC_8 \geq SC_7)$ = 0.927

The minimum degree of possibility of the superiority of each criterion over another is obtained with the help of Eqs.16 and 17 of the extent analysis method. The priority weights for the eight criteria are calculated as follows:

$d'(SC_1) =$ min $V\ (SC_1 \geq SC_2, SC_3, \ldots .SC_8)$ = min (1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00) = 1.00

Similarly,

$d'(SC_2)$ = min (0.841, 0.927, 0.923, 0.932, 0.957, 0.945, 1.00) = 0.841

$d'(SC_3)$ = min (0.937, 1.00, 0.997, 1.00, 1.00, 1.00, 1.00) = 0.937

$d'(SC_4)$ = min (0.944, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00) = 0.944

$d'(SC_5)$ = min (0.924, 1.00, 0.995, 0.992, 1.00, 1.00, 1.00) = 0.924

$d'(SC_6)$ = min (0.902, 1.00, 0.845, 0.972, 0.979, 0.990, 1.00) = 0.845

$d'(SC_7)$ = min (0.916, 1.00, 0.985, 0.983, 0.989, 1.00, 1.00) = 0.916

$d'(SC_8)$ = min (0.831, 0.976, 0.911, 0.907, 0.915, 0.938, 0.927) = 0.831

Then the weight vector is defined as

$W' = (1.00, 0.841, 0937, 0.944, 0.924, 0.845, 0.916, 0.831)^T$

Using the extent analysis method, the normalised value of this vector decides the priority weights of each criterion over another. Therefore, normalised weight vectors of $C_{1,}$ C_2 C_3 C_4 C_5 C_6 C_7 C_8 are calculated as follows.

$(0.137, 0.115, 0.128, 0.13, 0.127, 0.124, 0.126, 0.114)^T$

Following the same procedure discussed above, the various sub-criteria are compared separately under each criterion. Appendix V shows each sub-criterion's fuzzy comparison matrix and weight vectors. Each sub-criteria's priority weight has been established using the same technique as previously described.

Each criterion's and sub-criterion's relative priority weight are determined at this point. The outcomes of the instance are displayed in Table 6.5. This hierarchy is deemed appropriate as each level's consistency is less than 0.1.

Table 6-5: Priority and consistency ratios for benchmarking performance of IWT

Criterion	Priority of criterion	Sub-Criterion	Priority of Sub-criterion	CR of sub-criteria
		S_1	0.168	
		S_2	0.181	
		S_3	0.154	
C1	0.137	S_4	0.172	0.016
		S_5	0.165	
		S_6	0.16	
		S_7	0.264	
		S_8	0.26	
C2	0.115	S_9	0.21	0.93
		S_{10}	0.266	
		S_{11}	0.207	
		S_{12}	0.229	
C3	0.128	S_{13}	0.213	0.021
		S_{15}	0.193	
		S_{16}	0.158	
		S_{17}	0.154	
		S_{18}	0.14	
		S_{19}	0.15	
C4	0.13	S_{20}	0.136	0.023
		S_{21}	0.143	
		S_{22}	0.137	
		S_{23}	0.14	
		S_{24}	0.193	
		S_{25}	0.221	
C5	0.127	S_{26}	0.177	0.034
		S_{27}	0.224	
		S_{28}	0.185	
		S_{29}	0.234	
		S_{30}	0.159	
C6	0.124	S_{31}	0.225	0.01
		S_{32}	0.187	

		S_{33}	0.194	
		S_{34}	0.219	
		S_{35}	0.266	
C7	0.126	S_{36}	0.294	0.003
		S_{37}	0.222	
		S_{38}	0.146	
		S_{39}	0.127	
		S_{40}	0.14	
C8	0.114	S_{41}	0.17	0.03
		S_{42}	0.137	
		S_{43}	0.151	

Source: Author work

6.4. Results and Discussion of Fuzzy AHP

Identifying the significant performance factors likely to hinder the efficient functioning of the IWT can be challenging. However, employing the fuzzy AHP method to prioritise the performance elements will guarantee a thorough and organised approach. Implementing the fuzzy AHP will enhance the performance measurement standards in the IWT, hence improving the efficiency of the transport system. The underlying performance indicators sources associated with IWT are categorised into eight main categories: mobility and reliability, efficiency and profitability, environmental impact and decarbonisation, infrastructure condition, safety and security, economic development, innovative transport technology and policy formulation and implementation for IWT. The results indicated that mobility/reliability and infrastructure conditions have the most remarkable effects and are of higher priority than the other factors. This implies that stakeholders and policymakers should prioritise and scrutinise the efficiency of their processes and actions within the IWT domain.

6.4.1. Mobility and reliability:

Mobility and reliability encompass performance factors associated with Carriage Capacity (0.172), Transit time (0.168), Handling performance (0.165), Quality level of traffic services (0.16) and availability and access to multimodal transport information (0.154) and navigability

(0.181). According to the analysis, navigability is considered the most significant factor, with a weighting of 0.181. The finding suggests that navigability is crucial for guaranteeing the safety of vessels, crew and cargo during freight transportation via waterways (Schweighofer, 2014; Vinke et al., 2022).

Navigability conditions, including the depth of the fairway, are crucial for waterway transportation as they directly impact the maximum cargo capacity of a vessel. The water depths in the fairway directly impact the cargo capacity of an inland cargo vessel, as they determine the maximum weight or volume of goods that can be transported. The draught of a vessel increases propositionally with the amount of cargo it carries. The draught carried by navigation corporations significantly impacts the cost-effectiveness of IWT. Analysing the deep waterway route uses criteria like depth and siltation by the rules established by European inland waterway codes (United Nations Economic Commission for Europe, 2018). A sufficient navigable depth is crucial for ensuring the safe passage of vessels with a draft of over three metres. Regular dredging is essential to accommodate huge volumes of products, while channel maintenance enhances waterway cleanliness and the environment (Beyer, 2018). Therefore, it is recommended that stakeholders implement techniques for improvement, such as dredging and large-scale construction projects like locks and dams, in order to enhance the depths and widths of navigation channels that are impacted by topography, traffic volume, and pre-existing infrastructure. Although dredging is still the most efficient approach, there is a need for efficient sediment control strategies.

Carriage capacity is ranked second within this group. A vessel's carrying capacity directly impacts its productivity and profitability, as it enables the transportation of larger quantities of goods/products in a single trip, leading to cost savings for inland shipping businesses. Additionally, utilising larger vessels improves customer services by capitalising on economies of scale, reducing transportation expenses and increasing reliability. Moreover, the size of a ship is closely linked to its environmental footprint, as it has the potential to decrease emissions per amount of cargo carried, aligning with the increasing global emphasis on ecological sustainability. However, it is crucial to note that certain difficulties arise when increasing the capacity of carriages, such as the need for deeper navigational channels and sufficient port infrastructure. Therefore, stakeholders should embrace and adopt appropriate modes and provide resources towards infrastructure development and maintenance in order to ensure efficient transportation of goods.

Transit time is ranked the third most significant in this group. The timeliness of transit is vital for maintaining the competitiveness of IWT since it directly affects supply chains, the global economy and environmental factors (Passchyna et al., 2016). Delays can interrupt the just-in-time manufacturing system, resulting in financial setbacks. Extended transportation durations might nullify the positive environmental effects of using waterways as a mode of transport, resulting in adverse consequences that affect parties not directly involved. Efficiently managing travel time is crucial for creating a suitable system and sustainably organising vessel schedules. Ports that have quicker, and more predictable transit times have a distinct advantage in terms of competition. Therefore, it is recommended that stakeholders involved in port affairs allocate resources towards technical innovations, engage in partnerships with other relevant parties and invest in automated locks and cargo handling systems in order to transport goods efficiently.

Next in line is the handling performance; the efficient handling performance in IWT operations enhances productivity (Grushevska and Notteboom, 2016). This result shows that when measuring the performance of IWT, metrics like cargo throughput, loading/unloading time, and vessel turnaround time can help stakeholders identify bottlenecks, optimise resource allocation and increase profitability. The quality of the IWT traffic service is distinct from road and railway traffic due to its unique characteristics and reliance on navigable channel conditions, which can vary and impose restrictions on vessel loading and the number of vessels in tow. An inherent advantage of IWT is minimal congestion compared to other inland transport modes (Deng et al., 2021). On the other hand, IWT scheduling reliability, safety, and infrastructure quality affect inland navigation. Thus, monitoring timetables and punctuality is vital to preventing increasing costs and supply chain disruption caused by delays.

Access to multimodal transport is weighted the least in this group. Accessing and using multimodal transport is crucial for fostering success and competitiveness in the transport sector as the world economy grows and becomes more interconnected (Saeedi et al., 2022). Integrated multimodal transport systems have been developed using various coordinated and integrated modes of transportation. The findings from this study indicate the relevance of these metrics to the performance of IWT, as access to information about the next leg of the freight journey plays a key role in influencing the competitors of the transport system. Business enterprises can make well-informed decisions regarding routing and scheduling(Hossain et al. (2019). Thus, these metrics are essential for improving the efficiency and cooperation in supply chain activities.

6.4.2. Efficiency and profitability:

Efficiency and profitability as performance metrics for IWT comprise the total cost and expense of river freight, energy efficiency, attractiveness of the transport system, and price alternatives. The most significant priority in this group is the price alternative, with a weight of 0.266. The next is the total cost and expense of river freight, weighing 0.264. energy efficiency and attractiveness of the transport system follow with a weight of 0.26 and 0.21, respectively. Price alternatives are the most significant in this group. According to Konstantinos and Nektarios (2021), prices are a crucial factor in the marketplace and play an essential role in customers buying freight transport services. The finding from this study indicates that price alternatives, such as freight transportation rates or costs, directly impact the efficiency of these systems. In order to optimise shipping efficiency, shipping companies and logistics service providers must find transportation modes that are both cost-effective and maintain high service quality. For example, deciding between a pricier yet faster route and a cheaper but longer one is important to carefully evaluate the trade-off between cost and performance to maintain efficient and timely operations. Hence, price alternatives are crucial as they serve as performance measures, enabling organisations to optimise resource utilisation, decrease transportation expenses, and improve productivity.

River Fright's total cost and expense are ranked second in this group. These metrics offer helpful insight into the financial performance of companies in the IWT sector (Karttunen et al., 2012). By examining expenses such as fuel, labour, maintenance, and overhead, businesses can pinpoint opportunities for cost reduction or enhance operational efficiency. This result shows that monitoring these metrics aids in evaluating the competitiveness of pricing plans, necessitating periodic adjustments to match financial objectives. Therefore, stakeholders are encouraged to observe these metrics to identify areas where operational efficiency can be enhanced, such as by investing in technologies that are more fuel-efficient. The cost breakdown facilitates the assessment of suppliers' performance by finding discrepancies in costs, service quality, and reliability (Wiegmans and Konings, 2015). Organisations may sustain a competitive edge in the market by selling suppliers that offer competitive rates and exceptional services.

The next in line is energy efficiency. This measure quantifies the number of services obtained relative to the amount consumed, typically expressed as a comparative value (Golaka et al., 2022). The finding from this study indicates that energy efficiency as a performance measure entails effectively controlling and limiting energy usage to enhance productivity while avoiding unnecessary wastage, as excessive energy use can adversely affect the economy, society and the environment.

The attractiveness of the transport system is ranked the lowest by weight in this group. The IWT is an appealing alternative for enterprises due to its reliable, cost-effective, environmentally sustainable and efficient performance measures (Flodén et al., 2017; Santén et al., 2021). The services provide secure and punctual delivery, reduce costs per unit via economies of scale, and produce lower GHGs per tonne. As such, business enterprises can gain a competitive advantage in the global economy by utilising the benefits of the transport systems to optimise their supply chain operation.

6.4.3. Environmental impact and decarbonization:

Environmental impact and decarbonisation comprised renewable and alternative energy, ranked as the most significant, weighing 0.229. Next, priorities in this category are the utilisation of incentives and funding for emission reduction with a weight of 0.213, Emission reduction with a priority weight of 0.207, Enforcement/monitoring with a priority weight of 0.193 and noise has the lowest level of importance within this group, as indicated by a weighting 0.158. The transport sector is among the economic sectors responsible for most GHGs in the EU and the UK (Eurostat, 2023; Department for Transport, 2020a). The European Union transport policies aim to lower emission rates from all sectors by 80%, just below 1990 levels until 2050 (Gielen et al. 2019). This result indicates that the utilisation of renewable and alternative energy sources holds the capacity to effectively mitigate the substantial carbon emissions originating from the transportation industry.

The finding also aligns with research by Kalajdzic et al. (2022), who examined the decarbonisation strategies to reduce emissions and promote sustainability in the IWT sector and concluded their studies by emphasising that the use of alternative fuels such as liquefied natural gas and compressed natural gas, gas-to-liquid, biofuel, methanol, ethanol and hydrogen substantially have a substantial impact in reducing local air pollution, hence promoting a more environmentally friendly IWT system. The next generation of propulsion fuels for inland vessels includes low-carbon and renewable biofuels. Since the utilisation of these fuels for inland vessels is a recent development that requires further investigation, this result informs the need for stakeholders to assess its technical feasibility as well as its economic, environmental, and socio-economic advantages. It is possible to obtain adequate economies of scale by sharing fuel infrastructure and powertrain technologies.

The utilisation of incentives and funding for emission reduction was another critical factor in this category. By utilising reliable and alternative energy sources, the technology enhances energy security, lowers GHGs, and promotes economic growth. Nevertheless, the process entails substantial initial expenses, which pose critical challenges that need to be overcome via funding and supportive policies. According to Raftis et al. (2023), the IWT sector needs a structural approach to reduce GHGs and harmful emissions, with a focus on innovation. This result shows that a financial support instrument is crucial for investments, as limited funding for updating and greening inland vessels limits sustainability efforts (Beyer, 2018). Therefore, stakeholders are encouraged to explore the financial opportunities of establishing a sustainability fund and another type of financial assistance at the European level.

Emission reduction was another vital consideration in this group. This result indicates that reducing emissions is a crucial aspect of performance in IWT that needs to be tackled to lessen the sector's environmental consequences. The imperative to reduce emissions is apparent given the industry's substantial role in generating GHGs and its detrimental impact on air quality and maritime well-being (Mako et al., 2021). The result of this study shows that persistent barriers still need to be addressed in achieving coordination, securing financing, and managing the lengthy lifespans of vessels, notwithstanding the advances made by regulatory measures and technical advancements. Hence, stakeholders are recommended to adopt suitable models to enforce more stringent emission regulations, allocate resources to cutting-edge technologies, and promote partnerships that can expedite the shift towards a greener and more suitable IWT industry, yielding advantages for both the sector and the natural environment.

Regulatory enforcement is crucial for upholding order and ensuring safety in the IWT domain. According to Okuma and Enughwure (2022), regulations oversee multiple facets of IWT operations, encompassing navigation, crew training, emergency response, vessel design and construction. However, monitoring is crucial for evaluating adherence, detecting hazards, and improving effectiveness and reliability (Krepak, 2021). Monitoring includes observing and supervising vessels, harbours, and navigational routes using sophisticated technical equipment and human personnel. This result shows that understanding the intelligence and surveillance methods employed to monitor safety and security threats is essential for devising inventive approaches to address the safety and changing risks in the IWT network. Monitoring systems that track vessel emissions and look for possible spills are also essential for environmental protection. Stakeholders understanding these complexities can help develop sustainable practices and eco-friendly policies in IWT operations.

The last within this group is noise, which weighs the least. Comprehending noise pollution in IWT is crucial for optimising performance and sustainability. Senzaki et al. (2020) state that noise pollution poses a significant threat, including detrimental long-term effects on humans, marine life, terrestrial life, and biodiversity. The findings from this study align with those of

Brusselaers and Momens (2022), who indicate that engine operations and propellers mainly cause noise in IWT and can interfere with performance by impeding crew communication, safety and reliability. This result highlights the importance of firms investing efficiently in innovative technologies that significantly decrease noise pollution. Novel solutions encompass quitters' propulsion systems, new insulating material and enhanced engine designs. Electric propulsion systems and noise-reducing coasting improve efficiency and performance. Thus, as a mitigation strategy, stakeholders can engage in effective noise reduction techniques by implementing proactive and reactive actions such as regular maintenance, structural improvement, and raising awareness about noise pollution. These initiatives can reduce damage, enhance vessel design, and promote best practices in the IWT sector.

6.4.4. Infrastructure condition:

Infrastructure conditions, including connectivity (0.154), ranked as the most significant priority in this group, weighing 0.154. Following this are modern fleets for competitiveness (0.15), maintenance of infrastructure (0.143), transhipment facilities for integration (0.14), limited geographical expansion (0.137) and congestion-free transport (0.136) system, which is the least within this group. Enhancing connectivity improves operational efficiency, capacity utilisation, safety, and energy efficiency in IWT (de Langen et al., 2017). Waterway routes play a vital role in enhancing port-hinterland connectivity as well as promoting sustainable freight transport. Nevertheless, several factors affect the efficiency of IWT connectivity, including the quality of port infrastructure, locks, the availability of vessels, and the coordination between IWT and other forms of transportation.

Ports are crucial entry points for global commerce, enabling the transportation of commodities. An advanced port infrastructure with contemporary amenities improves connection, minimising congestion, and delays. Vessel availability and frequency also affect connectivity performance. Integrated transport networks create smooth and reliable links between various modes of transport, improving an area or country's competitiveness in the global market. Enhancing connectivity is essential for boosting completeness, economic development, and sustainable growth in IWT networks. The result of this study indicates that consistent monitoring and assessment of this performance matrix by firms are crucial for making well-informed decisions within this sector. Also, this result informs the need for policymakers and other stakeholders to comprehend the dynamics of connectivity in IWT in order to make informed decisions and investments in the industry.

