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Digitalisation and Decarbonisation Challenges of Inland Waterways Freight Logistics Transport and their Integration into Regional Supply Chains – A Case Study

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Abstract **- an era of increased sustainable transport, the European inland navigation industry has received significant attention to attain sustainable transport. Tremendous opportunities to substantially move freight on waterways are present in the UK; however, several challenges have been appropriately addressed, including infrastructural gaps and various institutional support programs. The paper addresses the UK's current situation of inland navigation and the key challenges affecting the sectors as a viable alternative transport solution. The article explores and summarises the geographic opportunities, commercial feasibility, and the current condition of the UK'S inland navigation sector. From the practical scenario of the UK's experience, an attempt was made by the authors to find the critical challenges and issues faced by the industry. The emerging themes from the analysis of this paper indicated governance and leadership issues, cooperation, and coordination mechanism between establishments with various functions and responsibilities, merged with infrastructural investment, are strategic elements for expansion in the UK. Conclusively, the authors presented recommendations for improvement and sustainable development.**

Keywords **- inland waterway transport, decarbonisation, digitalisation, challenges, sustainable development, intermodal transport, modal shift, waterway infrastructure, investments**

I. INTRODUCTION

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). Concurrently, the transport sector is among the economic sectors responsible for most greenhouse gas emissions in the European Union (EU) and the United Kingdom (UK) (Eurostat, 2023; Department for Transport, 2020a). The freight transport industry has heavily discerned and continuously growing pressure from globalised markets in the last decades (Tomas et al., 2019). Freight transportation has grown enormously, with road transport absorbing most of them (ITF, 2018). European experts have projected 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 Green House Gas emissions (GHGs) while also handling the projected growth in freight transport that the increasingly globalised market flow has caused. Freight transportation by inland waterways can play an essential role in sustaining this ambitious aim set out by the EU. According to recent research findings, it has been determined that rail and truck transportation exhibit around 39% and 371% more Carbon dioxide (CO2) emissions, respectively, compared to the emissions associated with inland barges and vessels (Grosso et al., 2021; Camargo-Diaz et al., 2023). An irreversible shift towards this low-emission freight transport mode can help achieve the goal of a low-carbon economy (Barrow *et al.,* 2022). A pivotal route to sustainable transport includes shifting freight from road to rail and river-sea shipping (Rogerson *et al.,* 2019).

According to Plotnikova et al., (2022) this mode is an alternative to the unsustainable and congested road network. It has proven to be a "safe, economical, multifunctional, reliable, and environmentally friendly mode of freight transportation. Inland shipping is an excellent alternative to road, considering its energy consumption, gas emission, and high traffic safety, particularly when transporting dangerous goods due to vessels' economies of scale (Huang et al., 2021). However, it's cost competitiveness and unit cost tend to decrease over a longer distance (Wiegmans & Konings, 2015; Hofbauer *et al.,* 2020; Raza *et al.,* 2020). In the era of sustainable transport, all these advantages present inland waterways with a unique advantage over other modes (Wang *et al.,* 2020). Although, due to geographical prerequisites, the

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use of waterways for freight transportation differs at continental and country levels (Ines-Danube, 2017). Also, the density of the natural waterways route is much more subordinate than that of the road, giving road transport an edge in offering customers a wide range of services (Bak & Zalewski, 2021). Consequently, because the road mode is already well-developed and offers modern services to its customers, river transport is often faced with difficulty and various challenges in investment concerning logistics services centres and warehouses, among others which are often located away from waterways (Kotowska, 2018; Kaup *et al*, 2020). However, looking at the transportation of goods and people on waterways dating back to the medieval era, using floating craft and later using inland vessels and barges remains the oldest means of transportation, generating economic development (Adams, 2001). Although the sector is still relatively small, it contributes considerably to the EU's transport system (European Commission, 2018). In central (the Danube Rivers) and the North-western (hinterland ports of the Netherlands, Antwerp, and Hamburg) Europe, a significant amount of freight is transported via inland waterways. These European seaports with suitable inland waterways network connectivity form an interface with seaports and have redefined their operations and strategic location (Paulauskas *et al.,* 2022). The use of inland shipping as supporting transport has increased with the transport mode's share. Here, inland shipping offers various freight forwarding solutions and has been increasingly integrated into their contemporary logistics chain due to the volume of handled goods (Caris *et al.,* 2014; Beyer, 2018).

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). The UK's inland waterways are significantly 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 UK government (Department for Transport, 2017a). 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. Nevertheless, this involves several challenges.

Therefore, the study explores some of the critical issues and challenges preventing the full utilisation of IWT as a sustainable alternative for freight transportation in the UK and further suggests feasible measures towards addressing those problems to stimulate a modal shift in favour of IWT. The authors proposed a user-centric research method that prioritises the needs and perspectives of users in the sector by integrating qualitative and quantitative approaches to understand better the issues and challenges that hinder the sector's ability to function as a sustainable mode of freight transportation.

II. METHODOLOGY

This study employs an exploratory, descriptive methodology and a literature survey technique (scientific articles, books, reports, official government website, related entities and publicly accessible documents on inland navigation in continental Europe and the UK in order to have a holistic understanding of historical developments, state-of-the-art with regards to freight transportation respective infrastructure investments made by the government as well as relevant input from some ongoing and completed transnational research projects in promoting inland waterways for freight transport. Site visits and interviews were conducted with several stakeholders in the industry.

First, a literature survey was conducted, reviewing the current body of knowledge in the field. Next, a quantitative summary of EU-funded projects addressing digitalisation and decarbonisation in IWT is provided. The study uses the Transport Research and Innovation Monitoring and Information System (TRIMIS) database

(TRIMIS - 2023), which has around 9000 transport research and innovation projects that are publicly accessible. The study concentrates on the latest Framework Programmes: The Seventh Research Framework Programme, the Horizon 2020 Framework Program for Research and Innovation (H2020), and the EU Interreg Projects. The TRIMIS database incorporates a mode categorisation system that facilitates the identification of IWT projects. In addition, the selection of projects was expanded to include multimodal freight transport initiatives directly related to IWT.

To become more knowledgeable about the subject and gain a comprehensive idea of structural outlines, challenges and issues in the field. Focus group discussions (FGDs) were also held as part of the research. FGDs were employed to gather primary, broad-ranging insights into the perspective held by specific demographic groups. The purpose was to uncover areas of interest and establish initial connections with participants, fostering a conducive environment for subsequent in-depth expert interviews. According to Meleady *et al.* (2012), a group discussion helps members work together to solve a problem. Choi and Menghrajani (2011) used a small discussion group with only two to three people. Meleady *et al.* (2012) caution that an extensive group debate can hamper reaching a consensus. Therefore, the current study employed medium-sized groups of 4-5 individuals to consider these recommendations and applications. Subsequently, site visits and interviews have been directed with some players in the sector to attain a comprehensive scenario and supplement the literature survey findings. The comprehensive interviews yielded greater knowledge regarding the perspective and interrelationships of problems among the individual stakeholders of problems amongst the individual stakeholders, allowing for a broader range of interpretations. The quantitative interview encompassed 13 individuals conducted between December 2022 and May 2023.