Next in this group is fleet modernisation for competitiveness. With the expansion of trade and commerce worldwide, it has become essential to match customers' demand. The latest technology and infrastructure are required. Updating the fleet is essential for the effectiveness of IWT because it directly affects the efficiency, safety and sustainability of waterway activities. Puhar (2022) highlighted that upgrading the fleets enhances efficiency through the implementation of innovative technology, such as automated cargo handling system systems, Inland electronic chart display and information system (Inland ECDIS), Notices to Skippers (NtS), Inland (AIS) and Electronic Reporting International (ERI). This optimises transportation, decreases turnaround times and minimises delays. Contemporary vessels are fuel-efficient, which lowers operational expenses and environmental footprint. Advanced communication systems and navigational aids improve safety by decreasing accidents and collisions. This result shows that upgrading fleets helps sustainability efforts by decreasing carbon emissions and encouraging environmentally friendly activities. Thus, maritime firms/business stakeholders are encouraged to invest in fleet modernisation as a strategic decision that provides several benefits to improve their commercial performance and competitiveness while improving their image as environmentally conscious operators.

Infrastructure maintenance is ranked third under this category. Ensuring infrastructure maintenance is essential for IWT operations' safety, effectiveness, and environmental sustainability. It minimises accidents, delays, and interruptions while enhancing overall performance (Boudhoum et al., 2022). Poorly maintained infrastructure can result in reduced reliability, lower service quality, and higher operational expenses. This result shows that infrastructure maintenance is crucial for ensuring the system's effective functioning and investing in maintenance activities that can enhance the efficiency and efficacy of the IWT operation. Utilising eco-friendly materials in maintenance methods reduces environmental impact and enhances the sustainability of the transportation industry (Alias et al., 2020). Hence, IWT operators are encouraged to secure the long-term viability of their operations and support the regional economy by prioritising infrastructure maintenance and making regular maintenance and upgrade investments. On the other hand, stakeholders are urged to prioritise infrastructure repair to improve performance outcomes and establish a sustainable and resilient transportation system.

Next in line is the transhipment facilities for integration. The increasing demand for IWT highlights the necessity of efficient transhipment facilities to maintain the seamless transfer/movement of commodities within the transport system (Mircetic et al., 2017; Tokakura et al., 2022). Transhipment facilities are crucial for the seamless transfer of commodities between different modes of transportation, including vessels, barges, rail, and trucks. More than the availability of facilities is required to guarantee smooth transfer. The strategic location of facilities, especially near waterways, minimises the necessity for long-distance trucks or rail transportation. Improving the transhipment infrastructure of IWT can boost efficiency, resulting in cost savings and increasing reliability, while also enhancing the turnaround times and handling capacity, which can boost profitability and customer satisfaction (Ahadi et al., 2018). Geographical location is another essential aspect of the transhipment facilities, as being strategically positioned near import waterways and transportation routes helps reduce transportation distance and logistics expenses. Thus, IWT operators can enhance competitiveness by prioritising efficiency, capacity, and strategic location of facilities. Also, investing in interconnected infrastructure can optimise the supply chain's resilience and provide adaptable, economical transportation options.

The limited geographical expansion is an essential metric for companies and businesses operating in industries that rely on IWT (Wehrle et al., 2022). This metric provides managers with information to determine areas for growth and improvement, as well as possible risks and obstacles that may affect their expansion efforts by evaluating the company's ability to use IWT to expand into new geographic places. By monitoring these metrics, businesses may boost their competitiveness in the market and achieve sustainable growth and success in today's global economy by successfully navigating regulatory requirements, investing in new infrastructure and technology and utilising the existing waterways infrastructure. These strategies can help them become more competitive in the market.

Congestion-free transport is the least weighted within this group. The importance of efficient and reliable transportation systems grows as global trade expands. This result indicates that congestion in freight transportation can cause substantial delays, increased costs, and adverse environmental effects (Kellner, 2015; Masłowski et al., 2022). Congestion-free transport like the IWT guarantees the smooth and effective operation of freight transport activities on waterways. Efficient freight journeys without congestion are crucial metrics for IWT. Minimising congestion on waterways can enhance efficiency by reducing delays in transporting commodities, particularly time-sensitive cargo, or perishable products, decreasing the environmental impacts by reducing fuel consumption and GHGs, and enhancing safety by minimising collisions and accidents. Thus, it is crucial to ensure that waterway routes are free of congestion in order to optimise performance.

6.4.5. Safety and security:

The safety and security include seaworthiness, navigation safety and route capacity, traffic conditions, weather forecast, and vessel identification. From the analysis, seaworthiness has the highest priority, with a weight of 0.224, followed by navigation safety and route capacity, with a weight of 0.221. traffic condition, weather forecast, and vessel identification 0.177 follow, respectively, with a weight of 0.193, 0.185, and 0.177. Seaworthiness is a vital aspect of maritime transportation, impacting vessel safety, effectiveness, and reliability (Zhang and Philips, 2015). Complying with seaworthiness requirements guarantees safe navigation, reduced accidents, adhering to timetables and completing voyages within predicted timeframes, which is particularly beneficial for shipping firms and logistics providers. In general, seaworthy ships can safely transport various types of cargo, maintaining the security and integrity of the goods while enroute. Trust and confidence in the maritime business are upheld by adhering to seaworthiness requirements (Fulconis and Lissillour, 2021). Thus, all stakeholders should prioritise promoting a safer, efficient, and sustainable IWT system.

The next in this group is navigation safety and route capacity. Ensuring navigation safety and maximising route capacity are essential for the efficient functioning of the IWT system (Hesselbarth et al., 2020). Navigational safety encompasses the safe passage of vessels, installation of navigational aids, and enforcement of regulations. Consistent upkeep and rigorous adherence to speed limits and traffic regulations aid in accident prevention. On the other hand, route capacity is the highest number of vessels that can travel through waterways without experiencing congestion. Route capacity is influenced by factors such as waterway width, depth, the presence of locks and traffic volume (Huy-Tien et al., 2022). These results confirm the fundamental relevance of navigation safety and route capacity in IWT performance. Stakeholders are encouraged to work and collaborate with government agencies, waterway authorities, port operators, and vessel owners to improve navigation safety at all times. While the government can finance infrastructure upgrades, waterway authorities can establish safety protocols, and port operators can invest in technology and vessel owners can guarantee safe vessel operations.

Traffic condition is ranked the third priority in this group. Traffic conditions are crucial metrics such as vessel turnaround times, berth occupancy rates, and port congestion levels that are used to identify bottlenecks and inefficiencies (Zhang et al., 2022). Long waiting times for vessels may suggest congestion, whilst high Beth occupancy rates suggest limitations in port capacity. Thus, monitoring congestion levels enables port authorities to identify capacity limitations and implement measures to enhance efficiency and alleviate bottlenecks, ultimately enhancing overall system performance and port competitiveness.

The next in line in this group is the weather forecast. Weather substantially impacts the organisation and implementation of IWT. It can significantly influence IWT activities such as safety, efficiency, and overall outcome (Christodoulou et al., 2020). Thus, accurate weather forecasts are crucial in decision-making in IWT. Precise prediction assists IWT operators in making well-informed decisions on navigation, seeking shelter, and altering course, thereby averting mishaps and injuries. This result indicates that routes, speeds, and timetables can be optimised to reduce fuel consumption and operating costs, ultimately increasing profitability and competitiveness. Therefore, accurate predictions and weather forecasts assist in planning and decision-making by helping operators anticipate weather changes, identify risks, and plan for contingencies. Weather information can also assist companies and stakeholders in adapting their plans, schedules, and resources to ensure efficient and successful operations. The last in this group is vessel identification, weighing the least in this group. Identifying vessels is essential in the IWT sector for safety, security, regulatory adherence, environmental conservation, port security, and logistics efficiency (Nzengu et al., 2021). The identification allows appropriate authorities to monitor and track vessel movements, avoid accidents, and respond to emergencies accordingly. It also aids in combating piracy, smuggling, and unlawful operations. Identifying vessels also guarantees adherence to regulations, environmental laws, and port security. Thus, this metric is vital as it can assist port authorities in monitoring vessel capacity usage, organising port operations, and managing cargo handling tasks. It enables effortless collaboration among those involved, guaranteeing efficient IWT activities.

6.4.6. Innovative transport technology:

Innovative transport technology comprises information and communication flow along the supply chain with the highest priority, with a weight of 0.234. The next in line in this category is hierarchical tracking and data tracing at the logistic unit level, weighing 0.225. This is followed by voyage planning(0.194), interoperability with customers' systems (0.187), and shoreside data availability, which are weighed the least, with a weight of 0.159.

The most significant priority within this group is information and communication flow along the supply chain. The performance of IWT is affected by the real-time availability of information using ICT tools such as GPS, RIS tracking and IoT devices (James et al., 2020; Durajczky and Piotr, 2022). Better access to and sharing transport information allows stakeholders to make well-informed decisions, enhance route planning, and mitigate hazards. This result shows that efficient communication among all stakeholders is essential for seamless operations. Due to this industry's growth, complexity, and amount of data, the use of ICT technologies to make operations and decision-making efficient is paramount. Thus, stakeholders are encouraged to invest in developing digital tools as these ICT tools facilitate the collection and analysis of data, helping to identify bottlenecks and areas that need development. They improve safety and security through real-time monitoring and tracking of vessels and cargo. These techniques help with quick response and crisis control, minimising potential effects on human life and the environment. Using ICT solutions, stakeholders can enhance operations, foster collaboration, and stimulate innovation in the IWT sector.

The next in line in this category is hierarchical tracking and data tracing at the logistic unit level, ranked second within this group. Tracking and tracing contribute to operational efficiency and competitive advantage in the global market (Gkoumas et al., 2020). In the IWT domain, just like with road and rail transport, tracking and tracing are preserved as valuable performance metrics as they enhance real-time visibility, transparency, and security. This result shows that hierarchical tracking and data tracing are essential metrics as they help monitor ship and container movements to detect possible delays and interruptions, enabling corporations to implement pre-emptive actions. The structure also offers vital information on vessel performance, fuel usage, and maintenance needs, which helps improve operations and lower expenses (Specht et al., 2020). Although the concept of tracking and tracking is new in the IWT domain (Durajczyk and Piotr, 2022), fully utilising the system can benefit all parties involved in the transportation chain through improved security and compliance by identifying unauthorised operations while assuring adherence to international/local regulations. Companies can enhance operational efficiency, cut costs, and boost customer satisfaction by accurately monitoring and tracing shipments.

The next in line is voyage planning. Voyage planning is crucial for reducing the future of IWT and ensuring its viability in a continuously changing global economy. The voyage planning process requires meticulous coordination and evaluation of multiple aspects to guarantee the safe and effective transportation of goods on water routes (Munuzuri et al., 2019). This includes optimising routes, arranging cargo stowage, and ensuring regulatory compliance. An effective route planning process takes into account variables such as weather conditions, traffic congestion, and port accessibility in order to save both trip time and fuel usage. Therefore, efficient cargo stowage is essential for ensuring stability and safety and can be enhanced through the utilisation of innovative technologies and data analysis. By adhering to laws, companies operating in the waterway domain can showcase dedication to industry norms and public safety.

Within the innovative transport technology category, interoperability is ranked fourth. Interoperability with customers' systems improves IWT systems by offering up-to-date details on the status and location of shipments, facilitating well-informed decisions and streamlining supply chain operations (Asborno et al., 2022). This result indicates that interoperability is a crucial aspect of seamlessly sharing data. It enables the smooth integration of various systems and technologies, improving communication and data sharing among stakeholders and making all those involved in decision-making more transparent and accountable. However, it must also be acknowledged that implementation issues arise due to the absence of standardisation and interoperability among systems, as well as the high cost and complexity of implementing these indicators, especially for smaller enterprises with limited resources. Nevertheless, interoperability metrics offer significant advantages that surpass the associated costs, establishing them as crucial instruments for the future of IWT (Specht et al., 2020). Thus, stakeholders are encouraged to invest in this system's development and implementation.

The least weighted in this group is data availability on the shoreside. Data availability on the shoreside ensures IWT efficiency, reliability and safety (Niedzielski, 2022). Shoreside operators can increase decision-making and improve operational performance by measuring and monitoring data availability indicators. IWT enterprise can utilise innovative technologies and best practices to overcome data availability difficulties and improve IWT operations. Stakeholders should also focus on improving data availability on the landside, which is crucial for fully realising the potential of IWT in the digital era.

6.4.7. Economic development:

Economic development comprised employment which have the highest priority, with a weight of 0.294. The next in line in this category is the transportation system's development, weighing 0.266. This is followed by marketing and aggregated added value with a weight of 0.222 and 0.219, respectively. Employment in the IWT sector is vital for economic growth and development. It indicates the need for shipping services and impacts global trade, volumes, consumer consumption habits, and industrial production (Meersman et al., 2020). An expanding job market signifies a robust and dynamic industry with the potential for heightening business prospects and investment. Government agencies and stakeholders can use the employment data to evaluate the competitiveness and efficiency of IWT networks, pinpoint skill gaps, and establish specific training initiatives. Thus, a strong job market benefits local economies and communities by encouraging ethical corporate practices and decreasing social disparity. Relevant authorities can also use employment statistics to assess policy actions and strategic investments.

The transportation system's development is ranked second in this group. Transport is acknowledged as a crucial element in economic progress, and IWT has significantly promoted economic growth and development in its operational regions (Lenz et al., 2018; Šev˘ceko-Kozlovska and Cižiuniene, 2022). Economic development in the context of IWT provides a comprehensive view that sheds light on the overall competitiveness and attractiveness of the sector. The transportation system's development encompasses measures such as shipping volume, capacity utilisation per loaded kilometre, annual GDP growth rate, and the total number of investments in property categorised as gross investments. Hence, stakeholders can pinpoint opportunities for development and put plans into action to improve the performance of the IWT sector by keeping an eye on and evaluating this variable. By adopting these metrics, policymakers may make well-informed decisions to facilitate the expansion and advancement of IWT in a fast-changing global economy by utilising the data and insights derived from these indicators.

Marking is ranked third in this group. Marketing is crucial for firms and businesses that move goods by water as it aids in recruiting and retaining customers, increasing market visibility, and enhancing revenue and profitability (Kaup and Wiktorowska-Jasik, 2018). The finding from this study indicates that firms can both draw in new customers and keep their current ones by targeting certain market segments through customised advertising campaigns and loyalty programmes. Analysing market trends and competitors' strategies helps organisations develop unique services and promotions, giving them a competitive advantage (Nistor and Popa, 2019). Therefore, by examining essential marketing indicators, including the cost of acquiring clients and marketing return on investments, firms can evaluate the efficiency of their marketing strategies.

Aggregated added value is the least ranked in this group. The aggregated added value performance metric for IWT industries takes into account both direct and indirect economic advantages, such as income generated by IWT, tourism and fishing (Hernández, 2022). It thoroughly assesses the economic value produced by these activities, emphasising their complete economic influence. Investors, policymakers, and stakeholders are urged to consider these metrics because they help pinpoint areas for enhancement and investment, including suitable practice in IWT or responsible tourism, to increase economic results while reducing environmental and societal effects.

6.4.8. Policy formulation and implementation for IWT:

Policy formulation and implementation for IWT comprises knowledge transfer and best practices, which have the highest priority, with a weight of 0.170. The following priorities are assigned to education and skill development (0.151), administrative support for modal shift to inland waterways (0.146), incentives and grants for modal shift (0.14), logistic cluster formulation and collaboration (0.137), integrated transport policy (0.13) and existing legislative framework for modal shift to inland waterways (0.127) with the least weight in this group.

Knowledge transfer and best practices are essential metrics for evaluating the efficiency and effectiveness of transport operations (Pinto et al., 2019). This measure consists of several techniques, processes, and technologies that have been demonstrated to improve the overall performance of the transport business. In the domain of IWT, best practices encompass safety, efficiency, sustainability and innovation (Denise and Putz-Egger, 2022). The result of this study indicates that knowledge transfer and best practices are crucial performance metrics for improvement. Relevant authorities, stakeholders, and transport operators are encouraged to adopt best practices to improve and optimise performance.

Implementing safety rules, training programmes and risk management techniques can decrease accidents and incidents, safeguard personnel, and improve the company's reputation. On the other hand, efficiency is essential for improving procedures, optimising routes, and incorporating advanced technology, and sustainability is crucial for reducing environmental impact and appealing to eco-conscious clients. Adopting innovation, such as digitalisation, automation, and data analytics, can improve firms' processes and performance. By prioritising these practices, firms can enhance their operations, increase profitability, and attain long-term success. Companies can become leaders in the competitive global market of the IWT sector by following industry best practices and consistently looking for methods to improve performance.

The next priority within this group is education and training. Education in the IWT sector ensures adherence to rules, promotes safety, and fosters critical thinking skills (Vidan et al., 2012; Praveen and Jegan, 2015; Tournaye, 2022). Proficiency indicators such as navigation, communication, and problem-solving are crucial for effective vessel operations. Education and skill performance evaluation can be conducted through examinations, certification, training programmes, simulations, on-the-job assessments, and feedback from supervisors and peers (Pfoser et al., 2018; Santen et al., 2021). These metrics are essential for the success of the IWT business as industry stakeholders can pinpoint areas of enhancement and implement necessary changes by closely monitoring and analysing these indicators.

Administrative support for the modal shift to waterways is ranked third within this group. Administrative support is essential for supporting the shift from roads to waterways

(Grezelakowski, 2019). The administrative process can be accomplished through subsidies, incentives, and legislative measures (Totakura et al., 2020). Better use of all transport infrastructure can be fully achieved. Administrators can balance expenses and create a favourable environment by providing financial incentives and prioritising IWT. Relevant authorities and stakeholders can tackle infrastructure constraints and regulatory hurdles through administrative support. Improving waterway infrastructure and standardising laws can simplify the transition process. Encouraging a transition in transport modes can improve efficiency, sustainability, economic growth, and competitiveness.

Incentives and grants are ranked fifth within this group. Offering incentives and grants to encourage modal shifts is crucial for advancing sustainable and efficient transportation modes (Roso et al., 2020). IWT modal shift can be accomplished by utilising intermodal solutions, which incorporate several modes of transportation. By providing incentives for intermodal transport, minimising empty container movements, and advocating for sustainable transportation practices, stakeholders can boost transportation efficiency, decrease environmental impact and enhance supply chain sustainability. This result supports some findings by Kruse et al. (2014) and Rogerson et al. (2020), who emphasised that incentives and grants are vital to the smooth functioning of the transport system as these funds encourage enterprises to move their goods to waterways while also supporting research and development, which can promote innovation and advancement towards a more sustainable future. In addition, cooperation and collaboration among policymakers, industry stakeholders, and consumers are essential to establishing a conducive environment for promoting a modal shift to waterways, thereby fostering a more sustainable future for the freight transportation sector.

Logistic cluster formulation and collaboration are the next in line. Developing a logistic cluster framework is essential for optimising IWT efficiency by engaging important players and fostering cooperative partnerships (Kotowaska et al., 2018). The finding from this study indicates that Logistic cluster formulation and collaboration are vital metrics for IWT performance. It improves efficiency by simplifying operations, minimising delays, optimising routing and scheduling decisions, and strengthening risk management abilities (Santen et al., 2021). Organisations can enhance on-time delivery performance by analysing elements such as shipping routes, vessels, capacities, and port capabilities to reduce transit times and costs. Stakeholders adopting this proactive strategy can ensure the smooth flow of the supply chain and reduce the effects of unexpected events on operations.

Performance metrics for integrated transport policy are crucial for evaluating the effectiveness of IWT and informing policy decisions to enhance its sustainability, efficiency, reliability, safety and security. (Grzelakowski, 2019). Policymakers can utilise these measures to identify strengths and weaknesses in the transport system, set improvement objectives, and monitor progress over time. Well-crafted and compelling policies can bolster the sustainability of IWT and enhance the effectiveness of integrated transport plans.

The existing legislative framework for a modal shift to inland waterways is ranked the least in this group. The EU has established regulatory frameworks to promote a transition to IWT, with regional programmes such as the CEF projects supporting this transition (Mihic et al., 2011; Mihic et al., 2012; Caris et al., 2014; Schoneich et al., 2022). The existing legislative framework provides a solid basis for encouraging a modal shift to IWT. By implementing regulations, offering financial support, and creating incentives for companies to move goods via waterways, this structure not only aids in the expansion and durability of the IWT industry but also enhances the effectiveness and eco-friendliness of the transportation network (Williamson et al., 2020). Thus, policymakers, stakeholders and transport operators are encouraged to collaborate and innovate in order to develop and reinforce the current legislative framework for an effective shift to waterways.

6.5. TOPSIS Method

The prior section computed the relative weight of essential performance factors in IWT. This section will continue with the result. The following actions are taken to rank the UK's IWT with four others European IWT's using TOPSIS.

6.5.1. Identify the decision-making alternative (Step 1)

IWT has reinforced its reliance on maritime access even more strongly than in the past. According to the rhythms of increasing pressure from the globalisation market flow, European seaports with suitable inland waterway network connectivity form an interface. The use of inland waterways as supplementary transport has grown with an increase in the share of waterborne transport in the Netherlands, Belgium, Germany, and France. Here, inland shipping offers various freight forwarding solutions and has been increasingly integrated into contemporary logistics chains due to the volume of handled goods.

6.5.2. Identify the criteria that will be used to assess the alternative (Step 2)

An expert opinion survey was sought through a questionnaire to determine the selected alternative. The quality of the expert judgment is built based on their proficiency, capability, experience, and knowledge. The experts comprised industry practitioners, academicians and professionals working in IWT agencies with knowledge and experience in the relevant area.

6.5.3. Gathering data through the use of TOPSIS survey (step 3)

An expert opinion survey was sought through a questionnaire to determine the selected alternative (see Appendix IV). The quality of the expert judgment is built based on their proficiency, capability, experience, and knowledge. The experts comprised industry practitioners, academicians and professionals working in IWT agencies with knowledge and experience in the relevant area. Table 6.6 provides the expert's respondent profiles.

6.5.4. TOPSIS survey (Step 4)

Relevant data was gathered for TOPSIS analyses. To capture the experts' opinions from the inland waterway transport-related sectors, a questionnaire constructed in step 3 was developed and completed. In contacting appropriate experts, steps similar to those used for the fuzzy AHP were taken in the earlier section of this chapter.

6.5.5. Alternative ranking using the accumulated data (Step 5)

The procedure followed for the TOPSIS is as the follows:

IX. Establish a decision matrix.
X. Construct normalised decision matrix.
XI. Determine the weighted normalised decision matrix.
XII. Determine the positive ideal and negative ideal solutions.
XIII. Calculate the relative closeness to the idea solution.
XIV. Calculate the separation measures for each alternative.
XV. Calculate the relative closeness to the idea solution CC_i

XVI. Rank the alternatives.

6.6. Choosing the appropriate rating values for alternatives with regards to the criteria

In this study, experts were consulted to construct an evaluation matrix using the scale presented in Table 3.13 for subjective judgment. The study utilises the basic preference for this work: Low (L), Below average (BA), Average (A), Good (G) and Excellent (E). Thus, the judgement scale is used to measure the performance of the identified criteria.

6.6.1. Case study to determine the ranking of alternative.

The method adopted for the fuzzy AHP has already been established in the previous section of this chapter. In this case, the subjective knowledge and judgement of experts in the field provide data for analysis through a combination of fuzzy AHP and TOPSIS. With this in mind, the following section gives a detailed explanation of the TOPSIS-based approach.

6.6.2. Alternative rating of performance for decision-making using the accumulated data from TOPSIS.

The TOPSIS procedure comprises various steps that utilise the weights calculated in fuzzy AHP to determine the alternative rankings provided by experts.

6.6.2.1. Experts profile

Expert surveys were used to provide quantitative data for this section. The questionnaire survey was conducted over five weeks, from 15th Dec to 17th Jan 2023. The respondents were selected based on their involvement or professional knowledge in intermodal transport, IWT or supply chain management related to this research's objectives. Respondents of this survey were contacted in advance to determine if they would participate in a further survey to increase the valid and completed survey rate. The main sets of inclusion criteria to serve experts participating in the opinion survey aimed to identify individuals with equal interest, knowledgeable background, and a wealth of experience operating intermodal IWT and supply chain management.

The study conducted a content validity assessment on the questionnaire before distributing it for data collection to verify its relevance, simplicity, and clarity (Hilton, 2017). The supervisory teams examined the initial drafted version of the questionnaire to comment on the appropriateness and clarity of the question. The questionnaire was modified and approved based on the teams' feedback. A cover note was attached at the beginning of the questionnaire, describing the study's main aims and assuring the participants of the strict confidentiality and anonymity of the data supplied in the questionnaire, which is safeguarded under the Liverpool John Moores University Ethical Guidelines.

Next, a pilot study was conducted to address the questions' content ambiguity and other biases. Finally, after the pilot study, the revised questionnaire was circulated to experts by email for data collection. A high percentage of valid responses were received within five weeks. Table 6.6 presents the distribution of experts who participated in the opinion survey in terms of their background, geographical location, and knowledge of their field.

Table 6-6: Survey respondent profile

No	Expertise	Position	Method	Country of Operation
1	Inland waterway project delivery partner	Project Head	Email	Antwerp, Hamburg, and UK
2	Consultants working in supply chain	Consultants	Email	Europe and the UK
3	Marine experts (inland port official)	Port officer	Email	Europe (Rhine and Danube)
4	Project officer/partner	Partner	Email	UK and Hamburg
5	Inland waterway project delivery partner	Head of section	Email	Seine region
6	Academician from transport and logistic background	Head of stimulator	Email	The Netherlands
7	Legitimising agent	IWT agent	Email	Netherlands
8	Inland waterway project delivery partner	Partner	Email	Belgium and the UK

9	Inland waterway project delivery partner	Partner	Email	Europe
10	Maritime transport experts	Marine of operations	Email	Belgium and Antwerp
11	IWT Logistic service company	Consultant	Email	Europe
12	Maritime transport experts	Consultant	Email	Worldwide
13	Academician from transport and logistic background	Senior lecturer	Email	Antwerp and Belgium
14	Waterway agency	Clearing and forwarding	Email	Rhine port

Source: Author work

6.6.3. Identification of the decision-making alternative

The inland waterway transport has reinforced its reliance on maritime access even more strongly than in the past. The maritime gateways that have been selected as alternatives to be included in this model are:

- France (Seine gateway)
- The Netherland (Rotterdam gateway)
- Germany (Hamburg gateway)
- Belgium (Antwerp gateway)
- UK (Thames and Liverpool/Manchester Ship Canal)

These maritime gateways have been chosen as they reflect Chapter four's outputs and carry the most freight by volume in this geographical area. In particular, they were chosen because these gateways showed similar features of river-sea connectivity and played a significant role in transporting intermodal shipping containers. The integration of waterways into the freight transportation network in these case study countries resulted in more complex organisational structures where the benefits of cost, capacity, and regularity are utilised.

6.6.4. Utilise the collected data to establish the ranking of alternative.

Once the data has been collected, it was used to rank the priority order of the selected alternatives. This was done by utilising the TOPSIS methodology. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is used to rank the priority order of several alternatives. It can be realised as outlined in Chen (2011).

To follow this approach, the formula contains the steps as follow.

Step I: Construct normalised decision matrix.

Various attribute dimensions are transformed in this step into non-dimensional attributes, allowing comparisons over criteria. Eq. (3.20) is utilised to calculate the normalised score, and the output is presented in Table 6.8

Step II: Construct the weighted normalised decision matrix.

A weighted evaluation matrix is obtained in this step. Eq. (3.21) is used to build the weighted evaluation matrix using the priority weight determined by fuzzy AHP in the previous section. Table 6.9 displays the results of this process.

Step III: Determine the positive ideal and negative ideal solutions.

The Positive Ideal Solution (V_{j+}) and Negative Ideal Solutions (V_{j-}) are identified by locating the highest and lowest values in each column of the weighted normalised decision matrix. In this study, Eq. (3.22) and Eq. (3.23) are used to calculate the positive ideal solution (PIS) and negative ideal solutions (NIS). Table 6.10. presents each criterion's PIS and NIS.

Step IV: Calculate the separation measures for each alternative.

The distance between each alternative, the PIS, and the NIS is determined by computing the Euclidean distance between the alternative and the ideal solution. This is accomplished using Eq. (3.25).

The formula denotes D_{i+} as the Euclidean distance between a solution and the PIS. The Euclidean distance between a solution and the NIS is calculated using Eq. (3.26).

In this study, both of these formulas were utilised with the current data. This method used the outcomes from step II, which involved calculating the weighted normalised choice matrix, and step III, which determined the PIS and the NIS.

Step V: Calculate the relative closeness to the idea solution $\mathrm{CC_i} *$

This step calculates the relative closeness of the ideal solution of each alternative by using Eq. (3.27). A relative degree of closeness close to 1 indicates that the alternative is closer to the PIS and distant from the NIS.

The formula CC_{i+} denotes the relative closeness of the alternative to the ideal solution. Eq. (3.27) was used on the data obtained from step e to compute the separation distance of each alternative PIS and NIS. Table 6.11 presents the results of each alternative's relative degree of closeness to the ideal solution.

Step VI: By comparing $CCi *$ values, the ranking alternatives are determined.

The ideal alternative is determined by ranking the calculated value from step v in descending order and identifying the highest value of CC_i (closest to 1). The relative degree of each alternative's closeness to the ideal solution and its ranking is presented in Table 6.12.

Table 6-7: Decision matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22
France (Seine Gateway)	1.8125	2.4375	1.625	1.8125	1.5	1.625	1.625	1.625	2	2.0625	1.8125	1.875	2.0625	1.875	1.75	2.4375	1.875	1.625	1.875	1.6875	1.75	1.4375
Netherlands (Rotterdam Gateway)	2.4375	2.6875	2.4375	2.4375	2.25	2.5625	2.0625	2.25	2.5s	2.5625	2.375	2.0625	2.25	2.1875	2.4375	2.5625	2.0625	2.3125	2.25	2.25	2.375	2.4375
Germany (Hamburg Gateway)	2.625	2.4375	2.5625	2.3125	2.5	1.8125	2.5	2.4375	2.125	1.9375	2.375	2.3125	2.125	2.25	2.5625	1.8125	2.25	2	2.6875	1.6875	1.8125	2.1875
Belgium (Antwerp Gateway)	1.875	2.0625	1.8125	2.0625	2.0625	1.75	1.875	1.9375	1.75	2	2.25	2.0625	2.4375	2.125	2.0625	2.5625	2.125	2.0625	1.875	2.1875	2	1.6875
UK (Thames/Liverpool/Manchester Gateway)	1.5625	1.9375	1.5	1.9375	2	1.6875	1.75	1.625	1.5	1.5625	1.5	1.75	1.6875	1.3125	1.25	1.5625	2	1.6875	1.5625	1.5625	1.625	1.1875

	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40	S41	S42	S43
France (Seine Gateway)	2.0625	1.9375	1.8125	2.1875	1.6875	2.1875	1.875	2.125	2.375	2.375	1.8125	2.125	1.875	2.3125	2.0625	1.5625	2.3125	1.75	1.875	2	2.1875
Netherlands (Rotterdam Gateway)	2.625	2.4375	2.4375	2.5	2.4375	2.25	2.0625	2.25	2.25	2.75	2.6875	2.4375	2.125	2.5625	2.4375	2.375	2.5	2.125	2.4375	2.75	2.1875
Germany (Hamburg Gateway)	2.625	2.25	2.0625	2	2.875	2.125	2.0625	2.25	2.125	2.5625	1.9375	1.9375	2.1875	2.125	2.125	1.75	2.0625	2.3125	2.0625	1.9375	2.125
Belgium (Antwerp Gateway)	2.3125	2.1875	2.4375	2	1.9375	1.8125	2	2.1875	1.9375	1.9375	1.8125	1.8125	1.75	2.25	1.9375	1.5625	2.3125	2.125	2	2.125	1.75
UK (Thames/Liverpool/Manchester Gateway)	1.5625	1.6875	1.5625	1.4375	2	1.5	1.6875	1.625	1.375	1.625	1.6875	1.6875	1.75	1.5	1.5625	1.375	1.875	1.4375	1.25	1.5625	1.5

Table 6-8: Normalised decision matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
France (Seine Gateway)	0.386	0.468	0.357	0.381	0.321	0.379	0.366	0.363	0.446	0.45	0.387	0.415	0.434	0.424	0.378	0.489	0.406	0.372	0.402	0.398
Netherlands (Rotterdam Gateway)	0.519	0.516	0.536	0.513	0.482	0.597	0.464	0.503	0.558	0.559	0.508	0.456	0.473	0.494	0.527	0.515	0.446	0.529	0.482	0.531
Germany (Hamburg Gateway)	0.559	0.468	0.563	0.487	0.535	0.423	0.563	0.545	0.474	0.423	0.508	0.512	0.447	0.508	0.554	0.364	0.487	0.458	0.576	0.398
Belgium (Antwerp Gateway)	0.399	0.396	0.399	0.434	0.442	0.408	0.422	0.433	0.391	0.436	0.481	0.456	0.512	0.48	0.446	0.515	0.46	0.472	0.402	0.516
UK (Thames/Liverpool/Manchester Gateway)	0.333	0.372	0.33	0.408	0.428	0.393	0.394	0.363	0.335	0.341	0.321	0.387	0.355	0.296	0.27	0.314	0.433	0.386	0.335	0.368

	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40	S41
France (Seine Gateway)	0.405	0.348	0.406	0.409	0.388	0.476	0.339	0.49	0.432	0.452	0.52	0.464	0.401	0.471	0.431	0.475	0.451	0.397	0.465	0.396	0.427
Netherlands (Rotterdam Gateway)	0.55	0.59	0.517	0.515	0.521	0.544	0.489	0.504	0.475	0.479	0.493	0.538	0.595	0.54	0.488	0.526	0.533	0.604	0.503	0.481	0.555
Germany (Hamburg Gateway)	0.42	0.53	0.517	0.475	0.441	0.435	0.577	0.476	0.475	0.479	0.465	0.501	0.429	0.43	0.503	0.436	0.465	0.445	0.415	0.524	0.47
Belgium (Antwerp Gateway)	0.463	0.409	0.455	0.462	0.521	0.435	0.389	0.406	0.46	0.466	0.424	0.379	0.401	0.402	0.402	0.462	0.424	0.397	0.465	0.481	0.456
UK (Thames/Liverpool/Manchester Gateway)	0.376	0.288	0.307	0.357	0.334	0.313	0.402	0.336	0.388	0.346	0.301	0.318	0.374	0.374	0.402	0.308	0.342	0.35	0.377	0.325	0.285

Table 6-9: Weighted normalised matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
France (Seine Gateway)	0.065	0.085	0.055	0.066	0.053	0.061	0.097	0.094	0.094	0.12	0.08	0.095	0.092	0.082	0.06	0.075	0.057	0.056	0.055	0.057
Netherlands (Rotterdam Gateway)	0.087	0.093	0.083	0.088	0.079	0.096	0.123	0.131	0.117	0.149	0.105	0.104	0.101	0.095	0.083	0.079	0.062	0.079	0.066	0.076

	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40	S41
France (Seine Gateway)	0.056	0.049	0.078	0.09	0.069	0.107	0.063	0.115	0.069	0.102	0.097	0.09	0.088	0.125	0.127	0.105	0.066	0.05	0.065	0.067	0.059
Netherlands (Rotterdam Gateway)	0.075	0.083	0.1	0.114	0.092	0.122	0.091	0.118	0.075	0.108	0.092	0.104	0.13	0.144	0.144	0.117	0.078	0.077	0.07	0.082	0.076