Geographically, the participants' interviews were drawn from IWT actors operating on and along the River Thames, River Humber and the MSC, representing Manchester and Liverpool's main waterway hinterland links in the UK. Participants include those involved in IWT infrastructure, port authorities, barge owners, administrative staff of IWT, Canal and River Trust (the Inland Waterway Authority for the UK), project partners linked to IWT, freight transport bodies, hinterland logistics experts and academician with knowledge in intermodal transport/supply chain management. The primary emphasis was placed on infrastructure managers, port authorities, and transport officials in order to optimise adherence to organisation requirements, transport policies and regulations. The study adequately considered these factors to ensure a holistic overview of the challenges and issues faced by the sector, as well as the innovations to enhance the sector's competitiveness.

Finally, operators of waterborne transport were employed to ensure a comprehensive perspective on freight transportation advancements. The issue of underrepresentation among this particular group of actors was indirectly addressed during a round table discussion/site visit to the river Thames as part of the Smart Track for Waterways (ST4W) Interreg-EU projects research seminar hosted by the Port of London Authority. 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.

III. RESULTS

A. Inland Waterway Transport in the EU

The network

The navigable inland waterways network within the EU exceeds 40,000km linking critical economic areas in central Europe (European Court of Auditors, 2015). These navigable rivers and canals of around 10,000km connect Germany, Belgium, the Netherlands, France, Luxembourg, Slovakia, Austria, and Hungary within the EU with other countries like Switzerland, Serbia, Poland, Croatia, and Romania outside the union (Erceg, 2018). Figure 1 illustrates an overview of the European inland waterways.

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Figure 1: Overview of the European Inland Waterway (United Nations Economic Commission for Europe, 2018)

A close look into the European waterways network shows that the backbone of this network is constituted by major rivers such as the Rhine and the Danube (Mako *et al.,* 2021). The Danube connected to the Rhine through the main River, thus establishing the Rhine-main-Danube canal. The main-Danube corridors connect 15 European countries through waterways with a navigable total length of approximately 2145km, connected from Germany, ending in the black sea in Romania (Totakura *et al.,* 2020). Two third of all goods in the European inland waterway pass through the Rhine due to the geographical position of the Rhine delta supported by quality infrastructure (rivers and canals) connecting large European hinterland, thus, making the Rhine River by far the essential by European waterways (Ines-Danube, 2017; Bu & Nachtmann, 2021).

With many smaller European towns and industrial centres accessible by numerous tributaries and canals, this points out that waterways in the heart of Europe's trading routes are perfectly placed to offer intermodal connections with other modes like the road, rail and even sea lanes (Havinga, 2021).

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 & 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 2021 (Havinga, 2021; Eurostat, 2022(b).

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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 (CE Delft, 2011).

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). 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)

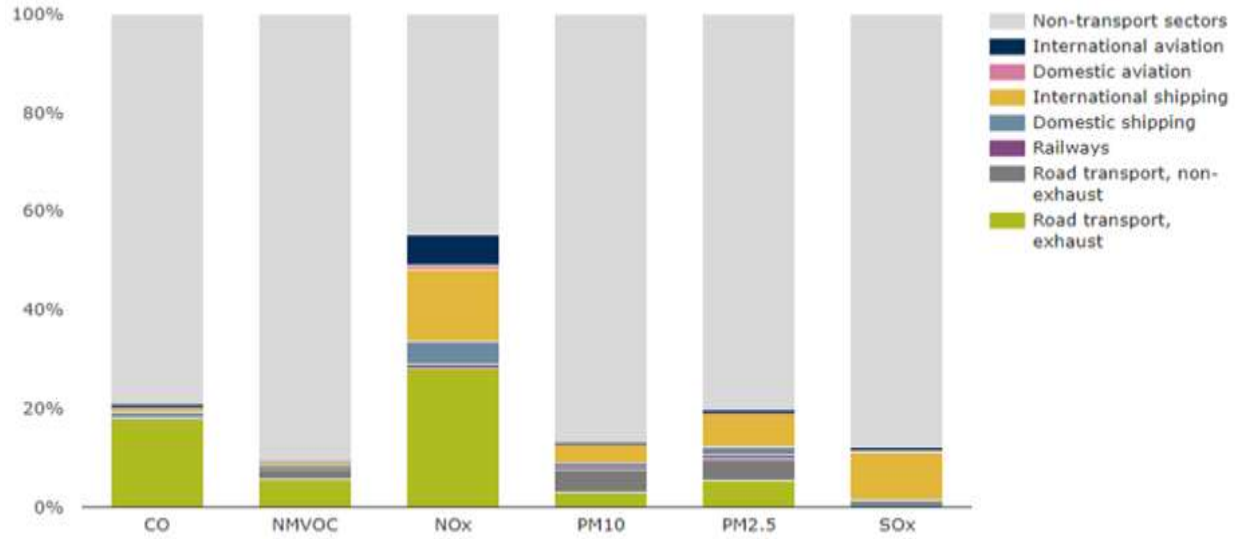

Figure 2: Contribution of the transport sector to total emissions of the main air pollutants (European Environmental Agency, 2019)

B. Promoting Inland Waterway Transport: The European Experience

The EU operate on standard policies enabling a single economic market within its member states (Mihić, *et al.,* 2012). The EU has explicitly tried to put the concept of sustainability at the centre of its transport strategy. The common objective is to develop a regional transportation system, enabling good quality services in efficiency, safety, security, and an environmentally friendly network. 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 transportation, which over the years were seen to have inclined too far towards road transport (European Court of Auditor, 2015).

In 2006, the European Commission introduced the Navigation and Inland Waterway Action and Development in Europe (NAIADES) programme with various action plans to enhance the utilisation of inland waterways as part of its intermodal transport solutions (Commission of the European Communities, 2006). After the finalisation of this programme, the commission refocused its inland navigation policy on improving the sector's economic and environmental performance by adopting the NAIADES II action programme

(European Commission, 2011). The NAIDES II action programme focuses on making long-term structural transformations in the industry more modern, innovative, and attractive. For this, the initiative set out by the commission was around various domains and areas with the highest added values, including developing smart infrastructure, technological innovation, environmental performance, functioning of the single market, human factor, and integration into the multimodal transport and logistics chains (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 the 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 (Specht *et al,* 2022).

Within the EU, the promotion of inland navigation to a large degree is financed through institutions keen to develop it as a sustainable alternative transport system (Amos *et al.,* 2009; Beyer, 2018). Two river commissions in the EU, the Central Commission for the Navigation on the Rhine (CCNR) and the Danube Commission, are examples of a cooperation and collaboration mechanism between member state institutions. Cohesion instruments primarily fund the development of the EU's member state inland navigation infrastructures (European Federation of Inland Ports, 2015). Other past and present proposals to support and encourage start-ups through European funding include Macro polo structures funds, Horizon 2020, and the Connecting European Facility (CEF) (INE, 2018). Additionally, as inland navigation has reinforced its reliance on maritime access, national transport policies of different European countries (Belgium, the Netherlands, Germany, and France) with good inland waterway connectivity have promoted the use of waterborne transport in their hinterland transport mode (Zweers *et al.,* 2019; Government of Netherlands, 2023). Table 1 summarises some ongoing and recently completed key EU projects promoting inland waterways for freight transportation.

Table 1 Reviews of some selected (2015 to 2023) ongoing and recently completed key EU projects promoting inland waterways for freight transportation (authors work - compiled from: Schepper & Gebraad, 2019; WEASTFLOWS, 2015; PROMINENT, 2018; DAPHNE, 2019; DANTE, 2020; RIS COMEX, 2020; CLINSH, 2020; IWTS2.0, 2020; EMMA, 2020; RIVER, 2020, CLINSH, 2021; NOVIMAR, 2021 & TRIMIS, 2023)

TITTLE	DURATION	PROJECT IDEA
PROMINENT	2015 – 2018	The project aims further to decrease the energy consumption and carbon footprint of IWT.
NOVIMAR	2017 – 2021	Coordinated by the Netherlands maritime technology. The NOVIMAR is a platooning concept for inland waterway transport through the vessel train concept.
RIS COMEX	2016 – 2020	The CEF RIS COMEX project works on RIS corridor management to overcome the current national data barriers. It aims to implement and operate cross-border River Information Services based on the operational exchange of RIS data.

DANTE	2017- 2019 and 2021 – 2027	The Dante is a Danube project that aimed at identifying barriers to IWT
WESTFLOWS	2011 – 2015	It aims to encourage a shift towards greener freight transport in Northwest Europe.
DAPHNE	2017 – 2019	The project aims to facilitate a balanced development of Danube ports as eco-friendly, well-accessible multimodal hubs for the region's transport system.
CLINSH	2016 – 2021	The project CLINSH is a European consortium promoting clean IWT. The project aims to improve air quality in urban areas by speeding up low-emission technologies around inland waterways.
RIVER	2017 – 2021	The river projects aim to reduce or eliminate the pollutants from polluting marine engines by applying an Oxy-fuel combustion technology for diesel engines that eliminate NO_X (part of the GHG), and capture, store all CO_2 emissions and reduce fuel consumption by up to 15%.
ST4W	2017 – 2021	The project Smart Track for Waterways works on tools and solutions for small waterways operators providing them with standardised data exchange and simple and cheap access to secure data track and trace shipment services.
IWTS2.0	2017 – 2021	The project seeks to enhance smaller waterway transport potential in a transnational context. (New waterway barges and training solution to enable a green modal shift from road to waterways)
CLINSH	2016 – 2021	The project aims to improve air quality in urban areas by speeding up low-emission technologies around inland waterways.
EMMA	2014 – 2020 and 2019 – 2021	Project EMMA is a Baltic Sea Region (BSR) project which aims at enhancing inland navigation in the BSR by implementing new logistics concepts and digitalisation of the transport system.

C. Digitalisation of inland waterways in Europe

Information and Communication Technology (ICT) has developed rapidly during the last decades creating new functionalities (Bharadwaj *et al.,* 2013). The ICT tools and new technologies concept (i.e., big data analysis, artificial intelligence, internet of things, cloud storage and computing) are penetrating more social life and are increasingly becoming of great significance in economic processes (Fruth & Teuteberg, 2017). These digital technologies are being used in an increasing number of fields nowadays. According to Lansiti & Lekhani (2014), many industries and organisations now capitalise on digitalisation due to the fourth industrial revolution attained by industries linking industrial processes and technologies to revolutionise the way and manner business activities have been performed. This is to meet customers' demands and withstand

competitive pressures (Westerman *et al.,* 2011). According to the work of Willems & Brodsky in the PIANC report (2018), it was deduced that the transformation towards a digital business had become an essential management priority for various businesses, including the inland maritime transport industry where digitalisation is at its early stage. The barrel towards digitalisation at the latter has been attributed to the economic situation during the past decades (Sanchez-Gonzalez *et al.,* 2018). Paravianen *et al.* (2017) identify digitalisation as a significant trend-changing society, economy, and business. This has been corroborated by Leviakangas (2016) in his studies which he views digitalisation as the most significant technology trend globally faced today, which has an impact on the transport industry, among others.

To a large extent, digitalisation relies on the concept of Intelligent Transport System (ITS), which according to Andersen & Sutcliffe (2000), is the application of the state-of-the-art information and communication technologies in transport. This is clearly in line with the majority of the given definition by the European Commission (2020) and the UK Department for Transport (2017(b), which covers the entire transport system, such as administration, stakeholders, infrastructure, and other related industries. At the European level, the digitalisation of IWT is mainly a task jointly progressed by member states through the framework of diverse EU projects (European Commission, 2017). However, the systematic review of the maritime transport sector of certain EU countries in terms of digitalisation has been extreme for a seaport in the past decades (Fruth & Teuteberg, 2017; Peeters *et al,* 2020(a). In recent times, the road and rail modes have predominately established themselves in digital transformation, whilst in the maritime transport industry, digitalisation tends to be at its early stage (Durajczyk, 2020; Specht *et al.,* 2022)

Digitalisation in ports

According to the European Federation of Inland Ports (2015), seaports have been recognised as the primary access gateway for trade and commerce in Europe. As a multidimensional system combining economic function, infrastructure system, geographical space and trade, and intelligence technologies are beginning to be implemented to manage operational activities better to meet new challenges while maintaining safe, secure, and energy-efficient facilities that mitigate environmental impacts. This aligns with the adoption of intelligent port technologies developed by many ports, with leading ports like Hamburg providing a single interconnection platform by connecting multiple individual systems, making all aspects of the port and transportation closely connected through various networks (Troegl & Sattler 2018). In a report by Deloitte Port Services (2017), the importance of ports as gateways for trade was recognised; the port services presented its view of the smart port and pointed out the main challenges furthering the need for intelligent ports, these include operational excellence, migration activities and new business opportunities. Figure 3. Shows the evolution of ports development overtime.