Germany (Hamburg Gateway)	0.094	0.085	0.087	0.084	0.088	0.068	0.149	0.142	0.1	0.112	0.105	0.117	0.095	0.098	0.088	0.056	0.068	0.069	0.078	0.057
Belgium (Antwerp Gateway)	0.067	0.072	0.061	0.075	0.073	0.065	0.111	0.113	0.082	0.116	0.1	0.104	0.109	0.093	0.07	0.079	0.064	0.071	0.055	0.074
UK (Thames/Liverpool/Manchester Gateway)	0.056	0.067	0.051	0.07	0.071	0.063	0.104	0.094	0.07	0.091	0.066	0.089	0.076	0.057	0.043	0.048	0.061	0.058	0.046	0.053

Germany (Hamburg Gateway)	0.058	0.074	0.1	0.105	0.078	0.098	0.107	0.111	0.075	0.108	0.087	0.097	0.094	0.114	0.148	0.097	0.068	0.056	0.058	0.089	0.064
Belgium (Antwerp Gateway)	0.063	0.057	0.088	0.102	0.092	0.098	0.072	0.095	0.073	0.105	0.079	0.073	0.088	0.107	0.118	0.103	0.062	0.05	0.065	0.082	0.062
UK (Thames/Liverpool/Manchester Gateway)	0.052	0.04	0.059	0.079	0.059	0.07	0.074	0.079	0.062	0.078	0.056	0.062	0.082	0.1	0.118	0.068	0.05	0.044	0.053	0.055	0.039

Table 6-10: The positive and negative ideal value

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22
Positive ideal	0.094	0.093	0.087	0.088	0.088	0.096	0.149	0.142	0.117	0.149	0.105	0.117	0.109	0.098	0.088	0.079	0.068	0.079	0.078	0.076	0.075	0.083
Negative ideal	0.056	0.067	0.051	0.066	0.053	0.061	0.097	0.094	0.07	0.091	0.066	0.089	0.076	0.057	0.043	0.048	0.057	0.056	0.046	0.053	0.052	0.04

	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40	S41	S42	S43
Positive ideal	0.1	0.114	0.092	0.122	0.107	0.118	0.075	0.108	0.097	0.104	0.13	0.144	0.148	0.117	0.078	0.077	0.07	0.089	0.076	0.088	0.065
Negative ideal	0.059	0.079	0.059	0.07	0.063	0.079	0.062	0.078	0.056	0.062	0.082	0.1	0.118	0.068	0.05	0.044	0.053	0.055	0.039	0.05	0.044

Source: Author work

Table 6-11: Distance to positive and negative ideal points

	Distance to positive ideal	Distance to negative ideal
France (Seine Gateway)	0.161	0.119
The Netherlands (Rotterdam Gateway)	0.042	0.222
Germany (Hamburg Gateway)	0.096	0.186
Belgium (Antwerp Gateway)	0.14	0.131
UK (Thames/Liverpool/Manchester Gateway)	0.235	0.023

Source: Author work

6. 7. Results from TOPSIS

This section collected quantitative data from industry experts for this case study. It then processed this data through the TOPSIS. The case study results are represented in section 6.6.3.

6.7.1. Ranking of alternatives through the TOPSIS

Industry experts were sought to collect relevant data for this section. Data were further processed using TOPSIS, which produced the results of this case study. Table 6.11 and Figure 6.2 show the results.

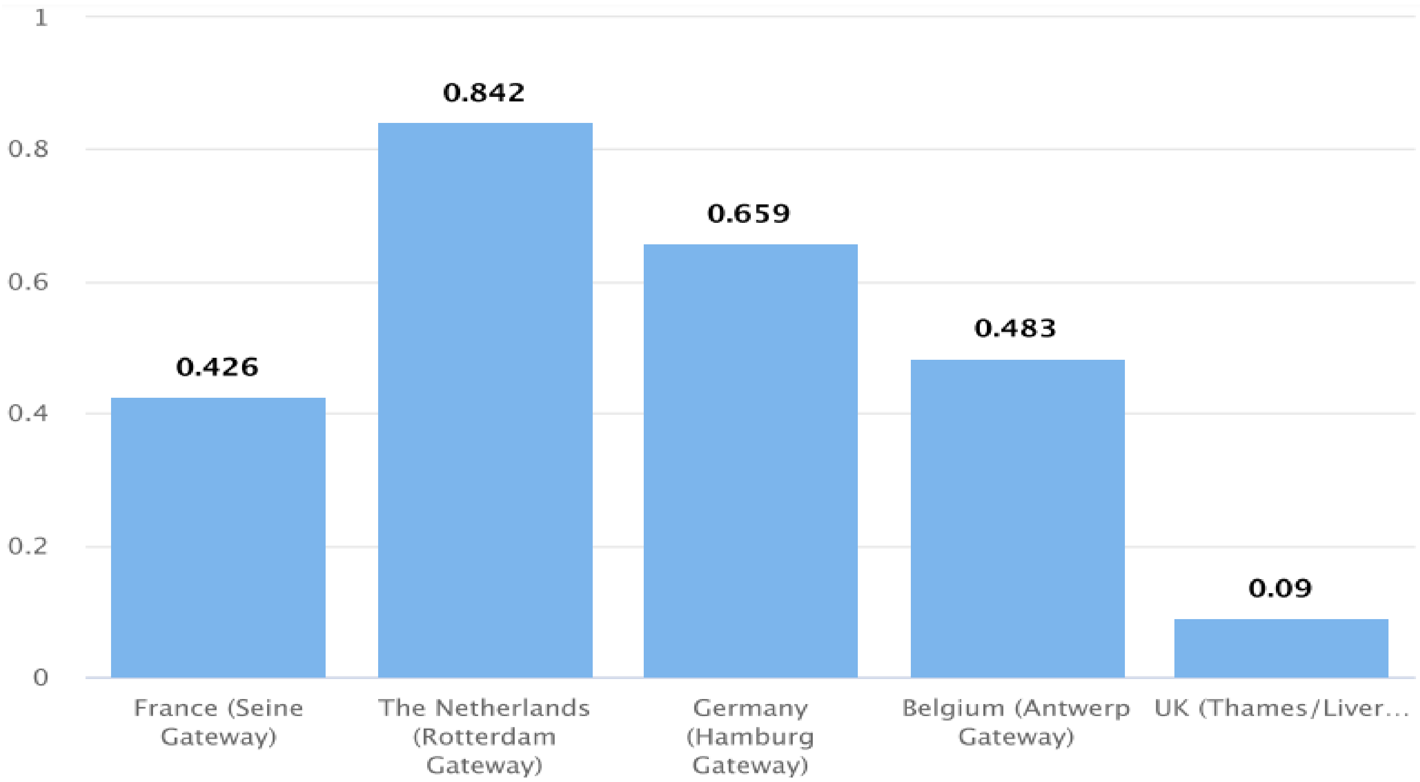

Figure 6-2: The shows C_i value

Source: Author work

Table 6-12: The C_i value and ranking

	C_i	**Rank**
France (Seine gateway)	0.426	4
The Netherlands (Rotterdam gateway)	0.842	1
Germany (Hamburg gateway)	0.659	2
Belgium (Antwerp gateway)	0.483	3
UK (Thames/Liverpool/Manchester gateway)	0.09	5

Source: Author work

6.7.2. Selection of alternatives

IWT has reinforced its reliance on maritime access even more strongly than in the past. According to the rhythms of increasing pressure from the globalisation market flow, European seaports with suitable inland waterway network connectivity form an interface. The use of inland waterways as supplementary transport has grown with an increase in the share of waterborne transport in the Netherlands, Belgium, Hamburg, and France. As a direct result, the IWT players have become more integrated into modern logistics systems due to increased freight volume and the integration of supply chains in these regions. The advancements are compelling the IWT industry to adapt and redefine its operations and strategic positionings. In these case study countries, incorporating waterways into the freight transportation network has led to the development of increasingly complex organisational structures that leverage cost, capacity, and regularity advantages. The IWT offers various freight-forwarding solutions and shows better adaptability and flexibility than the rail network.

Meanwhile, the UK has an inland waterway infrastructure that lies dormant. These waterways are feasible with sustainable commercial benefits, enabling the waterways to be used for freight transportation and significantly contributing to sustainable transport development. However, IWT has played a marginal role in the UK freight transportation system. Since the advantages of moving much freight onto waterways are apparent and consistent with government priorities in the UK, especially with environmental policies, a solid rationale exists to support waterways for freight transportation. In particular, all the case studies chosen in this study showed similar and comparable features of river-sea connectivity and played a significant role in transporting intermodal shipping containers via waterway.

6.7.3. Significance of the order of preference

The study used the weight created by fuzzy AHP, and the TOPSIS method delivered an order of preference for the maritime freight and logistics gateways used as a case study of this research. The European Commission's white paper roadmap aims to optimise the performance of a multimodal logistic chain by shifting 30% of road freight over 300 km to other modes like rail or water transport by 2030 and over 50% by 2050.

Since the publication of the European transport white paper "Transport Policy for 2010:Time to Decide", various initiatives and measures have been proposed to tackle these challenges, including rebalancing the modal split, revitalising and boosting waterways for freight transportation use, and integrating their use as a vital part of the intermodal transport socio-economic development in terms of traffic congestion, safety and environmental issues and economic system. As part of the concept, inland waterway links were proposed with other transport modes (Road, rail and short sea shipping), providing accessible, safe, green, and environmentally friendly alternative transport. Over the years, several action programmes, cost benefits and modal shift projects have been carried out to support the ambitious aim. However, using inland navigation as a sustainable alternative for freight transport differs at the country level due to geographical prerequisites. Nevertheless, findings from the study show that European seaports with good waterway connectivity have increasingly integrated inland waterways into their contemporary logistics chain.

As shown in Figure 6.5, The Netherlands (Rotterdam gateway) has the highest performance in terms of freight transportation via waterways (closeness coefficient 0.842), followed by Germany (Hamburg gateway), with a closeness coefficient of 0.842, Belgium (Antwerp gateway) came third with a closeness coefficient 0.483, next was France (Seine gateway) with a closeness coefficient of 0.426 and the least among this gateways was the UK (Thames/Liverpool/Manchester) with a distance closeness coefficient of 0.09. Statistics revealed that while the four European case study countries were high, the corresponding value for the UK regional gateways remained very low. The margin by which the Netherlands, Germany, Belgium, and France lead the UK shows how these countries and their strategic positioning have adapted inland shipping operations, aligning with the demands and dynamics of the global market. Here, the competitive business environment compels decision-makers to possess a profound comprehension of the critical aspects influencing performance in the industry to ensure adequate improvement. From the UK perspective, the result illustrates the level of effort required to be done to promote and increase the performance of IWT in the future.

Shifts in the transport systems are primarily influenced by supply conditions (e.g., infrastructure, innovations) and demand factors (e.g., flow shifts), as well as regulation. Technological advancements could result in effective innovations like digitalisation, automation, networking, renewable fuels and electrification.

6.8. Chapter Summary

This chapter adopted a combination of fuzzy AHP and TOPSIS methodology to analyse qualitative data provided by the experts in this sector. The fuzzy AHP was employed to reduce vagueness and imprecision while making judgmental decisions. In this study, FAHP was successfully used to prioritise the performance indicators, and the TOPSIS method was used for subsequent ranking. A case study approach was used in this work for necessary evaluation of the situation with reference to the identified performance indicators.

The analysis through the presented results revealed that enhanced competitiveness is the unifying aspect within every industry and drives improved performance and a demand for high-quality services. The case study presented in this study observed that while inland navigation is increasingly integrated into the contemporary logistic chain in the Netherlands, Germany Belgium and France, the corresponding figures in the United Kingdom were found to be low.

Chapter 7. Conclusion and Recommendation

7.1. Introduction

The last chapter summarises the findings and suggests possible directions for further research and development. The chapter starts with revisiting the study's objectives and research questions to present the most significant findings of this study. Next is an explanation of how the research contributes to the existing body of knowledge and its practical implications. The final part of this chapter outlines the study's limitations and proposes directions for future research drawing from the study results.

7.2. Research Findings

Globalisation and commercialisation have greatly expanded the logistics chain's development, complexity, and competitiveness. This growth has placed significant demands on intermodal transport networks, requiring constant and integrated transport planning to increase system reliability and efficiency. At the same time, the ever-increasing acknowledgement of the external outcome of transport has necessitated attention to a more sustainable transport mode. Core European maritime gateway seaports form an interface with intermodal transport, facilitating cargo concentration and distribution by different transport forms, particularly waterways, which offer efficient and reliable transport services to their hinterlands. Even more than before, the IWT has reinforced its reliance on maritime access.

The demand and rhythms of globalised flows determined how the seaport interacts with IWT. The utilisation of inland waterways as supplementary transport has grown with an increase in the share of waterborne transport in the Netherlands, Belgium, Germany, and France. As a direct result, the IWT players have become more integrated into modern logistics systems due to increased freight volume and the integration of supply chains in these regions. The advancements are compelling the IWT industry to adapt and redefine its operations and strategic positionings. In an era of the increased importance of sustainable transport, inland shipping is used optimally as a supplementary transport to offer freight forwarding solutions from these maritime gateways to various hinterlands, centres of commerce and consumption. Decision-makers are compelled by the competitive nature of the business to have a thorough understanding of the primary factors behind performance. By identifying the factors that directly and indirectly affect goal attainment and the accompanying outcomes, performance indicators offer useful and widely acceptable tools to help decision-making processes. To ensure effective progress, successful market leaders must have reference or measurement standards for internal and external comparison for quality improvement and benchmarking.

Thus, it has become essential to strengthen the role of inland shipping beyond the individual or company level, facilitated by efficient and green freight corridors where the benefits of cost, capacity, and regularity are utilised. Shifting freight transport from road to waterborne transport has been an essential strategic element in EU transport policy. Existing policies attempt to optimise the performance of the logistics chains, including using more inherently resource-efficient modes through better planning. Recent years have seen impressive progress in this area for European transport policy. Various measures have been launched to achieve the goal of more balanced use of transport capacity on major European waterways routes as an integrated part of commercial cargo transportation. From the environmental point of view, this entails cutting down on emissions and energy consumption and boosting innovation.

The UK has produced a clean maritime plan, including regulations to address air pollution and greenhouse gas emissions from shipping while guaranteeing the UK can gain economically from the transition to zero-emission shipping on a global scale. The UK's environmental policies, in particular, provide a strong foundation for inland shipping as a substitute for other modes of freight transportation. An acceptable system for measuring and evaluating the performance of inland shipping, with information on capacity, reliability and applicability for intermodal transport, will enable comparability to other transport modes. The constantly increasing supply chains and the associated demands for reliability and efficiency necessitate enhanced standards for performance and measurement. Standardised and accepted tools allow decision-makers to analyse the performance against objectives and evaluate achievements.

This study commences by doing a thorough literature review of the performance trend in IWT and the existing state-of-the-art application of performance measurement in IWT and intermodal IWT to identify research gaps. Several research gaps were found based on the literature review in chapter two of this study. Firstly, this study discovered that there is a lack of general insight into the performance of IWT compared to single-mode road freight transport.

Secondly, there is a lack of detailed insight into the aspects that influence the perception of performance in the domain of IWT. No comprehensive framework is available to measure the performance of IWT, including identifying performance variables and conducting performance evaluations. Where performance is evaluated, it is usually in most instances, case-specific to a particular variable. Enhancing competition is a common factor across all industries, leading to better performance and a need for high-quality services. Therefore, new techniques and tools are required to accurately assess the efficiency of IWT to facilitate accurate decision-making and enhance competitiveness. The third study gap pertained to the need for a systematic and integrated performance evaluation, as previous studies have primarily focused on individual performance metrics without considering the interrelation and interdependence of performance factors.

Finally, research has yet to prioritise the severity of different performance criteria to determine which should receive the greatest attention from relevant authorities and stakeholders involved in IWT. Conducting this research is essential as it provides a detailed understanding of the key success factors and variables that impact performance in the IWT. It also enables all relevant authorities and industry practitioners to adjust operational procedures to focus on the most critical success factors. Thus, these research gaps were filled in by formulating the research questions for the study. The answer was determined by a disciplinary approach that combined document analysis, semi-structured interviews, direct observations, and a questionnaire survey. In the next section, further discussion of the research questions will follow.

RQ1. What are the main relevant factors determining the perception of performance in the IWT industry, and how can those influencing factors be addressed?

A system model was developed to assist managers in enhancing their performance by analysing performance drivers, decision-making processes, and performance results. The system model in this approach includes mapping the main process involved in transporting goods along waterways, the necessary infrastructure, resources required for execution (such as information technologies, employees, vehicles), traffic conditions affecting transportation performance (like water level, locks, dams, legal regulations and clearance height, icing), critical success factors (ICT, equipment, fleet), and stakeholders in the IWT system.

The emphasis is on the proposed model, acknowledging that the essential elements offer a more robust representation of the aspects influencing performance in the field of IWT. The process is sequential, recurring and articulated in a circulation pattern, showing independence between components. To ensure improvement in the competitiveness of IWT, the performance drivers must identify all essential features and characteristics that impact the perception of the performance.

Next comes the step of identifying the resources necessary to enable and back performance management measures. Companies or businesses using waterways for freight transportation might apply several performance measures based on a suitable attitude to improve high-quality services and achieve their desired goal. Because of their distinct perspective, IWT managers can prioritise improving service quality and assess performance results. If adopted, the proposed system models can function as an integrated set of indicators for evaluating IWT performance in order to enhance quality and set standards. It can improve quality, establish benchmarks, cater to business requirements for robust decision-making approaches and facilitate the integration of advanced techniques such as the fuzzy AHP and TOPSIS to enhance performance in the IWT sector.

RQ2. What are the primary sources of performance factors impacting the efficiency and competitiveness of the IWT system, and how can these factors be identified and categorised?