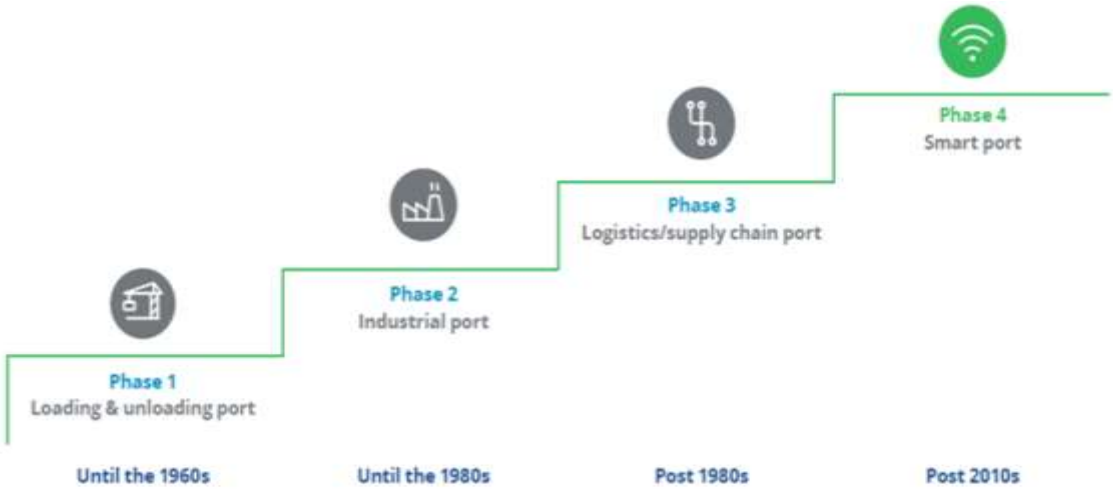

Figure 3. The evolution of ports development (Deloitte, 2017)

At the end of their report, they viewed smart port as a development stage where the digitalisation of port activities is at the forefront and new services replaced traditional practices through digital integration. Digitalisation can achieve an acceptable margin for waterways utilisation in freight transportation (Durajczyk & Drops, 2021). An acceptable margin for waterways utilisation in freight transport can be achieved through higher demand for transport and a modal shift within the hinterland transportation chain as well as maintaining a high-quality infrastructure (Kotowska *et al.,* 2018). Business activities in such seaports are shifted into becoming service providers with a significant focus on integrating all stakeholders who contributed to seaport operations in the digital platform (Jovic *et al.,* 2019). Figure 4. Shows the actors and their interrelationship 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 service quality and operational process (Pradana et al. 2019).

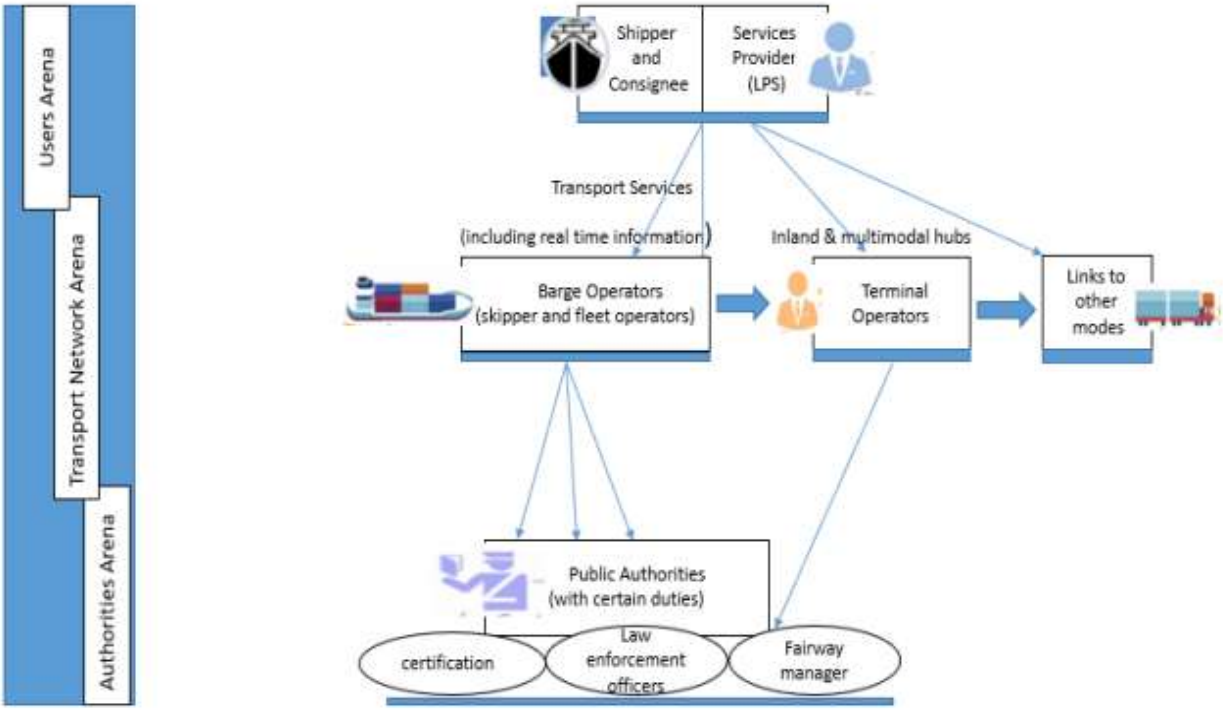

Figure 4: Actors and their interrelationship (authors work based on European Commission, 2017)

According to Tournaye *et al.* (2010), modern traffic and logistics management requires intensive information exchanges between partners in the transport chain (see Figure 4). Digitalisation can foster the seamless information flow between all parties and help stimulate the integration into the modern supply chain by improving traffic and transport management through more detailed information on infrastructure, traffic, cargo, and vessel location (EMMA, 2020). Extensive information exchange could increase the efficiency and profitability of the transport system (Peeters *et al.,* 2020 (a). Wide ranges of new business opportunities can be achieved with better access to and sharing digital transport data (Willems & Brodsky, 2018).

This is possible because real-time information on order status is made available for monitoring and invoicing (Heilig *et al.,* 2014), leading to shorter waiting and cost savings (Heilig & Vob, 2017). Therefore, since inland navigation needs to be competitive to be integrated into a more comprehensive 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 (Durajczyk & Drops, 2021). Achieving a modal shift can only be possible if it fits very well and shows features comparable with the corresponding ones available in other modes of transport thus, many criteria are considered (Roso *et al,* 2020). To stimulate intermodal

inland waterways transport in line with the development policy measure, enhancing the modelling of transport and freight demand is essential to elevate the efficacy of the policy measures. In particular, to have complete coverage of information on the coordination and interaction between different actors in the intermodal chain (Schilk & Seemann, 2012).

Academic researchers have put forward the need for further enhancement of the RIS; in particular, Pfliegl & Back (2006) have long suggested that increasing the attractiveness of RIS can enhance the service quality of inland navigation for the sector to gain from the increasing transport demand. According to Troegel & Sattler (2019), the RIS was developed to advance the use of IWT regarding safety and transport efficiency through a telematics system, a similar initiative to the road sector ITS. Since its creation, it has actively been supported by the EU. In line with the digital single market strategy, studies for stimulating the digitalisation of logistics information flow for IWT have been launched by the European Commission called the *"Digital Inland Navigation Area'* (DINA) (European Commission, 2017). According to Troegel & Sattler (2019), the so-called DINA will be closely linked to RIS and highly dependent on concrete development and implementation of a project like the RIS COMEX. The RIS is expected to become an essential component of the DINA initiative to support the logistics processes of IWT in Europe (European Commission, 2017).

D. Inland Waterways Transport Sector in the UK

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 presents those suitable for their use for freight transportation.

Table 2: Waterway Categories and Characteristics (remodified from the Department for Transport (2004; 2021)

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
	• Lock size determines craft size. • Lock size considerably larger than broad waterway • Vessel payload in hundreds of tonnes	-Land drainage - Some leisure use	- Aire & Calder navigation - River Weaver - River Severn - Manchester Ship Canal

Large non-tidal waterways	• 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		- 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 • Unlikely to be suitable for containers	- Significant leisure use which may restrict capacity for freight. - Land drainage - Leisure use of towpath	- Grand Union Canal - Leeds & Liverpool canal - River Great Ouse
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

England and Wales have around 3,170 miles - 5,100 kilometres of canals and other navigable waterways (Department for Transport, 2004). 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 inland waterways transport (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). Compared to continental Europe, British waterways are used significantly less for freight transport. However, it has also been argued that Europe's natural geography has been of much help (Wiagmans, 2018; Gosling, 2019). Figure 5 below shows the domestic waterborne freight goods moved and lifted in 2021 in the UK.

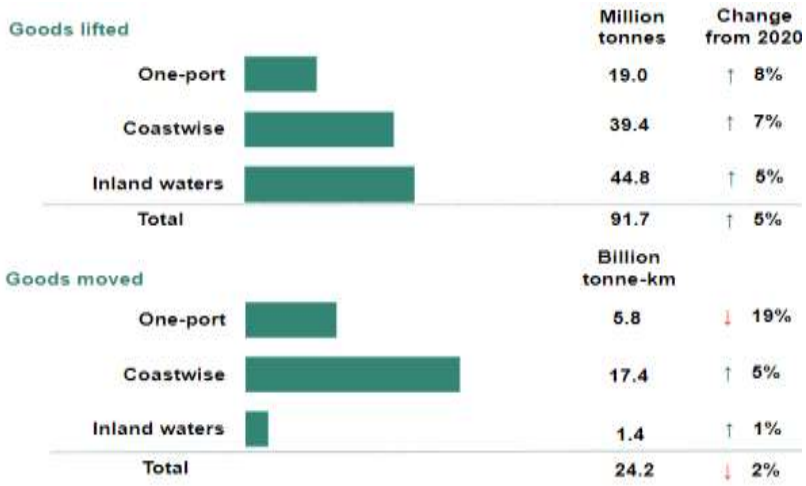

Figure 5: Domestic waterborne freight goods moved and lifted, 2021 (Department for Transport, 2022)

Analysing freight transport of many countries across Europe reveals that while freight statistics in Germany and Netherlands remain substantially constant over four years (2014 - 2018), the corresponding figures in the UK are seen to be much smaller and showing a significant decline over this year (Rogerson *et al.,* 2019). Figure 6 shows freight moved by individual waterways in the UK in 2021.

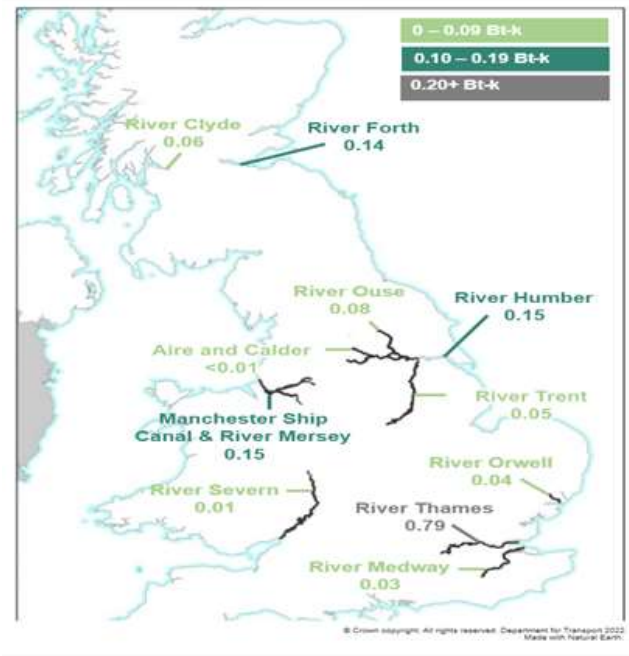

Figure 6: Domestic waterborne freight goods moved by waterway (Department for Transport, 2022)

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). 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 7. Shows freight transported via inland waterways in the UK from 2006 to 2020.