Identifying all relevant aspects and factors is the first step of the IWT performance improvement process. Next, an assessment is needed to establish the relevance of the performance metric and its eligibility for further examination. Decision-makers and industry practitioners must profoundly comprehend the primary factors that influence performance. Through a literature review, this thesis first determined a thorough list of performance factors in the IWT system.

Initially, 48 potential performance factors were identified in this study through a literature review. Although the IWT systems share many performance aspects with regular intermodal transport, they also possess distinct performance characteristics that differentiate them. Particularly, "quality of traffic service", the technical conditions on waterway channels influence specific features that differ from roads and railways, affecting vessel loading and towing. "The pronounced influence of current climate change", seasonal conditions and climate change pose challenges to navigation, causing traffic breaks and reducing the cost-effectiveness and reliability of IWT due to high costs. "Limited geographical expansion", possible factors and obstacles that may affect their expansion efforts by evaluating the company's ability to use IWT to expand into new geographic places. "Spatial planning", integration of land and water spatial planning, including IWT and economic policies, legislation on IWT saving spatial planning to promote freight via waterways. "Incentives and grants for modal shift to waterways", offering incentives and grants to encourage modal shifts to waterways, "information and communication technologies", fostering seamless information flows and "education and skill development", awareness and campaign, eco navigation and fostering critical thinking for safety.

Experts are consulted to compile the inputs for the system model. Experts provided valuable feedback on the proposed categorisation approaches for performance factors and questionnaires outlining the most crucial aspects of the IWT systems. The novel categorisation approach utilised in this study categorises different performance criteria into eight various categories in the following way: Mobility and reliability, efficiency and profitability, infrastructure conditions, environmental impact and decarbonisation, safety and security, efficiency and profitability, innovative transport technology and policy formulation and implementation.

This study introduced a hierarchical structure model for identifying potential performance metrics to assess IWT performance. The study team and other professionals in internal transport, IWT, and supply chain management were consulted several times to verify the accuracy and reliability of the hierarchy diagram created. After deliberation, the professionals achieved a consensus and approved the hierarchy diagram.

RQ3. Which influencing factors are relatively more significant in improving the performance of the IWT network?

Analysing the level of each factor is the next step after determining all possibly essential aspects and factors that influence the perception of performance in the IWT system. It is commonly acknowledged that performance evaluations are essential. Companies and government organisations are compelled to increase the transparency of their operations. In the transport sector, innovative or alternative transport solutions frequently fail to succeed due to a lack of transparency caused by inadequately selected or absent performance indicators. This is a contributing factor to the limited significance of IWT as a primary mode of freight transportation in multimodal supply chains. To handle the uncertainty involved in mapping experts' opinions, fuzzy AHP was devised in this thesis using the principle of fuzzy set theory. The fuzzy AHP model was developed, and data was gathered to evaluate the expert's judgement utilising linguistic variables for pairwise comparisons of the criterion and sub-criteria. 27 valid responses were obtained from the UK, France, The Netherlands, Germany, and Belgium. The expertise of the respondents spans a broad spectrum in both industry and academia, and most of the respondents were decision-makers in their various domains of operations. The capacity of IWT to provide efficient and reliable transportation services is crucial for the seamless operations of the supply chain with a weighted of 137; the results indicate that performance associated with mobility and reliability has the highest priority and is of the utmost importance. Inland vessels/barges must operate smoothly and dependably to deliver goods to their destinations swiftly and effectively. The next influencing factor was the infrastructure condition, with a weight of 0.13, followed by environmental impact and decarbonisation at 0.128. Safety and security, weighing 0.127, are influential measures that can help stakeholders mitigate risks, build resilience, and uphold industry integrity. The fifth influencing factor is economic development (0.126), as the efficiency and performance of IWT systems are crucial indicators of economic development, followed by innovative transport technology (0.124), a crucial measure fostering seamless information flows among all relevant stakeholders, efficiency (0.115), policy formulation and implementation for IWT (0.114). Each of these distinctive features can drastically change and improve the complexity of the IWT system.

RQ4. What best practices can the UK adopt from continental Europe regarding the use of IWT for freight?

Empirical studies from the Netherlands, Belgium, Germany, France and the UK IWT were used in this study to determine the present performance level of the case study countries and highlight best practices. In this study, the performance approaches were ranked using the TOPSIS method. The Netherlands (Rotterdam gateway) has the highest performance in terms of freight transportation via waterways, followed by Germany (Hamburg gateway), Belgium (Antwerp gateway) came third, next was France (Seine gateway), and the least among these gateways was the UK (Thames/Liverpool/Manchester) with a distance rating among the case studies. Statistics revealed that while the four European case study countries were high, the corresponding value for the UK regional gateways remained very low. The margin by which the Netherlands, Germany, Belgium, and France lead the UK shows how these countries and their strategic positioning have adapted inland shipping operations, aligning with the demands and dynamics of the global market.

However, it is also acknowledged that each maritime gateway has a different level of maturity and qualities to enhance the development and use of waterways in its domestic freight logistics system. Stakeholders and relevant authorities can adopt best practices from these regional maritime freight gateways to improve the performance services within the UK inland waterway freight transport industry.

7.3. Contribution to knowledge

7.3.1. Research implications

- The study complements the existing body of literature in the field of IWT by providing a detailed overview of performance measures in the industry. This can serve as a groundwork for research in the domain of IWT by establishing a common understanding of measurement standards for internal and external comparison to ensure effective progress monitoring.
- The study proposed a system model that provides detailed insight into various elements influencing performance perception in the IWT sector. It consists of eight basic criteria categories and forty-three sub-categories derived from different kinds of performance in the IWT sector. This extensive performance classification model aids in identifying many potential performance factors, including internal and external to the IWT network, with varying degrees of influence.
- The research complies with a comprehensive list of potential performance elements that impact the eight main criteria outlined in the study by integrating perspectives from academics and industry professionals. This will assist researchers, industry practitioners and all relevant authorities in the IWT domain in identifying and categorising specific performance elements related to a particular improvement scenario. It will also serve as a foundation for measuring the standard of the IWT performance index model to facilitate the widespread implementation of standardised performance metrics across the industry.

7.3.2. Managerial implications

- The proposed model is novel because it integrates the fuzzy AHP and TOPSIS models as part of an integrated methodology. This allows decision-makers preferences to be taken into account when making strategic decisions about performance improvement on the IWT system. Furthermore, the uncertainty resulting from unknown data is taken into account by the model. Thus, applying fuzzy logic theory to practice can help firms quickly and efficiently address ambiguity and manage uncertainty in decision-making.
- This research contributes practically by performing empirical studies in the IWT sectors of the UK, France, the Netherlands, Germany, and Belgium to aid

managers in making resource-effective and time-efficient decisions. Thus, the findings from this study can offer relevant firms or decision-makers with up-to-date information that accurately represents the current practices and status of the country's IWT sectors to ensure accurate decision-making and enhance competitiveness.

- The research findings allow stakeholders and decision-makers to anticipate and address potential performance factors using the IWT performance index model. Although the IWT connects the operational execution of pre- and post-waterway carriage transportation. In this study, performance metrics for pre- and post-carriage transportation are excluded as their values are not directly impacted by the system. However, the study thoroughly examines the critical performance factors involved in the physical execution of freight transport by waterways, procedures, and operations at the destination port. It utilises previous academic literature, direct observation, official reports and insight from relevant authorities and industry practitioners in various relevant positions within the IWT sector.

7.4. Research Limitations

Below, the limitations of this research are addressed.

- The performance factors identified in this study were mainly sourced from literature studies focused on the IWT system. Through systematic locating, screening and synthesising high-quality data sources, data gathering was constrained between 2003 and 2022. Although it constrained the study's time span, it offered a means of concentrating on the growth of IWT research during the last 19 years. If the excluded literature could be reviewed, it would be more thorough.
- Conducting empirical studies on firms operating on waterways is challenging due to the confidential nature of the data, making it difficult to collect primary and secondary data. Furthermore, specified professional occupations were the only ones included in the sample selection based on the study's inclusion criteria. The participants in this research possess extensive expertise in academia or substantial practical experience and occupy managerial positions or higher in professional domains. As a result, the sample size represents yet another study limitation.
- The professional knowledge, experience, and attitude of the respondents are crucial components of the proposed system model and could introduce subjectivity. Respondent and their opinions or impressions could be influenced by the context in

which they took part in the study's survey. Unforeseen variables, such as personal conflicts with firms or external influence, can affect their perspectives. Thus, this illustrates yet another way that this study is limited.

7.5. Recommendation and Future Research

Several research areas require more investigation. It is therefore recommended that the following areas be focused on in the future:

- Additional research is needed to determine the applicability of the performance index model in various industry sectors and supply chain levels, including pre-and post-carriage transportation. Applying identical study processes to other domains will expand understanding of IWT performance.
- Expanding the geographical breadth of the research can facilitate the cross-validation of the proposed system model. This study examined performance aspects and measures in the field of IWT in France, the Netherlands, Germany, Belgium, and the UK. These countries were chosen for a sample because of the existing similar features of river-sea connectivity and are due to their advanced IWT system, extensive market, and high IWT demands driven by cost, capacity, and reliability factors. Comparing countries with favourable transport geographies (waterways) and diverse social and economic systems will offer new perspectives on the development of the IWT performance improvement initiatives.
- Modal shifts in the freight transportation industry are mainly impacted by supply factors such as infrastructure and innovation and demand conditions such as flow shifts and regulation. The ease of achieving modal shifts to waterways depends on the favourability of conditions. Future research should thoroughly examine the elements that impact modal shift decisions made by shippers and stakeholders.

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Appendix I

The questionnaire used in survey A for Chapter five of this thesis

LIVERPOOL JOHN MOORES UNIVERSITY

CONSENT FORM

Project Title; River-Sea Freight Transport in Major Logistic Gateways: A Performance Evaluation of The United Kingdom's and Continental Europe's Inland Waterways

Name of Researcher and School/Faculty:

Gbako Shekwoyemi

Researcher at Liverpool Logistics, Offshore and Marine Research Institute (LOOM)

Liverpool John Moores University, Byrom Street, Liverpool L3 3AF.

S.Gbako@2019.ljmu.ac.uk
Phone: 01512312121

1. I confirm that I have read and understand the information provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and that this will not affect my legal rights. ☐

3. I understand that any personal information collected during the study will be anonymised and remain confidential ☐

4 I agree to take part in the above study survey involving the administration of a questionnaire ☐

Name of Participant	Date	Signature
Name of Researcher	Date	Signature

Pre-test Questionnaire Survey

Dear Sir/Madam,

My name is Gbako Shekwoyemi, I am currently studying for a PhD degree at Liverpool Logistics, Offshore and Marine Research Institute (LOOM) at Liverpool John Moores University. My research topic is "River-Sea Freight Transport in Major Logistic Gateways: A Performance Evaluation of The United Kingdom's and Continental Europe's Inland Waterways". At this stage, your feedback will help for the development of a universal framework for modelling and assessing the state of the art of inland waterways in different geographical areas of interest in the UK but also in Europe and other regions. You may also suggest any additional criteria and sub-criteria that you feel may add value to the development of the model and are relevant to the purpose of this study.

The main purpose of these questionnaires is to analyse the set of indicators for the assessment of inland/river-sea transport and the inter-relationship between river-sea transport performances. I should be very pleased if you can take part in this study in view of your professional knowledge in intermodal transport, inland waterway transport or supply chain management. It is necessary to pre-test the reliability and validity of the identified indicators and sub-indicators in the research and your assistance would be greatly appreciated in making this a meaningful questionnaire. The information gathered in this survey will be treated in the strictest confidence. However, your decision to take part is entirely voluntary and will be safeguarded under the *Liverpool John Moores University Ethical Guidelines*. All responses will be treated with strict confidence, as the researcher will make every effort to prevent anyone who is not on the research team from knowing that you provided this information, or what the information is about.

I hope that you find participating in the study enjoyable and thought-provoking. If you have any questions or would like further clarification, please do not hesitate to telephone on (44)7367339732, or email me at S.Gbako@2019.ljmu.ac.uk, or my Director of Studies Dr Dimitrios Paraskevadakis, at +44 (0) 151 231 2766 or by email at d.paraskevadakis@ljmu.ac.uk.

Thank you for your assistance.

Yours faithfully,

Gbako Shekwoyemi,

PhD Candidate

Liverpool Logistics, Offshore and Marine Research Institute (LOOM)
Liverpool John Moores University, Byrom Street, Liverpool L3 3AF.
Email: S.Gbako@2019.ljmu.ac.uk
Phone: (44)7367339732

Section A: Expert Profile

1. Type of organisation……………………………………………………………………….
2. Country(ies) of operation……………………………………………………………
3. Job title and position (optional)……………………………………………………………
4. Years of experience …………………………………………………………………………
5. Would you be willing to participate in the next survey if necessary?............................

Section B: Questionnaire

The fast-moving economy of the world and industrial competition recognize the important of high quality and best practices in products and services. The constant growth in traffic volume must be dealt with accordingly by both decision makers and logistics service providers and present challenges. Thus, it is of important that decision makers have deep understanding of the key factors that drive performance in IWT business environment. There is need for a common accepted approach that supports the development of a consistent performance indicator system within the inland waterway industry.

Based on this research, performance indicators are categorised into eight main categories: 1) mobility and reliability; 2) efficiency and profitability; 3) environmental impact and decarbonisation; 4) infrastructure condition; 5) safety and security; 6) innovative transport and technologies; 7) economic development; 8) policy formulation and implementation for IWT. The following questions are related to rank and modify the identified set of indicators for assessment of inland waterways transport performance.

Mobility and Reliability: *Criterion that indicate how well a transport system function.*

Mobility and Reliability:

- (S1) Transit time
- (S2) Navigability
- (S3) Availability and access to transport
- (S4) Carriage capacity
- (S5) Handling performance
- (S6) Quality level of traffic services
- (S7) Availability of transport infrastructure such as river port and multimodal connectivity

From the identified set of indicators used in the assessment of IWT performance, what level of importance do you think should be attributed to this sub-indicator and what other indicator /sub-indicator should be considered.

(1=Highly Unimportant; 2=Slightly Unimportant; 3=Unimportant; 4=Neutral; 5=Important; 6=Slightly Important; 7=Highly Important)

Identified Set of Indicators		**Important Level**
Mobility and Reliability	(S1) Transit time	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S2) Navigability	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S3) Availability and access to transport	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S4) Carriage capacity	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S5) Handling performance	☐1 ☐ 2☐ 3 ☐ 4☐ 5 ☐ 6☐ 7
	(S6) Quality level of traffic services	☐1 ☐ 2☐ 3 ☐ 4☐ 5 ☐ 6☐ 7
	(S7) Availability of transport infrastructure such as river port and multimodal connectivity	☐1 ☐ 2☐ 3 ☐ 4☐ 5 ☐ 6☐ 7
Please add any other indicator you think should be considered		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7

Efficiency and Profitability: *A necessary condition that reflects the transport operating margin. (The effectiveness and efficiency of the transport system has been identified to contribute substantially to the overall competitiveness and attractiveness of an industrial area)*

Efficiency and Profitability:

- (S8) Total cost and expense of river freight
- (S9) Energy efficiency
- (S10) Attractiveness of the transport system
- (S11)Price alternative (e.g., road and rail)
- (S12) Transhipment cost in seaport (time and cost saving)

(1=Highly Unimportant; 2=Slightly Unimportant; 3=Unimportant; 4=Neutral; 5=Important; 6=Slightly Important; 7=Highly Important)

Identified Set of Indicators		Important Level
Efficiency and Profitability	(S8) Total cost and expense of river freight	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S9) Energy efficiency	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S10) Attractiveness of the transport system	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S11)Price alternative (e.g., road and rail)	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S12) Transhipment cost in seaport (time and cost saving)	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
Please add any other indicator you think should be considered		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7

Environmental impact and decarbonisation: *Environmental consideration. (Sustainability of the transport with regards to energy consumption and gas emission (air). Tons of CO_2, PM, SO_X, NO_X and HC_X resulting from transport)*

Environmental impact and decarbonisation:

- (S13) Emission reduction
- (S14) Renewable and alternative energy
- (S15) Emission reduction funding
- (S16) Enforcement/monitoring

- (S17) Noise

(1=Highly Unimportant; 2=Slightly Unimportant; 3=Unimportant; 4=Neutral; 5=Important; 6=Slightly Important; 7=Highly Important)

Identified Set of Indicators		Important Level
Environmental impact and decarbonization	(S13) Emission reduction	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S14) Renewable and alternative energy	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S15) Emission reduction funding	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S16) Enforcement/monitoring	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S17) Noise	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
Please add any other indicator you think should be considered		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7

Infrastructure Condition: *Factor influencing the competitiveness of IWT. (Maintenance, better connections to other modes of transport and logistics centres, filling missing links and bottlenecks)*

Infrastructure Condition:

- (S18) Connectivity (road and rail interchange)
- (S19) Transhipment facilities for integration)
- (S20) modern facilities and fleets for competitiveness
- (S21) congestion-free transport system
- (S22) Maintenance of infrastructure
- (S23) Limited geographical expansion
- (S24) Spatial planning

(1=Highly Unimportant; 2=Slightly Unimportant; 3=Unimportant; 4=Neutral; 5=Important; 6=Slightly Important; 7=Highly Important)

Identified Set of Indicators		Important Level
Infrastructure Condition	(S18) Connectivity (road and rail interchange)	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S19) Transshipment facilities for integration)	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S20) modern facilities and fleets for competitiveness	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S21) congestion-free transport system	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S22) Maintenance of infrastructure	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S23) Limited geographical expansion	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S24) Spatial planning	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
Please add any other indicator you think should be considered		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7

Safety and Security: *Shipping safety an important concern (records of injuries, fires, fatalities, collisions, groundings, and any other accidents resulting from the transportation of shipments between their origin and destination as well as security of the supply chain between the shipment's origin and destination*

Safety and Security:

- (S25) Traffic condition
- (S26) Navigation safety and route capacity
- (27) Vessel identification
- (28) Seaworthiness
- (29) Weather forecast