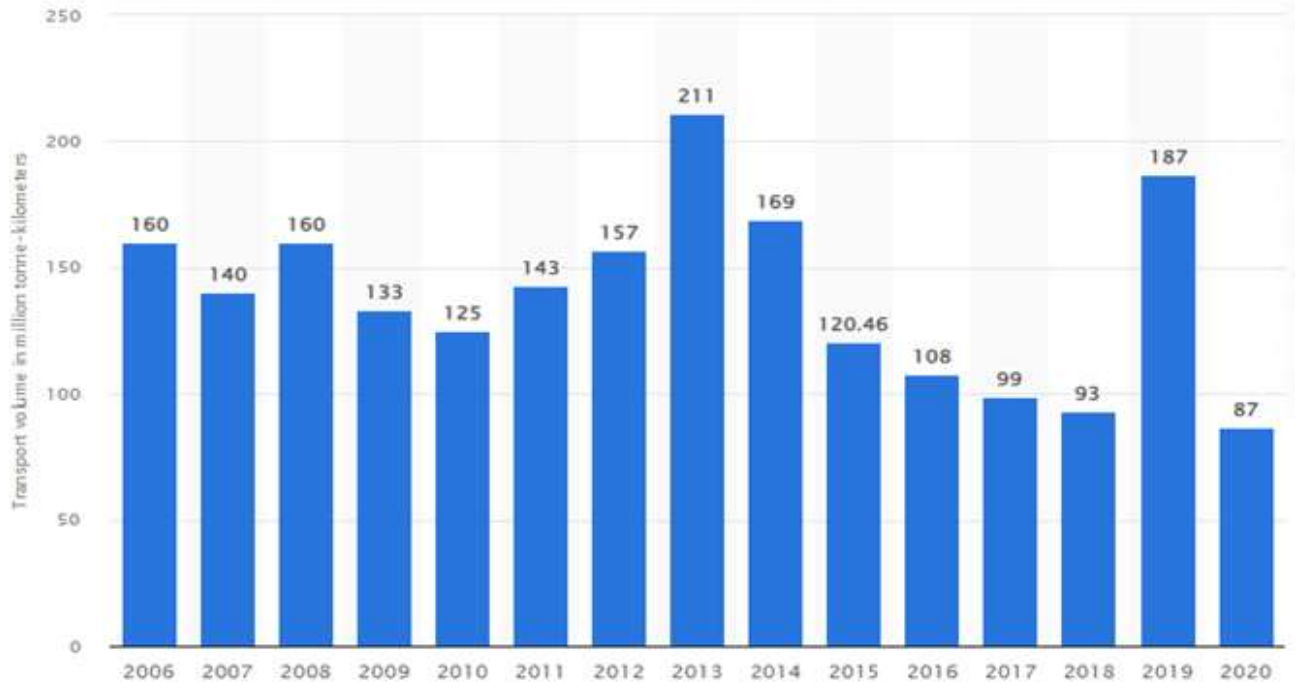

Figure 7: Amount of Freight Transported by Inland Waterway in the United Kingdom from 2006 to 2020 (in million tonne kilometres) (OECD, 2021)

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). In this review, the critical issues faced by the sector in the UK are categorised into four major groups, including technical, geo-political factors, investment, and cooperation through integrated transport development, as illustrated in Figure 8.

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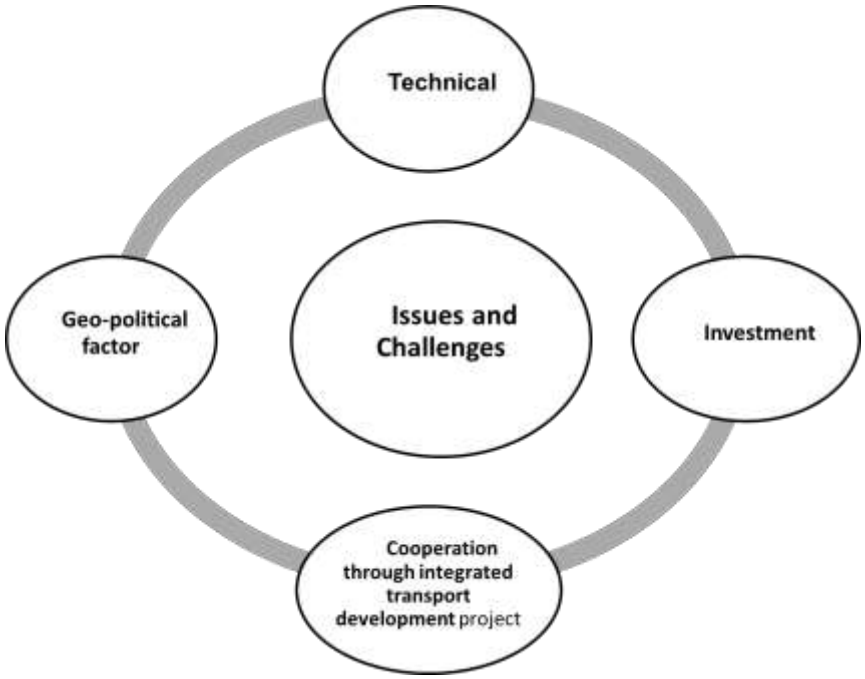

Figure 8. Key issues and challenges in the inland waterway transport sector in the UK (authors elaboration)

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).

Inadequate fairway depth – As illustrated in Table 2 (section 4.1), 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 simultaneously navigate upstream and downstream at a 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. The UK's inland waterways, especially the River Seven, River Medway, River Clyde and the Aire and Calder Navigation, faced serve problems in this regard, thus restricting cargo movement via this mode.

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.

Maintenance – With maintenance, transport infrastructure can retain its value. Making waterways navigable through the year, dredging, and constructing canals, and building a set of locks have substantial financial implications. Maintenance is necessary for this infrastructure to maintain its value. Lighter loads are often carried on a barge due to inadequate dredging. Infrastructure managers often postpone waterway infrastructure maintenance or modernisation due to underutilisation. Maintenance, repairs, and overhaul often need improvement in the UK context.

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. Compared to other sectors like road and rail, a poor margin characterised the UK inland navigation sector in fleet modernisation. Largely, the competitiveness of waterborne transport lies in modern fleets.

Lack of service centres - The lack of infrastructure and services centres, for example, intermodal connectivity, terminal and terminal equipment, storage facilities, and value-added services, enables smooth cargo transfer between nodes.

Investment

Government investment - Linked investment and transport policies are frequently too focused on road and rail transport. 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.

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

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.

Cooperation through integrated transport development

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.

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.

Geo-political factors

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. The strategic importance of the connectivity is essential to other regions with limited waterways due to their geographical position.

Integrated river management system/Hydropower generation projects - To ensure all year-round navigation, integrating the river basin is important. 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. 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.

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.

UK government transport policy

The use of waterways for freight transportation has declined in recent decades, from commercial operations to leisure and recreational purposes (Veitch, 2016). Some exceptions include the River Thames, River Fourth, the Liverpool/Manchester Ship Canal, the Humber, and parts of the canal network. Recently, planning, and environmental policies have provided a solid rationale to sustain waterborne transport as a carbon-efficient alternative transportation mode for freight to reduce congestion and emission potentially (Gosling, 2019). The DfT, metropolitan transport agencies and other private entities have continued to explore different pathways to use the investment strategies and modal shift incentives for effectively utilising all parts of the transportation systems for freight. Where there is a practical alternative and economic benefits, freight partnership has been created in some areas to help local authorities through their Local Transport Plans (LTPs). For example, as an alternative transport system, the Thames carries approximately around 56% of the inland waterway traffic, keeping traffic flowing in a congested urban environment. The guidance presented by the LTPs helps to formulate complex planning guidance and more acceptable promotional measures for waterborne transport, taking its various advantages while encouraging the business community to work in

partnership with the government through freight grants schemes. Figure 9 presents some of the freight strategies adopted by the UK government to endorse inland waterways as a carbon-efficient alternative transportation mode for freight -integration in local transport plans or transport planning policy.

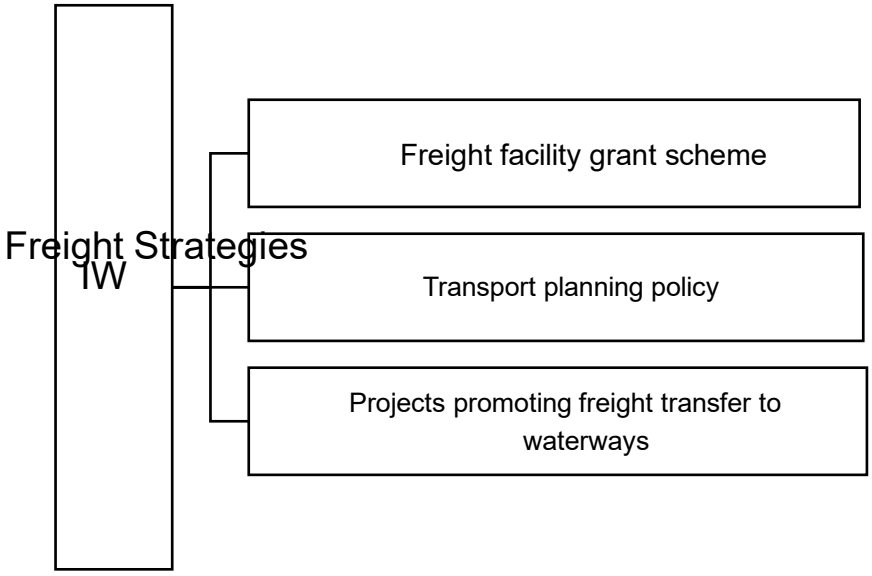

Figure 9. IWT freight strategies adopted by the UK government (authors own elaboration)

The freight grants scheme (freight mode revenue support and waterborne freight grant schemes) is part of the encouragement schemes adopted by the government to assist freight movement on waterways while tackling many environmental issues, including traffic congestion, emissions, climate change and noise. It is considered an essential factor for a business decision to move freight by waterways. Although the assessment of the grants is subjected to certain criteria (DfT, 2020b; DfT, 2022b), it is made available through the DfT. Other includes projects promoting freight transfer to the waterway (refurbished steel handling wharf facilities for vegetable oil transfer, fuel distribution terminal at Leeds, distribution sites for aggregates and waste product, inland barge refurbishments and the upgrading of the ship to barge bulk terminal at new holland), also assisted by freight grants, future transport policy development and public awareness perception on waterways potentials. Although freight strategies presented by the UK government have yielded little impact over the years, analysis of the UK government strategies in Figure 9 shows considerable positive thinking about using this mode for freight.

IV. DISCUSSION

A. Prospects for the development of inland waterways transport in the UK

The inland waterway transport sector is starting to expand and redefine itself regarding strategic positioning and transport services operations in some geographical regions (Beyer, 2018). In the era of an increase in the importance of using sustainable transport, the use of environmentally friendly alternatives to the unstable and congested road network is growing Mako *et al.,* 2021). Many firms within the UK are looking to boost their "green credentials" Inland shipping can play a vital role in sustainable transport and logistics within the UK if used optimally (Zolfaghari *et al.,* 2019). Nevertheless, the development of inland navigation in the UK remains challenging. The drive for sustainability has evolved and become more critical in recent times, mainly to lower CO_2 and particulate emissions from all modes of transportation. This might enhance inland shipping competitiveness compared to the UK's most preferred transport mode (the road). A quest for scale increase will continue to play in the drive towards lower costs. However, it must also be acknowledged that new and innovative transport technologies are fast developing in the road industry as a measure of increasing environmental sustainability through truck platooning and electrification (Peeters et al., 2020(a). The inland shipping industry must improve the quality of its services to gain from the increasing transport

market in the UK (Wiagmans, 2018). The use of information and communication tools and cooperation possibility offers more considerable opportunities to move the industry towards seamless integration into the contemporary logistic chain (Specht, 2022). Figure 10 shows some of the potential core developmental factors.

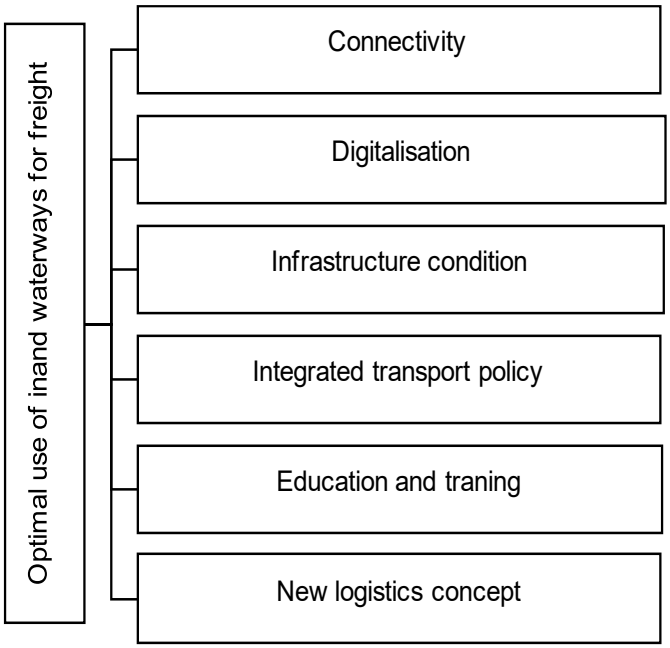

Figure 10. Some of the potential core developmental factors for IWT in the UK (authors own elaboration)

Promoting more freight traffic on waterways primarily depends on the potential prospective demands for these movements. Changes are driven explicitly by supply and demand conditions in transport, including transport infrastructures, innovation, and flow changes. The integration of actors in the modern logistics chain leads to the increasing insertion of inland shipping into a more complex organisational structure where price and capacity benefits have their place (Restrepo-Arias, 2022). Improving an operational interface through infrastructural connectivity is significant from the UK perspective. Here infrastructural managers can directly influence the utilisation of this transport mode through connectivity, for example, road links and re-evaluation of a prominent rail location that makes UK ports a potential model for intramodality. Improvement of the operating interface of inland navigation with other transport modes within the logistic nodes helps to enhance the transport potential further. One of the significant benefits offered by the system of rivers in the UK is that the rivers and canals are closely correlated with structures of settlements, industrial and metropolitan areas. Seaports and estuaries are also present in a few cases. Also, the efficiency and sustainability of this transport mode could be enhanced by extending the usage of Information and Communication Technology (ICT). Information for strategic transport operations planning, including forecasted traffic conditions, logistics services, lock planning management, and infrastructure availability/condition (i.e., delay, and network services disruption due to electro-mechanical failure on locks or planned maintenance work being carried out along the route, rises in demand, and accident occurrence). Having almost immediately available information in such a situation can help cargo diversion to other modes (Durajczyk & Drops, 2021); however, more robust cooperation between service operators is needed for this to occur. Adequate access to digitally sharing transport data along the logistic chain can facilitate seamless information flows and unlock vast new business opportunities (Lisaj, 2019). On the European scale, River Information Services (RIS) is a significant initiative in this respect (Durajczyk, 2020).

The prerequisite to enable an effective transport network is the availability of infrastructures linking economic areas, the availability not just in its natural presence and sufficient capacity but also in terms of quality. In the UK, to a large extent, there is uncertainty about planning to remove significant bottlenecks and

the filling of missing links, which generally affects the overall efficiency of the transport network (Veitch, 2016). 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 benefits of moving freight via waterways are often supported by government policy. From the UK perspective, although the government has endorsed the use of waterborne transport for freight movement within the country, the policies still need to be converted into action.