(1=Highly Unimportant; 2=Slightly Unimportant; 3=Unimportant; 4=Neutral; 5=Important; 6=Slightly Important; 7=Highly Important)

Identified Set of Indicators	Important Level

Safety and Security	(S25) Traffic condition	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S26) Navigation safety and route capacity	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(27) Vessel identification	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(28) Seaworthiness	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(29) Weather forecast	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
Please add any other indicator you think should be considered		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7

Innovative transport technology: *Enhancing transport competitiveness through best practises (Improve data integration across transport mode. Availability and transparency of freight flow information in combination with ICT facilities as well as standards for communication and information exchange to foster integration into modern supply chain)*

Innovative transport technology:

- (S30) Information and communication flow along the supply chain (data exchange)
- (S31) AIS coverage (Shore side data availability)
- (S32) Hierarchical tracking of data at logistic unit level
- (S33) interoperability with customers systems
- (34) Voyage planning
- (S35) Tracking and tracing based on GS1/EPCIS standards in the supply chain
- (S36) RIS and VTS services

(1=Highly Unimportant; 2=Slightly Unimportant; 3=Unimportant; 4=Neutral; 5=Important; 6=Slightly Important; 7=Highly Important)

Identified Set of Indicators		Important Level
Innovative transport technology	(S30) Information and communication flow along the supply chain (data exchange)	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S31) AIS coverage (Shore side data availability)	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7

	(S32) Hierarchical tracking of data at logistic unit level	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S33) interoperability with customers systems	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(34) Voyage planning	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(35) Tracking and tracing based on GS1/EPCIS standards in the supply chain	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S36) RIS and VTS services	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
Please add any other indicator you think should be considered		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7

Economic Development: *Significant impact of IWT on a country's economic development. (Enhancing a country's international market access through Improve performance)*

Economic Development:

- (S37) Aggregate added value (of transportation and infrastructure)
- (S38) Development (regional and local)
- (S39) Potential of the transport
- (S40) Employment (direct and indirect)
- (S41) Marketing

(1=Highly Unimportant; 2=Slightly Unimportant; 3=Unimportant; 4=Neutral; 5=Important; 6=Slightly Important; 7=Highly Important)

Identified Set of Indicators		**Important Level**
Economic Development	(S37) Aggregate added value (of transportation and infrastructure)	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S38) Development (regional and local)	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S39) Employment (direct and indirect)	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7

	(S40) Marketing	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
Please add any other indicator you think should be considered		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7

Policy formulation: *Policy to promote alternative to road transport for freight movement. (Best practise planning for freight on inland waterways)*

Policy formulation:

- (S41) Administrative support for modal shift to inland waterways
- (S42) Existing legislative framework for modal shift to inland waterways
- (S43) Incentives and grants for modal shift
- (S44) Knowledge transfer and best practices
- (S45) Logistic clusters formulation and collaboration
- (S46) Education and skill development
- (S47) Integrated transport policy.
- (S48) Cooperation/collaboration

(1=Highly Unimportant; 2=Slightly Unimportant; 3=Unimportant; 4=Neutral; 5=Important; 6=Slightly Important; 7=Highly Important)

Identified Set of Indicators		**Important Level**
Policy formulation	(S41) Administrative support for modal shift to inland waterways	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S42) Existing legislative framework for modal shift to inland waterways	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S43) Incentives and grants for modal shift	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S44) Knowledge transfer and best practice	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7

	(S45) Logistic clusters formulation and collaboration	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S46) Education and skill development	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S47) Integrated transport policy.	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
	(S48) Cooperation/collaboration	☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7

Please add any other indicator you think should be considered		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7
		☐1 ☐ 2☐ 3 ☐4☐ 5 ☐ 6☐ 7

THANK YOU ONCE AGAIN FOR YOUR KIND PARTICIPATION IN THIS SURVEY.

YOUR ANSWERS WILL BE KEPT CONFIDENTIAL

Appendix II - Semi-structured Interview

LIVERPOOL JOHN MOORES UNIVERSITY

CONSENT FORM

Project Title: River-Sea Freight Transport in Major Logistic Gateways: A Performance Evaluation of The United Kingdom's and Continental Europe's Inland Waterways

Name of Researcher and School/Faculty:

Gbako Shekwoyemi

Researcher at Liverpool Logistics, Offshore and Marine Research Institute (LOOM)

Liverpool John Moores University, Byrom Street, Liverpool L3 3AF.

S.Gbako@2019.ljmu.ac.uk
Phone: 01512312121

1. I confirm that I have read and understand the information provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and that this will not affect my legal rights. ☐

3. I understand that any personal information collected during the study will be anonymised and remain confidential ☐

4 I agree to take part in the above study survey involving the administration of a questionnaire ☐

Name of Participant	Date	Signature
Name of Researcher	Date	Signature

.

Appendix II - Semi-structured Interview

Interview protocol

1. Type of organisation?
2. Country(ies) of operation ?
3. Job title and position ?
4. Years of experience ?
5. Is your organisation/firm concerned about IWT performance?
6. How is the performance of your firm's supply chain?
7. Does your organisation have established procedures for identifying performance metrics? If your answer is "Yes", then:
    - For what duration has it been in place?
    - What aspects does your performance programme encompass?
    - Performance measures are meant to be revised as circumstances change. What is the frequency of reviewing and updating your identification of performance factors?

8. Based on the literature review, various features and factors that influence the perception of performance in IWT have been identified to assist managers. What are your opinions on these specific performance factors?

9. What is the level of significance of each identified performance factor?

- Mobility and reliability
- Efficiency and profitability

- Environmental impact
- Infrastructure condition standard
- Safety and security
- Information and communication technology
- Economic development
- Policy formulation

Appendix III

The questionnaire used in survey B for Chapter Six of this thesis

LIVERPOOL JOHN MOORES UNIVERSITY

CONSENT FORM

Project Title; River-Sea Freight Transport in Major Logistic Gateways: A Performance Evaluation of The United Kingdom's and Continental Europe's Inland Waterways

Name of Researcher and School/Faculty:

Gbako Shekwoyemi

Researcher at Liverpool Logistics, Offshore and Marine Research Institute (LOOM)

Liverpool John Moores University, Byrom Street, Liverpool L3 3AF.

S.Gbako@2019.ljmu.ac.uk
Phone: 01512312121

1 I confirm that I have read and understand the information provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily ☐

2 I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and that this will not affect my legal rights. ☐

3 I understand that any personal information collected during the study will be anonymised and remain confidential ☐

4 I agree to take part in the above study survey involving the administration of a questionnaire ☐

Name of Participant	Date	Signature
Name of Researcher	Date	Signature

Questionnaire

Dear Sir/Madam,

My name is Gbako Shekwoyemi; I am currently studying for a PhD at Liverpool Logistics, Offshore and Marine Research Institute (LOOM) at Liverpool John Moores University. My research topic is "River-sea freight transport in major logistic gateways: a performance evaluation of the united kingdoms and continental Europe's inland waterways". At this stage, your feedback will help develop a universal framework for modelling and assessing the state of the art of inland waterways in different geographical areas of interest in the UK, Europe, and other regions.

The purpose of the questionnaire is to evaluate the indicators identified to determine their priority (weight). The information gathered in this survey will be treated in the strictest confidence. I would be delighted if you could take part in this study in terms of your professional knowledge in intermodal transport, inland waterway transport, or supply chain management. However, your decision to participate is entirely voluntary and will be safeguarded under the *Liverpool John Moores University Ethical Guidelines.* All responses will be treated with strict confidence, as the researcher will make every effort to prevent anyone, not on the research team, from knowing that you provided this information or what the information is about.

I hope that you find participating in the study enjoyable. Please feel free to complete the questionnaire and send it back. If you have any questions or need further clarification, please do not hesitate to telephone me at (44)7367339732 or email me at *S.Gbako@2019.ljmu.ac.uk*, or my Director of Studies Dr Dimitrios Paraskevadakis, at +44 (0) 151 231 2766 or by email at *d.paraskevadakis@ljmu.ac.uk*

Thank you for your assistance.

Yours faithfully,

Gbako Shekwoyemi,

PhD Candidate

Liverpool Logistics, Offshore and Marine Research Institute (LOOM)

Liverpool John Moores University, Byrom Street, Liverpool L3 3AF.

Section A: Respondent Profile

1. Type of organization………………………………………………………….

2. Country(ies) of operation………………………………………………….

3. Job title and position (optional)……………………………………………

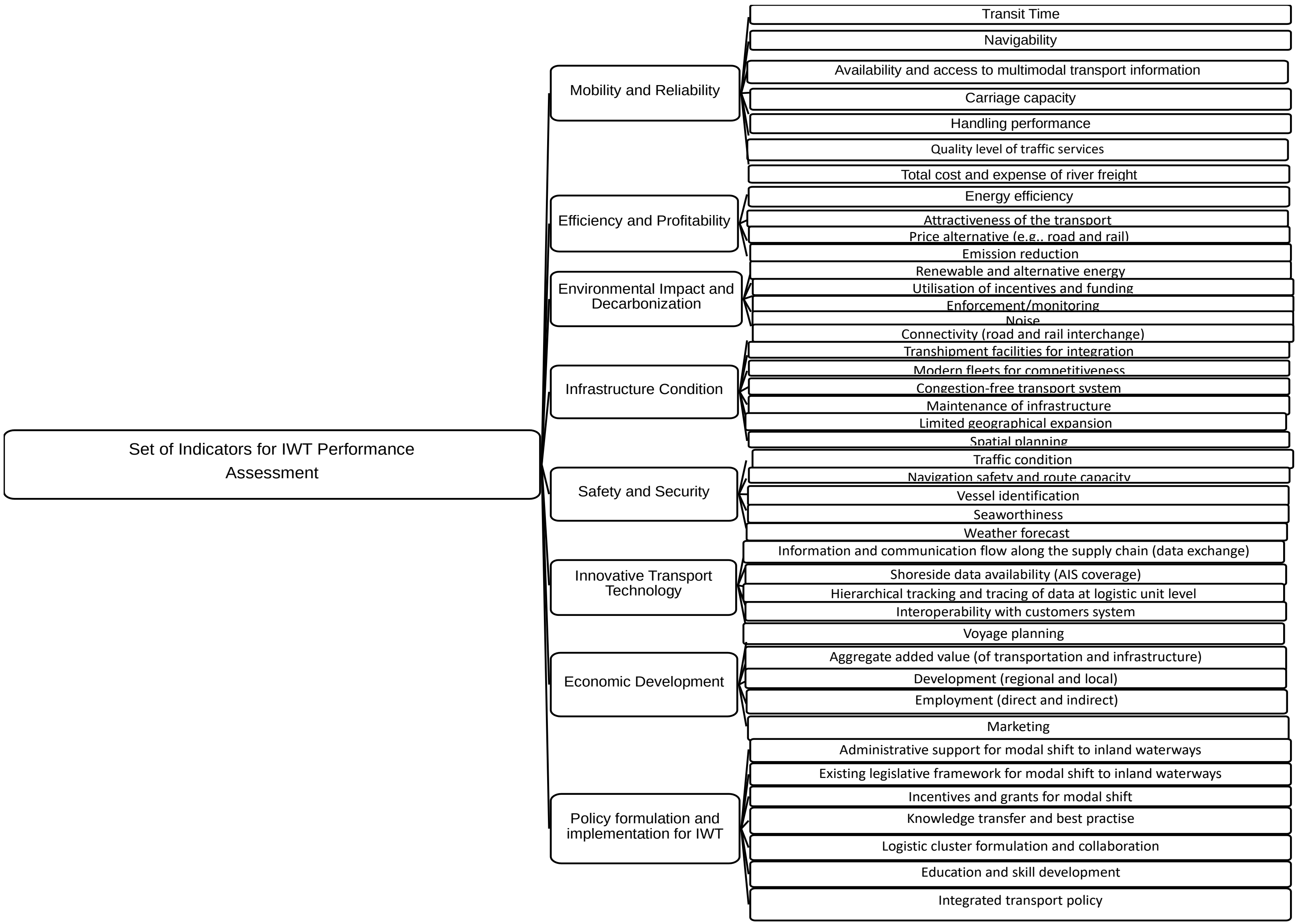
4. Inland waterways you are familiar or indirectly involved with…………………….

5. Years of experience

☐1-5 years ☐6-10 years ☐11-15 years ☐16-19 years ☐≥20 years

Section B: Fuzzy Analytical Hierarchical Process (FAHP)

Part A: Introduction and Explanation



Set of Indicators for IWT Performance Assessment
Mobility and Reliability
Transit Time
Navigability
Availability and access to multimodal transport information
Carriage capacity
Handling performance
Quality level of traffic services
Total cost and expense of river freight
Efficiency and Profitability
Energy efficiency
Attractiveness of the transport
Price alternative (e.g., road and rail)
Environmental Impact and Decarbonization
Emission reduction
Renewable and alternative energy
Utilisation of incentives and funding
Enforcement/monitoring
Noise
Infrastructure Condition
Connectivity (road and rail interchange)
Transhipment facilities for integration
Modern fleets for competitiveness
Congestion-free transport system
Maintenance of infrastructure
Limited geographical expansion
Spatial planning
Safety and Security
Traffic condition
Navigation safety and route capacity
Vessel identification
Seaworthiness
Weather forecast
Innovative Transport Technology
Information and communication flow along the supply chain (data exchange)
Shoreside data availability (AIS coverage)
Hierarchical tracking and tracing of data at logistic unit level
Interoperability with customers system
Voyage planning
Economic Development
Aggregate added value (of transportation and infrastructure)
Development (regional and local)
Employment (direct and indirect)
Marketing
Policy formulation and implementation for IWT
Administrative support for modal shift to inland waterways
Existing legislative framework for modal shift to inland waterways
Incentives and grants for modal shift
Knowledge transfer and best practise
Logistic cluster formulation and collaboration
Education and skill development
Integrated transport policy

Key definitions of main criteria:

- *Mobility and Reliability:* Criterion that indicate how well a transport system function.
- *Efficiency and Profitability:* A necessary condition that reflects the transport operating margin. (The effectiveness and efficiency of the transport system has been identified to con-tribute substantially to the overall competitiveness and attractiveness of an industrial area)
- *Environmental impact and decarbonization:* Environmental consideration. (Sustainability of the transport with regards to energy consumption and gas emission (air). Tons of CO_2, PM, SO_X, NO_X and HC_X resulting from transport)
- *Infrastructure Condition:* Factor influencing the competitiveness of IWT. (Maintenance, better connections to other modes of transport and logistics centres, filling missing links and bottlenecks)
- *Safety and Security:* Shipping safety an important concern (records of injuries, fires, fatalities, collisions, groundings, and any other accidents resulting from the transportation of shipments between their origin and destination as well as security of the supply chain be-tween the shipment's origin and destination
- *Innovative transport technology:* Enhancing transport competitiveness through best practices (Improve data integration across transport mode. Availability and transparency of freight flow information in combination with ICT facilities as well as standards for communication and information exchange to foster integration into modern supply chain)
- *Economic Development:* Significant impact of IWT on a country's economic development. (Enhancing a country's international market access through Improve performance)
- *Policy formulation and implementation for IWT:* Policy to promote alternative to road transport for freight movement. (Best practice planning for freight on inland waterways

Pairwise comparison of indicators

Example: if you believe that the indicator mobility and reliability are more important than efficiency and profitability, tick one of the checkboxes on the left-hand side of "Equal Important" based on the level of importance in comparing the two indicators.

If you believe that the indicator efficiency and profitability are more important than mobility and reliability, tick one of the checkboxes on the right-hand side of "Equal Important".

Part B: Questionnaire

1) With respect to the main criteria identified, in your opinion what is the relative importance in inland waterway transport (IWT)?

	Extremely strong Importance	Very strong importance	Strong importance	Moderate importance	Equal importance	Moderate importance	Strong importance	Very strong importance	Extremely Strong Importance	
Mobility and reliability	☐	☐	☐	☐	☐	☐	☐	☐	☐	Efficiency and profitability
Mobility and reliability	☐	☐	☐	☐	☐	☐	☐	☐	☐	Environmental Impact and Decarbonisation
Mobility and reliability	☐	☐	☐	☐	☐	☐	☐	☐	☐	Infrastructure Condition
Mobility and reliability	☐	☐	☐	☐	☐	☐	☐	☐	☐	Safety and Security
Mobility and reliability	☐	☐	☐	☐	☐	☐	☐	☐	☐	Innovative Transport Technology
Mobility and reliability	☐	☐	☐	☐	☐	☐	☐	☐	☐	Economic Development
Mobility and reliability	☐	☐	☐	☐	☐	☐	☐	☐	☐	Policy Formulation and Implementation for IWT
Efficiency and profitability	☐	☐	☐	☐	☐	☐	☐	☐	☐	Environmental Impact and Decarbonisation
Efficiency and profitability	☐	☐	☐	☐	☐	☐	☐	☐	☐	Infrastructure Condition
Efficiency and profitability	☐	☐	☐	☐	☐	☐	☐	☐	☐	Safety and Security

Efficiency and profitability	☐	☐	☐	☐	☐	☐	☐	☐	☐	Innovative Transport Technology
Efficiency and profitability	☐	☐	☐	☐	☐	☐	☐	☐	☐	Economic Development
Efficiency and profitability	☐	☐	☐	☐	☐	☐	☐	☐	☐	Policy Formulation and Implementation for IWT
Environmental Impact and Decarbonisation	☐	☐	☐	☐	☐	☐	☐	☐	☐	Infrastructure Condition
Environmental Impact and Decarbonisation	☐	☐	☐	☐	☐	☐	☐	☐	☐	Safety and Security
Environmental Impact and Decarbonisation	☐	☐	☐	☐	☐	☐	☐	☐	☐	Innovative Transport Technology
Environmental Impact and Decarbonisation	☐	☐	☐	☐	☐	☐	☐	☐	☐	Economic Development
Environmental Impact and Decarbonisation	☐	☐	☐	☐	☐	☐	☐	☐	☐	Policy Formulation and Implementation for IWT
Infrastructure Condition	☐	☐	☐	☐	☐	☐	☐	☐	☐	Safety and Security
Infrastructure Condition	☐	☐	☐	☐	☐	☐	☐	☐	☐	Innovative Transport Technology
Infrastructure Condition	☐	☐	☐	☐	☐	☐	☐	☐	☐	Economic Development
Infrastructure Condition	☐	☐	☐	☐	☐	☐	☐	☐	☐	Policy Formulation and Implementation for IWT
Safety and Security	☐	☐	☐	☐	☐	☐	☐	☐	☐	Innovative Transport Technology
Safety and Security	☐	☐	☐	☐	☐	☐	☐	☐	☐	Economic Development
Safety and Security	☐	☐	☐	☐	☐	☐	☐	☐	☐	Policy Formulation and Implementation for IWT
Innovative Transport Technology	☐	☐	☐	☐	☐	☐	☐	☐	☐	Economic Development
Innovative Transport Technology	☐	☐	☐	☐	☐	☐	☐	☐	☐	Policy Formulation and Implementation for IWT
Economic Development	☐	☐	☐	☐	☐	☐	☐	☐	☐	Policy Formulation and Implementation for IWT

2) With respect to the sub-criteria, in your opinion what is the relative importance of these performance indicators under “mobility and reliability” of IWT performance?