Using inland navigation for freight movement offers value to customers in terms of low cost, the economics of scale and efficient operations. Introducing a modern concept and logistics to adapt to new market needs would better exploit the existing free capacity of the transport system.

V. CONCLUSION AND FUTURE RESEARCH WORK

The transport industry perceives the steadily rising pressure from the globalised market flow. Following the growing cargo demand and transport services realised in the past decades, the intensity of inland transportation, explicitly on the road, has increased. These growing cargo demands have raised concerns about increasing commercial traffic, contributing considerably to traffic safety and environmental issues, particularly road transport. The ever-increasing acknowledgement of the external outcome of transportation has necessitated the direction of a more sustainable transport mode. It is widely recognised that one of the major global causes of pollution is related to the transportation sector. Environmental issues are currently receiving increasing attention from society. Consequently, one of the future solutions is the development of more environmentally friendly modes of freight transportation.

Promoting IWT has become a longstanding priority in pursuing sustainable European transport systems. This sector has consistently received significant attention and effort to foster sustainability, and evidence of this is seen in several large EU-funded projects within the transportation domain. Due to its sustainability and less congestion operational approach, the implication of inland waterways, especially within the European intermodal transport chain, gives European policymakers more cause for integration. As a result, most of the leading Western European seaports are now prioritising inland waterways in their hinterland transportation network. Although the natural geography of the European mainland has generally been considered advantageous compared to the UK, the continent still presents valuable lessons.

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, inland navigation has continued to play a marginal role in the UK transportation system. Underutilising the IWT capacity's potential in the present circumstance signifies a substantial reservoir for advancing freight transportation using this particular mode. Analysis of freight transport statistics of many countries across Europe reveals that while freight statistics in Germany and the Netherlands remain substantially constant over four years (2014 - 2018), the corresponding figures in the UK are seen to be much smaller and show a significant decline over the year, the corresponding figures in the UK are seen to be much smaller and offer a substantial reduction over the years. Further analysis reveals this is mainly due to political factors, including IWT infrastructures and established freight routes within the country. These challenges range from poor maintenance, navigation parameters (the channel's dimension, the depth of the trail and width, and the height of the bridges), terminal facilities, ageing fleets, low public perception of waterways potential and improved road network resulting in fierce competition from the road transport.

In the UK, road and rail transport are frequently the focus of transport policies and related investment. Many waterways in the UK remain feasible and offer strong commercial benefits. However, substantial infrastructure and waterways maintenance investment is needed to fully exploit this transport's potential. The benefits of waterborne transport concerning sustainability and external costs for society have yet to be considered adequately. More links and cleared bottlenecks are needed to ensure the overall effectiveness of the transport network.

Nevertheless, it is worth noting that these investments possess significant potential for waterways in the UK. This is mostly due to the fact that investments in waterways offer multifaceted benefits beyond their

primary function of facilitating transportation, such as promoting leisure activities and supporting white fleet business. The social return on investment should be prioritised when strategising for more investments, as it increases overall societal benefits. 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 waterborne transportation for freight. IWT modal share will rise in the coming years. To effectively meet future challenges and enhance the competitive edge of IWT, it is imperative to consider the potential and prospects associated with this mode of transport.

From a UK perspective, research on IWT primarily centres on environmental impacts and the promotion of collaborative efforts to optimise its use, particularly within intermodal transportation. We expect that more researchers will focus on increasing environmental sustainability in the future. This will involve the exploration of energy-efficient navigation techniques and advancement in hydrodynamics. Strengthening competitiveness (developing new technologies that enable fleets to adapt to climate change and facilitate more efficient handling, maintenance, and repair processes). Furthermore, a research focus on effectively managing growth and adapting to changing trade patterns involves adopting new logistics approaches and establishing advanced RIS services and security standards. This work may assist researchers, policymakers, regulators and transportation firms in developing relevant policies, programmes, and business plans by providing an up-to-date assessment of the digitalisation and decarbonisation challenges of inland waterway freight transport logistics from the UK perspective. The study also complements the existing body of literature in the field of IWT.

Nevertheless, this study has potential limitations. The limitation of the study arises from the medium-sized group of FGDs employed. Although an in-depth expert interview was conducted, there were few participants involved. Moreover, research interviews mostly centre on self-reports, meaning what an individual says, does or believes. Furthermore, the scope of the study is limited to the European and UK contexts, which does not allow direct interference with other significant IWTs worldwide. In light of the limitations imposed by the methods used, the results provide a profound insight into the digitalisation and decarbonisation challenges of IWT in the UK. However, they should be interpreted with caution. Nevertheless, we believe that the FGDs, experts' interviews, site visits and the previous qualitative research phase provide a reliable representation and overview of the prevailing perceptions regarding the digitalisation and decarbonisation challenges of inland waterways freight logistics transport and their integration into regional supply chains.

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CONFLICTS OF INTEREST

Authors declare no conflict of interest.

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Izzivi digitalizacije in dekarbonizacije logističnega prevoza blaga po celinskih plovnih poteh in njihovo vključevanje v regionalne oskrbovalne verige - študija primera

Povzetek - V dobi vse bolj trajnostnega prometa je evropska industrija celinske plovbe deležna velike pozornosti za doseganje trajnostnega prometa. V Združenem kraljestvu obstajajo izjemne priložnosti za bistvene premike tovora po vodnih poteh, vendar je bilo ustrezno obravnavanih več izzivov, vključno z infrastrukturnimi vrzelmi in različnimi institucionalnimi podpornimi programi. Dokument obravnava trenutni položaj celinske plovbe v Združenem kraljestvu in ključne izzive, ki vplivajo na te sektorje kot izvedljivo alternativno prometno rešitev. Članek raziskuje in povzema geografske priložnosti, komercialno izvedljivost in trenutno stanje sektorja celinske plovbe v Združenem kraljestvu. Na podlagi praktičnega scenarija izkušenj Združenega kraljestva so avtorji poskušali najti ključne izzive in vprašanja, s katerimi se sooča industrija. Teme, ki so se pojavile na podlagi analize tega dokumenta,

so pokazale, da so strateški elementi za širitev v Združenem kraljestvu vprašanja upravljanja in vodenja, sodelovanje in mehanizem usklajevanja med ustanovami z različnimi funkcijami in odgovornostmi, združeni z infrastrukturnimi naložbami. Na koncu so avtorji predstavili priporočila za izboljšanje in trajnostni razvoj.

Ključne besede - promet po celinskih plovnih poteh, razogljičenje, digitalizacija, izzivi, trajnostni razvoj, intermodalni promet, modalni premik, infrastruktura plovnih poti, naložbe