	Extremely strong Importance	Very strong importance	Strong importance	Moderate importance	Equal importance	Moderate importance	Strong importance	Very strong importance	Extremely Strong Importance	
Transit time	☐	☐	☐	☐	☐	☐	☐	☐	☐	Navigability
Transit time	☐	☐	☐	☐	☐	☐	☐	☐	☐	Availability and access to multimodal transport information
Transit time	☐	☐	☐	☐	☐	☐	☐	☐	☐	Carriage capacity
Transit time	☐	☐	☐	☐	☐	☐	☐	☐	☐	Handling performance
Transit time	☐	☐	☐	☐	☐	☐	☐	☐	☐	Quality level of traffic services
Navigability	☐	☐	☐	☐	☐	☐	☐	☐	☐	Availability and access to multimodal transport information
Navigability	☐	☐	☐	☐	☐	☐	☐	☐	☐	Carriage capacity
Navigability	☐	☐	☐	☐	☐	☐	☐	☐	☐	Handling performance
Navigability	☐	☐	☐	☐	☐	☐	☐	☐	☐	Quality level of traffic services
Availability and access to multimodal transport information	☐	☐	☐	☐	☐	☐	☐	☐	☐	Carriage capacity
Availability and access to multimodal transport information	☐	☐	☐	☐	☐	☐	☐	☐	☐	Handling performance
Availability and access to multimodal transport information	☐	☐	☐	☐	☐	☐	☐	☐	☐	Quality level of traffic services
Carriage capacity	☐	☐	☐	☐	☐	☐	☐	☐	☐	Handling performance
Carriage capacity	☐	☐	☐	☐	☐	☐	☐	☐	☐	Quality level of traffic services
Handling performance	☐	☐	☐	☐	☐	☐	☐	☐	☐	Quality level of traffic services

3) With respect to the sub-criteria, in your opinion what is the relative importance of these performance indicators under "efficiency and profitability" of IWT performance?

	Extremely strong Importance	Very strong importance	Strong importance	Moderate importance	Equal importance	Moderate importance	Strong importance	Very strong importance	Extremely Strong Importance	
Total cost and expense of river freight	☐	☐	☐	☐	☐	☐	☐	☐	☐	Energy efficiency
Total cost and expense of river freight	☐	☐	☐	☐	☐	☐	☐	☐	☐	Attractiveness of the transport system
Total cost and expense of river freight	☐	☐	☐	☐	☐	☐	☐	☐	☐	Price alternative (e.g., road and rail)
Energy efficiency	☐	☐	☐	☐	☐	☐	☐	☐	☐	Attractiveness of the transport system
Energy efficiency	☐	☐	☐	☐	☐	☐	☐	☐	☐	Price alternative (e.g., road and rail)
Attractiveness of the transport system	☐	☐	☐	☐	☐	☐	☐	☐	☐	Price alternative (e.g., road and rail)

4) With respect to the sub-criteria, in your opinion what is the relative importance of these performance indicators under “environmental Impact and decarbonization” of IWT performance?

	Extremely strong Importance	Very strong importance	Strong importance	Moderate importance	Equal importance	Moderate importance	Strong importance	Very strong importance	Extremely Strong Importance	
Emission reduction	☐	☐	☐	☐	☐	☐	☐	☐	☐	Renewable and alternative energy
Emission reduction	☐	☐	☐	☐	☐	☐	☐	☐	☐	Emission reduction funding
Emission reduction	☐	☐	☐	☐	☐	☐	☐	☐	☐	Enforcement/monitoring
Emission reduction	☐	☐	☐	☐	☐	☐	☐	☐	☐	Noise

Renewable and alternative energy	☐	☐	☐	☐	☐	☐	☐	☐	☐	Emission reduction funding
Renewable and alternative energy	☐	☐	☐	☐	☐	☐	☐	☐	☐	Enforcement/monitoring
Renewable and alternative energy	☐	☐	☐	☐	☐	☐	☐	☐	☐	Noise
Emission reduction funding	☐	☐	☐	☐	☐	☐	☐	☐	☐	Enforcement/monitoring
Emission reduction funding	☐	☐	☐	☐	☐	☐	☐	☐	☐	Noise
Enforcement/monitoring	☐	☐	☐	☐	☐	☐	☐	☐	☐	Noise

5) With respect to the sub-criteria, in your opinion what is the relative importance of these performance indicators under “Infrastructure Condition” of IWT performance?

	Extremely strong Importance	Very strong importance	Strong importance	Moderate importance	Equal importance	Moderate importance	Strong importance	Very strong importance	Extremely Strong Importance	
Connectivity (road and rail interchange)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Transhipment facilities for integration
Connectivity (road and rail interchange)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Modern fleets for competitiveness
Connectivity (road and rail interchange)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Congestion-free transport system
Connectivity (road and rail interchange)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Maintenance of infrastructure
Connectivity (road and rail interchange)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Limited geographical expansion
Connectivity (road and rail interchange)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Spatial planning
Transhipment facilities for integration	☐	☐	☐	☐	☐	☐	☐	☐	☐	Modern fleets for competitiveness
Transhipment facilities for integration	☐	☐	☐	☐	☐	☐	☐	☐	☐	Congestion-free transport system
Transhipment facilities for integration	☐	☐	☐	☐	☐	☐	☐	☐	☐	Maintenance of infrastructure

Transhipment facilities for integration	☐	☐	☐	☐	☐	☐	☐	☐	☐	Limited geographical expansion
Transhipment facilities for integration	☐	☐	☐	☐	☐	☐	☐	☐	☐	Spatial planning
Modern facilities and fleets for competitiveness	☐	☐	☐	☐	☐	☐	☐	☐	☐	Congestion-free transport system
Modern facilities and fleets for competitiveness	☐	☐	☐	☐	☐	☐	☐	☐	☐	Maintenance of infrastructure
Modern facilities and fleets for competitiveness	☐	☐	☐	☐	☐	☐	☐	☐	☐	Limited geographical expansion
Modern facilities and fleets for competitiveness	☐	☐	☐	☐	☐	☐	☐	☐	☐	Spatial planning
Congestion-free transport system	☐	☐	☐	☐	☐	☐	☐	☐	☐	Maintenance of infrastructure
Congestion-free transport system	☐	☐	☐	☐	☐	☐	☐	☐	☐	Limited geographical expansion
Congestion-free transport system	☐	☐	☐	☐	☐	☐	☐	☐	☐	Spatial planning
Maintenance of infrastructure	☐	☐	☐	☐	☐	☐	☐	☐	☐	Limited geographical expansion
Maintenance of infrastructure	☐	☐	☐	☐	☐	☐	☐	☐	☐	Spatial planning
Limited geographical expansion	☐	☐	☐	☐	☐	☐	☐	☐	☐	Spatial planning

6) With respect to the sub-criteria, in your opinion what is the relative importance of these performance indicators under "Safety and Security" of IWT performance?

	Extremely strong Importance	Very strong importance	Strong importance	Moderate importance	Equal importance	Moderate importance	Strong importance	Very strong importance	Extremely Strong Importance	
Traffic condition	☐	☐	☐	☐	☐	☐	☐	☐	☐	Navigation safety and route capacity
Traffic condition	☐	☐	☐	☐	☐	☐	☐	☐	☐	Vessel identification
Traffic condition	☐	☐	☐	☐	☐	☐	☐	☐	☐	Seaworthiness
Traffic condition	☐	☐	☐	☐	☐	☐	☐	☐	☐	Weather forecast

Navigation safety and route capacity	☐	☐	☐	☐	☐	☐	☐	☐	☐	Vessel identification
Navigation safety and route capacity	☐	☐	☐	☐	☐	☐	☐	☐	☐	Seaworthiness
Navigation safety and route capacity	☐	☐	☐	☐	☐	☐	☐	☐	☐	Weather forecast
Vessel identification	☐	☐	☐	☐	☐	☐	☐	☐	☐	Seaworthiness
Vessel identification	☐	☐	☐	☐	☐	☐	☐	☐	☐	Weather forecast
Seaworthiness	☐	☐	☐	☐	☐	☐	☐	☐	☐	Weather forecast

7) With respect to the sub-criteria, in your opinion what is the relative importance of these performance indicators under “Innovative Transport Technology” of IWT performance?

	Extremely strong Importance	Very strong importance	Strong importance	Moderate importance	Equal importance	Moderate importance	Strong importance	Very strong importance	Extremely Strong Importance	
Information and communication flow along the supply chain (Data exchange)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Shoreside data availability (AIS coverage)
Information and communication flow along the supply chain (Data exchange)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Hierarchical tracking and tracing of data at logistics unit level
Information and communication flow along the supply chain (Data exchange)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Interoperability with customers systems
Information and communication flow along the supply chain (Data exchange)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Voyage planning
Shoreside data availability (AIS coverage)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Hierarchical tracking and tracing of data at logistics unit level
Shoreside data availability (AIS coverage)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Interoperability with customers systems
Shoreside data availability (AIS coverage)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Voyage planning

Hierarchical tracking and tracing of data at logistics unit level	☐	☐	☐	☐	☐	☐	☐	☐	☐	Interoperability with customers systems
Hierarchical tracking and tracing of data at logistics unit level	☐	☐	☐	☐	☐	☐	☐	☐	☐	Voyage planning
Interoperability with customers systems	☐	☐	☐	☐	☐	☐	☐	☐	☐	Voyage planning

8) With respect to the sub-criteria, in your opinion what is the relative importance of these performance indicators under "Economic Development" of IWT performance?

	Extremely strong Importance	Very strong importance	Strong importance	Moderate importance	Equal importance	Moderate importance	Strong importance	Very strong importance	Extremely Strong Importance	
Aggregate added value (of transport and infrastructure)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Development (regional and local)
Aggregate added value (of transport and infrastructure)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Employment (direct and indirect
Aggregate added value (of transport and infrastructure)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Marketing
Development (regional and local)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Employment (direct and indirect)
Development (regional and local)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Marketing
Employment (direct and indirect)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Marketing

9) With respect to the sub-criteria, in your opinion what is the relative importance of these performance indicators under "Policy Formulation and Implementation for IWT" performance?

	Extremely strong Importance	Very strong importance	Strong importance	Moderate importance	Equal importance	Moderate importance	Strong importance	Very strong importance	Extremely Strong Importance	
Administrative support for modal shift to inland waterways	☐	☐	☐	☐	☐	☐	☐	☐	☐	Existing legislative framework for modal shift inland waterways
Administrative support for modal shift to inland waterways	☐	☐	☐	☐	☐	☐	☐	☐	☐	Incentives and grants for modal shift
Administrative support for modal shift to inland waterways	☐	☐	☐	☐	☐	☐	☐	☐	☐	Knowledge transfer and best practise
Administrative support for modal shift to inland waterways	☐	☐	☐	☐	☐	☐	☐	☐	☐	Logistic clusters formulation and collaboration
Administrative support for modal shift to inland waterways	☐	☐	☐	☐	☐	☐	☐	☐	☐	Integrated transport policy
Administrative support for modal shift to inland waterways	☐	☐	☐	☐	☐	☐	☐	☐	☐	Education and skill development
Existing legislative framework for modal shift inland waterways	☐	☐	☐	☐	☐	☐	☐	☐	☐	Incentives and grants for modal shift
Existing legislative framework for modal shift inland waterways	☐	☐	☐	☐	☐	☐	☐	☐	☐	Knowledge transfer and best practise
Existing legislative framework for modal shift inland waterways	☐	☐	☐	☐	☐	☐	☐	☐	☐	Logistic clusters formulation and collaboration
Existing legislative framework for modal shift inland waterways	☐	☐	☐	☐	☐	☐	☐	☐	☐	Integrated transport policy
Existing legislative framework for modal shift inland waterways	☐	☐	☐	☐	☐	☐	☐	☐	☐	Education and skill development
Incentives and grants for modal shift	☐	☐	☐	☐	☐	☐	☐	☐	☐	Knowledge transfer and best practise
Incentives and grants for modal shift	☐	☐	☐	☐	☐	☐	☐	☐	☐	Logistic clusters formulation and collaboration
Incentives and grants for modal shift	☐	☐	☐	☐	☐	☐	☐	☐	☐	Integrated transport policy
Incentives and grants for modal shift	☐	☐	☐	☐	☐	☐	☐	☐	☐	Education and skill development
Knowledge transfer and best practise	☐	☐	☐	☐	☐	☐	☐	☐	☐	Logistic clusters formulation and collaboration
Knowledge transfer and best practise	☐	☐	☐	☐	☐	☐	☐	☐	☐	Integrated transport policy
Knowledge transfer and best practise	☐	☐	☐	☐	☐	☐	☐	☐	☐	Education and skill development

Logistic clusters formulation and collaboration	☐	☐	☐	☐	☐	☐	☐	☐	☐	Integrated transport policy
Logistic clusters formulation and collaboration	☐	☐	☐	☐	☐	☐	☐	☐	☐	Education and skill development
Integrated transport policy	☐	☐	☐	☐	☐	☐	☐	☐	☐	Education and skill development

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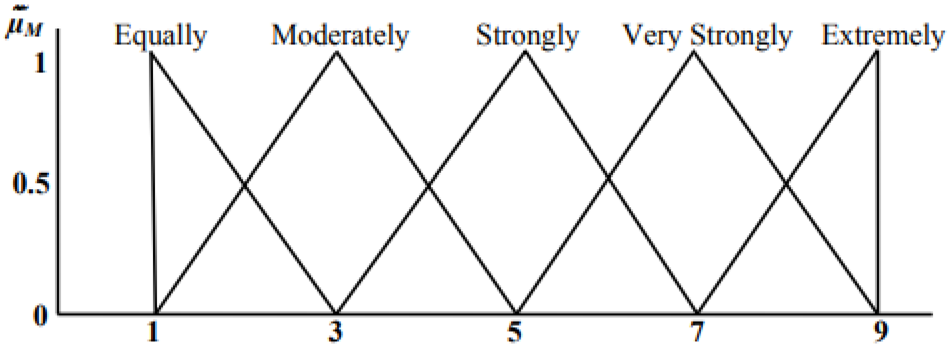
Based on your score, all pairwise matching will be combined by using a pairwise comparison scale.

In your opinion, as an expert, the pairwise comparison scale can be used to assess or express the importance of one indicator over another. The linguistic judgements and their explanations used for evaluating the importance of the elements in pairwise comparison is shown in Table 1.

Table 1. Linguistic judgements for fuzzy AHP

Linguistic judgements	Explanations
Equal importance (Eq)	Two activities contribute equally to the objective
Moderate importance (Mk)	Experience and judgement slightly favour one over another
Strong importance (St)	Experience and judgement strongly favour one over another
Very strong importance (Vs)	An activity is favoured very strongly over another
Extremely strong importance (Es)	The evidence favouring one activity over another is of the highest possible order of affirmation



THANK YOU ONCE AGAIN FOR YOUR KIND PARTICIPATION IN THIS SURVEY.

YOUR ANSWER WILL BE KEPT CONFIDENTIAL.

Appendix IV

The questionnaire used in survey C for Chapter Six of this thesis

LIVERPOOL JOHN MOORES UNIVERSITY

CONSENT FORM

Project Title; River-Sea Freight Transport in Major Logistic Gateways: A Performance Evaluation of The United Kingdom's and Continental Europe's Inland Waterways

Name of Researcher and School/Faculty:

Gbako Shekwoyemi

Researcher at Liverpool Logistics, Offshore and Marine Research Institute (LOOM)

Liverpool John Moores University, Byrom Street, Liverpool L3 3AF.

S.Gbako@2019.ljmu.ac.uk
Phone: 01512312121

1 I confirm that I have read and understand the information provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily ☐

2 I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and that this will not affect my legal rights. ☐

3 I understand that any personal information collected during the study will be anonymised and remain confidential ☐

4 I agree to take part in the above study survey involving the administration of a questionnaire ☐

Name of Participant	Date	Signature
Name of Researcher	Date	Signature

Questionnaire (TOPSIS)

Dear Sir/Madam,

My name is Gbako Shekwoyemi; I am currently studying for a PhD at Liverpool Logistics, Offshore and Marine Research Institute (LOOM) at Liverpool John Moores University. My research topic is "River-sea freight transport in major logistic gateways: a performance evaluation of the united kingdoms and continental Europe's inland waterways". At this stage, your feedback will help develop a universal framework for modelling and assessing the state of the art of inland waterways in different geographical areas of interest in the UK, Europe, and other regions.

This research proposed an assessment framework to measure and evaluate the influencing factors that significantly determine the overall performance in the inland waterway transport domain. The information gathered in this survey will be treated in the strictest confidence. I would be delighted if you could take part in this study in terms of your professional knowledge in intermodal transport, inland waterway transport, or supply chain management. However, your decision to participate is entirely voluntary and will be safeguarded under the Liverpool *John Moores University Ethical Guidelines.* All responses will be treated with strict confidence, as the researcher will make every effort to prevent anyone, not on the research team, from knowing that you provided this information or what the information is about.

I hope that you find participating in the study enjoyable. Please feel free to complete the questionnaire and send it back. If you have any questions or need further clarification, please do not hesitate to telephone me at (44)7367339732 or email me at S.Gbako@2019.ljmu.ac.uk, or my Director of Studies Dr Dimitrios Paraskevadakis, at +44 (0) 151 231 2766 or by email at d.paraskevadakis@ljmu.ac.uk

Thank you for your assistance.

Yours faithfully,

Gbako Shekwoyemi,

PhD Candidate

Liverpool Logistics, Offshore and Marine Research Institute (LOOM)

Liverpool John Moores University, Byrom Street, Liverpool L3 3AF.

Section A: Expert Profile

1. Type of organisation…………………………………………………………………….

2. Country(ies) of operation…………………………………………………

3. Job title and position (optional)…………………………………………………………

4. Years of experience …………………………………………………………………

Section B: Introduction and Explanation

This research proposed an assessment framework to measure and evaluate the influencing factors that significantly determine the overall performance in the inland waterway transport domain. Based on the expert's survey findings, the experts weighted the following as the most significant influencing factors determining performance for inland waterway transport in the regional case study. We further need your expertise and experience to decide on each criterion versus each region under investigation, including the Netherlands, France, Belgium and Germany, and the UK. The ratio scale measurement used in this study is shown below.

Key definitions of main criteria:

- *Mobility and Reliability:* Criterion that indicate how well a transport system function.
- *Efficiency and Profitability:* A necessary condition that reflects the transport operating margin. (The effectiveness and efficiency of the transport system has been identified to con-tribute substantially to the overall competitiveness and attractiveness of an industrial area)
- *Environmental impact and decarbonization:* Environmental consideration. (Sustainability of the transport with regards to energy consumption and gas emission (air). Tons of CO_2, PM, SO_X, NO_X and HC_X resulting from transport)
- *Infrastructure Condition:* Factor influencing the competitiveness of IWT.

(Maintenance, better connections to other modes of transport and logistics centers, filling missing links and bottlenecks)

- *Safety and Security:* Shipping safety an important concern (records of injuries, fires, fatalities, collisions, groundings, and any other accidents resulting from the transportation of shipments between their origin and destination as well as security of the supply chain be-tween the shipment's origin and destination
- *Innovative transport technology:* Enhancing transport competitiveness through best practices (Improve data integration across transport mode. Availability and transparency of freight flow information in combination with ICT facilities as well as standards for communication and information exchange to foster integration into modern supply chain)
- *Economic Development:* Significant impact of IWT on a country's economic development. (Enhancing a country's international market access through Improve performance)
- *Policy formulation and implementation for IWT:* Policy to promote alternative to road transport for freight movement. (Best practice planning for freight on inland waterways

Table 1: Evaluation scale for the alternative rating

Linguistic Variable	**Very Low**	**Low**	**Medium**	**High**	**Very high**
Grade	1	2	3	4	5

Section C: Questionnaire

Q1. With respect to Mobility and reliability, please determine the importance of each performance indicator in your region of operation.

	Important Level

	Very low	Low	Medium	High	Very High
Transit Time	☐	☐	☐	☐	☐
Navigability	☐	☐	☐	☐	☐
Availability and access to multimodal transport information	☐	☐	☐	☐	☐
Carriage capacity	☐	☐	☐	☐	☐
Handling performance	☐	☐	☐	☐	☐
Quality level of traffic services	☐	☐	☐	☐	☐

Q2. With respect to Efficiency and Profitability, please determine the importance of each performance indicator in your region of operation

	Important Level				
	Very low	Low	Medium	High	Very High
Energy efficiency	☐	☐	☐	☐	☐
Attractiveness of the transport system	☐	☐	☐	☐	☐
Price alternative (e.g., road and rail)	☐	☐	☐	☐	☐
Transhipment cost in seaport (time-cost saving)	☐	☐	☐	☐	☐

Q3. With respect to Environmental impact and decarbonisation, please determine the importance of each performance indicator in your region of operation

	Important Level				
	Very low	Low	Medium	High	Very High
Emission reduction	☐	☐	☐	☐	☐

Renewable and alternative energy	☐	☐	☐	☐	☐
Emission reduction funding	☐	☐	☐	☐	☐
Enforcement/monitoring	☐	☐	☐	☐	☐
Noise	☐	☐	☐	☐	☐

Q4. With respect to Infrastructure Condition, please determine the importance of each performance indicator in your region of operation

	Important Level				
	Very low	Low	Medium	High	Very High
Connectivity (road and rail interchange)	☐	☐	☐	☐	☐
Transhipment facilities for integration	☐	☐	☐	☐	☐
Modern fleets for competitiveness	☐	☐	☐	☐	☐
Congestion-free transport system	☐	☐	☐	☐	☐
Maintenance of infrastructure	☐	☐	☐	☐	☐
Limited geographical expansion	☐	☐	☐	☐	☐
Spatial planning	☐	☐	☐	☐	☐

Q5. With respect to Safety and Security, please determine the importance of each performance indicator in your region of operation.

	Important Level				
	Very low	Low	Medium	High	Very High
Traffic condition	☐	☐	☐	☐	☐
Navigation safety and route capacity	☐	☐	☐	☐	☐
Vessel identification	☐	☐	☐	☐	☐
Seaworthiness	☐	☐	☐	☐	☐
Weather forecast	☐	☐	☐	☐	☐

Q6. With respect to Innovative Transport Technology, please determine the importance of each performance indicator in your region of operation**.**

	Important Level				
	Very low	Low	Medium	High	Very High
Information and communication flow along the supply chain (Data exchange)	☐	☐	☐	☐	☐
Shoreside data availability (AIS coverage)	☐	☐	☐	☐	☐
Hierarchical tracking and tracing of data at logistics unit level	☐	☐	☐	☐	☐
Interoperability with customers systems	☐	☐	☐	☐	☐
Voyage planning	☐	☐	☐	☐	☐

Q7. With respect to Economic Development, please determine the importance of each performance indicator in your region of operation.

	Important Level				
	Very low	Low	Medium	High	Very High
Aggregate added value (of transportation and infra-structure)	☐	☐	☐	☐	☐
Development (regional and local)	☐	☐	☐	☐	☐
Employment (direct and in-direct)	☐	☐	☐	☐	☐
Marketing	☐	☐	☐	☐	☐

Q8. With respect to Policy formulation and implementation, please determine the importance of each performance indicator in your region of operation.

	Important Level				
	Very low	Low	Medium	High	Very High
Administrative support for modal shift to inland water-ways	☐	☐	☐	☐	☐
Existing legislative frame-work for modal shift inland waterways	☐	☐	☐	☐	☐
Incentives and grants for modal shift	☐	☐	☐	☐	☐
Knowledge transfer and best practise	☐	☐	☐	☐	☐
Logistic clusters formulation and collaboration	☐	☐	☐	☐	☐
Education and skill develop-ment	☐	☐	☐	☐	☐

Appendix V

Fuzzy comparison matrix of sub-criteria’s

Fuzzy comparison matrix of the sub-criteria with respect to mobility and reliability

C1	S_1	S_2	S_3	S_4	S_5	S_6
S_1	(1.000,1.000,1.000)	(0.222,0.507,3.500)	(0.400,1.562,4.500)	(0.286,0.895,4.500)	(0.400,0.965,3.500)	(0.400,1.080,2.500)
S_2	(0.286,1.972,4.505)	(1.000,1.000,1.000)	(0.400,2.151,4.500)	(0.222,1.367,4.500)	(0.400,1.552,4.500)	(0.500,1.830,4.500)
S_3	(0.222,0.640,2.500)	(0.222,0.465,2.500)	(1.000,1.000,1.000)	(0.222,0.518,2.000)	(0.222,0.815,2.500)	(0.222,0.866,2.500)
S_4	(0.222,1.117,3.497)	(0.222,0.732,4.505)	(0.500,1.931,4.505)	(1.000,1.000,1.000)	(0.400,1.320,3.500)	(0.400,1.185,3.500)
S_5	(0.286,1.036,2.500)	(0.222,0.644,2.500)	(0.400,1.227,4.505)	(0.286,0.758,2.500)	(1.000,1.000,1.000)	(0.500,1.266,3.500)
S_6	(0.400,0.926,2.500)	(0.222,0.546,2.000)	(0.400,1.155,4.505)	(0.286,0.844,2.500)	(0.286,0.790,2.000)	(1.000,1.000,1.000)

Fuzzy comparison matrix of the sub-criteria with respect to efficiency and profitability

C2	S_7	S_8	S_9	S_{10}	Weight
S_7	(1.000,1.000,1.000)	(0.286,1.265,4.500)	(0.500,1.830,3.500)	(0.286,1.240,3.500)	0.264
S_8	(0.222,0.791,3.497)	(1.000,1.000,1.000)	(0.400,2.037,4.500)	(0.286,1.002,4.500)	0.26
S_9	(0.286,0.546,2.000)	(0.222,0.491,2.500)	(1.000,1.000,1.000)	(0.222,0.372,0.667)	0.21
S_{10}	(0.286,0.806,3.497)	(0.222,0.998,3.497)	(1.499,2.688,4.505)	(1.000,1.000,1.000)	0.266

Fuzzy comparison matrix of the sub-criteria with respect to environmental impact and decarbonisation

C3	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	Weight
S_{11}	(1.000,1.000,1.000)	(0.222,0.481,3.500)	(0.222,1.097,3.500)	(0.400,1.417,3.500)	(0.500,2.614,4.500)	0.207
S_{12}	(0.286,2.079,4.505)	(1.000,1.000,1.000)	(0.222,2.084,4.500)	(0.500,2.740,4.500)	(0.500,3.036,4.500)	0.229
S_{13}	(0.286,0.912,4.505)	(0.222,0.480,4.505)	(1.000,1.000,1.000)	(0.500,2.029,4.500)	(1.500,2.823,4.500)	0.213

S_{14}	(0.286,0.706,2.500)	(0.222,0.365,2.000)	(0.222,0.493,2.000)	(1.000,1.000,1.000)	(0.500,2.753,4.500)	0.193
S_{15}	(0.222,0.383,2.000)	(0.222,0.329,2.000)	(0.222,0.354,0.667)	(0.222,0.363,2.000)	(1.000,1.000,1.000)	0.158

Fuzzy comparison matrix of the sub-criteria with respect to infrastructure condition

C4	S_{16}	S_{17}	S_{18}	S_{19}	S_{20}	S_{21}	S_{22}	Weight
S_{16}	(1.000,1.000,1.000)	(1.000,2.341,4.500)	(0.222,1.305,4.500)	(0.500,1.903,3.500)	(0.286,1.693,3.500)	(0.400,1.366,3.500)	(0.500,1.334,3.500)	0.154
S_{17}	(0.222,0.427,1.000)	(1.000,1.000,1.000)	(0.222,0.593,2.500)	(0.286,1.388,3.500)	(0.286,1.125,3.500)	(0.400,1.172,3.500)	(0.286,1.037,3.500)	0.14
S_{18}	(0.222,0.766,4.505)	(0.400,1.686,4.505)	(1.000,1.000,1.000)	(0.286,1.795,4.500)	(0.500,1.381,3.500)	(0.400,1.266,3.500)	(0.400,1.368,3.500)	0.15
S_{19}	(0.286,0.525,2.000)	(0.286,0.720,3.497)	(0.222,0.557,3.497)	(1.000,1.000,1.000)	(0.222,0.732,3.500)	(0.400,0.926,2.000)	(0.286,0.755,2.500)	0.136
S_{20}	(0.286,0.591,3.497)	(0.286,0.889,3.497)	(0.286,0.724,2.000)	(0.286,1.366,4.505)	(1.000,1.000,1.000)	(0.400,1.253,3.500)	(0.400,1.270,3.500)	0.143
S_{21}	(0.286,0.732,2.500)	(0.286,0.853,2.500)	(0.286,0.790,2.500)	(0.500,1.080,2.500)	(0.286,0.798,2.500)	(1.000,1.000,1.000)	(0.286,1.011,2.500)	0.137
S_{22}	(0.286,0.750,2.000)	(0.286,0.964,3.497)	(0.286,0.731,2.500)	(0.400,1.325,3.497)	(0.286,0.787,2.500)	(0.400,0.989,3.497)	(1.000,1.000,1.000)	0.14

Fuzzy comparison matrix of the sub-criteria with respect to safety and security

C5	S_{23}	S_{24}	S_{25}	S_{26}	S_{27}	Weight
S_{23}	(1.000,1.000,1.000)	(0.222,0.408,1.000)	(0.500,1.476,3.500)	(0.222,0.469,2.500)	(0.500,1.334,3.500)	0.193
S_{24}	(1.000,2.451,4.505)	(1.000,1.000,1.000)	(0.500,2.057,4.500)	(0.286,1.000,4.500)	(0.500,1.650,4.500)	0.221
S_{25}	(0.286,0.678,2.000)	(0.222,0.486,2.000)	(1.000,1.000,1.000)	(0.222,0.435,2.000)	(0.286,0.912,2.000)	0.177
S_{26}	(0.400,2.132,4.505)	(0.222,1.000,3.497)	(0.500,2.299,4.505)	(1.000,1.000,1.000)	(0.500,2.328,4.500)	0.224
S_{27}	(1.000,1.000,1.000)	(0.222,0.408,1.000)	(0.500,1.476,3.500)	(0.222,0.469,2.500)	(0.500,1.334,3.500)	0.185

Fuzzy comparison matrix of the sub-criteria with respect to innovative transport technology

C6	S_{28}	S_{29}	S_{30}	S_{31}	S_{32}	Weight
S_{28}	(1.000,1.000,1.000)	(1.000,2.883,4.500)	(0.400,1.455,4.500)	(0.500,2.751,4.500)	(0.500,1.820,4.500)	0.234
S_{29}	(0.222,0.347,1.000)	(1.000,1.000,1.000)	(0.222,0.415,1.000)	(0.222,0.750,2.000)	(0.286,0.635,2.000)	0.159
S_{30}	(0.222,0.687,2.500)	(1.000,2.410,4.505)	(1.000,1.000,1.000)	(0.500,2.626,4.500)	(0.500,1.678,4.500)	0.225
S_{31}	(0.222,0.364,2.000)	(0.500,1.333,4.505)	(0.222,0.381,2.000)	(1.000,1.000,1.000)	(0.400,0.716,2.000)	0.187
S_{32}	(0.222,0.549,2.000)	(0.500,1.575,3.497)	(0.222,0.596,2.000)	(0.500,1.397,2.500)	(1.000,1.000,1.000)	0.194

Fuzzy comparison matrix of the sub-criteria with respect to economic development

C7	S_{33}	S_{34}	S_{35}	S_{36}	Weight
S_{33}	(1.000,1.000,1.000)	(0.222,0.542,2.000)	(0.222,0.337,2.000)	(0.500,1.000,2.000)	0.219
S_{34}	(0.500,1.845,4.505)	(1.000,1.000,1.000)	(0.222,0.535,3.500)	(0.500,1.619,3.500)	0.266
S_{35}	(0.500,2.967,4.505)	(0.286,1.869,4.505)	(1.000,1.000,1.000)	(0.500,2.037,4.500)	0.294
S_{36}	(0.500,1.000,2.000)	(0.286,0.618,2.000)	(0.222,0.491,2.000)	(1.000,1.000,1.000)	0.222

Fuzzy comparison matrix of the sub-criteria with respect to policy formulation and implementation for IWT

C8	S_{37}	S_{38}	S_{39}	S_{40}	S_{41}	S_{42}	S_{43}	Weight
S_{37}	(1.000,1.000,1.000)	(0.500,2.079,3.500)	(0.400,1.257,3.500)	(0.222,0.339,2.000)	(0.222,0.926,2.500)	(0.286,0.644,3.500)	(0.500,1.585,4.500)	0.146
S_{38}	(0.286,0.481,2.000)	(1.000,1.000,1.000)	(0.286,0.630,2.500)	(0.222,0.376,1.000)	(0.286,0.890,2.500)	(0.286,0.616,2.000)	(0.400,1.167,2.500)	0.127
S_{39}	(0.286,0.796,2.500)	(0.400,1.587,3.497)	(1.000,1.000,1.000)	(0.222,0.404,1.500)	(0.500,1.197,2.500)	(0.286,0.667,2.000)	(0.500,1.791,3.500)	0.14
S_{40}	(0.500,2.950,4.505)	(1.000,2.660,4.505)	(0.667,2.475,4.505)	(1.000,1.000,1.000)	(1.000,2.736,4.500)	(0.400,1.345,4.500)	(0.400,2.462,4.500)	0.17
S_{41}	(0.400,1.080,4.505)	(0.400,1.124,3.497)	(0.400,0.835,2.000)	(0.222,0.365,1.000)	(1.000,1.000,1.000)	(0.286,0.743,2.500)	(0.286,1.149,2.500)	0.137
S_{42}	(0.286,1.553,3.497)	(0.500,1.623,3.497)	(0.500,1.499,3.497)	(0.222,0.743,2.500)	(0.400,1.346,3.497)	(1.000,1.000,1.000)	(0.500,1.823,3.500)	0.151
S_{43}	(0.222,0.631,2.000)	(0.400,0.857,2.500)	(0.286,0.558,2.000)	(0.222,0.406,2.500)	(0.400,0.870,3.497)	(0.286,0.549,2.000)	(1.000,1.000,1.000)	0.13