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Digital Information Services Needed for a Sustainable Inland Waterway Transportation Business

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Abstract: Inland waterway transportation (IWT) is highly efficient in terms of greenhouse gas emissions but lacks economic competitiveness when compared to other modes of transport. Digital information services that foster efficiency and sustainability of IWT are considered important elements for improving its attractiveness and thereby reducing greenhouse gas emissions of the transportation sector as a whole. Therefore, this paper addresses the question of what kind of digital information services are actually needed and should be provided, e.g., by port and waterway authorities, to stimulate a modal shift in favour of IWT. Though the concept of river information services (RIS) already provides a harmonised approach to information services in the sector, the current political and scientific discourse still lacks insight into what degree the currently available information services actually meet industry needs. Equally, possibilities to provide practical recommendations are limited. Therefore, this contribution fills this knowledge gap by providing data from the field gathered through a combination of qualitative and quantitative research methods. After elaborating on the underlying problem as well as the current state of research and practice, we will lay out observed information-relevant challenges to business actors and their respective needs. Based on this, practical recommendations for improvements of digital services and further avenues for research are derived.

Keywords: digital information services; inland waterway transport; digitalization; IWT operators; sustainable transportation

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1. Introduction

Inland waterway transportation plays an important role in transforming the transportation sector by providing large transport capacities, reduced costs, energy-efficiency, and, consequently, lower greenhouse gas (GHG) emissions compared to other transport modes [1,2]. Indeed, with IWT in its present state consuming just a fifth of energy per tonne-kilometre as compared to road transport and only half of the rail transport, resultingly being the most energy-efficient mode of transport, the exploitation of IWT's full potential that comes with a modal shift in its favour can be regarded as a pre-requisite to meet the European Commission's targets in terms of reducing GHG emissions [3,4]. Inland ports located along rivers and canals constitute potent distribution hubs regulating various freight flows [5] to cities, particularly those linked to global transport via seaport gateways [6]. IWT thus has the potential of providing environmentally friendly sustainable solutions whilst fuelling economic development.

High reliability of services in combination with low costs are crucial factors for modal shift [7]. Yet, to provide efficient and competitive transport services, stakeholders involved in IWT need to carry out a set of complex navigational and planning decisions [8]. For this, the provision of relevant digital information services is of high importance as it ultimately affects decision quality [9] and the efficiency and sustainability of transport operations. Sustainability in this context refers to the ability to mitigate the negative impacts of business

activity by providing socially inclusive working conditions, economic performance, and environmentally friendly transport services [10].

While the concept of river information services (RISs) already provides a common framework for digital information services operated by port and waterway authorities, practitioners and industry experts claim that current implementations and functionalities do not sufficiently allow the full exploitation of the potential of digitalisation [11]. Thus, "to ensure the competitiveness of the inland waterway system in the medium and long term, a significantly more intensive orientation of inland navigation towards digital trends will be indispensable in the future." [12].

The potential impact of digitalisation and information and communications technology (ICT) on the inland waterway transport business has been acknowledged in the research community [8,13–19]. However, a lack of scientific contributions that focus on the needs of IWT operators regarding digital services still clearly prevails. To overcome this research gap and to provide a better understanding of digital information services needed by IWT stakeholders for sustainable inland waterway transportation operations, the authors propose a user-centric research approach that combines qualitative and quantitative methods. This work, carried out within the scope of the EU Horizon 2020 project IW-NET [20], aimed to identify digital information services that are required for improved planning decisions by operational IWT stakeholders, such as crew members and transport planners. This goal, to further align and structure the research process, imposes a set of further inquiries on:

- The challenges that IWT operators face when making planning decisions before and during transport operations;
- The importance of specific information to carry out the respective planning tasks;
- Digital service functionalities to address the existing planning challenges;
- Ways for stakeholders to access those digital services.

The remainder of this article is organised as follows: First, the practical and scientific background of the relevant field of study is given in Section 2 by outlining current legislation of information services in European IWT and by providing a literature review on digital services in the IWT domain. Section 3 elaborates on the methodological approach that was used to answer our research questions while the results of the study are described in Section 4. Finally, a discussion along with the respective conclusions follows in Section 5.

2. European Legislative and Scientific Background

2.1. The RIS Directive as a Framework for Information Services in European IWT

At the European level, the need for information in the inland navigation domain has been addressed by the Directive 2005/44/EC on harmonised RISs on inland waterways in the community (commonly referred to as the "RIS Directive"). As a result of the harmonised action, the EU has required its member states to implement a set of information technologies that support traffic and transport management, including interfaces with other modes of transport. As such, RISs are intended to improve safety, efficiency, and environmental friendliness [21] and sustainability of inland navigation. The EU has taken a holistic approach that encompasses policy development, support for research and development, a legal framework (see Figure 1), and monitoring of the implementation of the legislation.

The RIS Directive defines four key technologies that are subject to common and continuous specification. This includes:

- Vessel tracking and tracing (VTT);
- Notices to skippers (NtS);
- Electronic reporting international (ERI);
- Inland electronic chart display and information system (inland ECDIS).

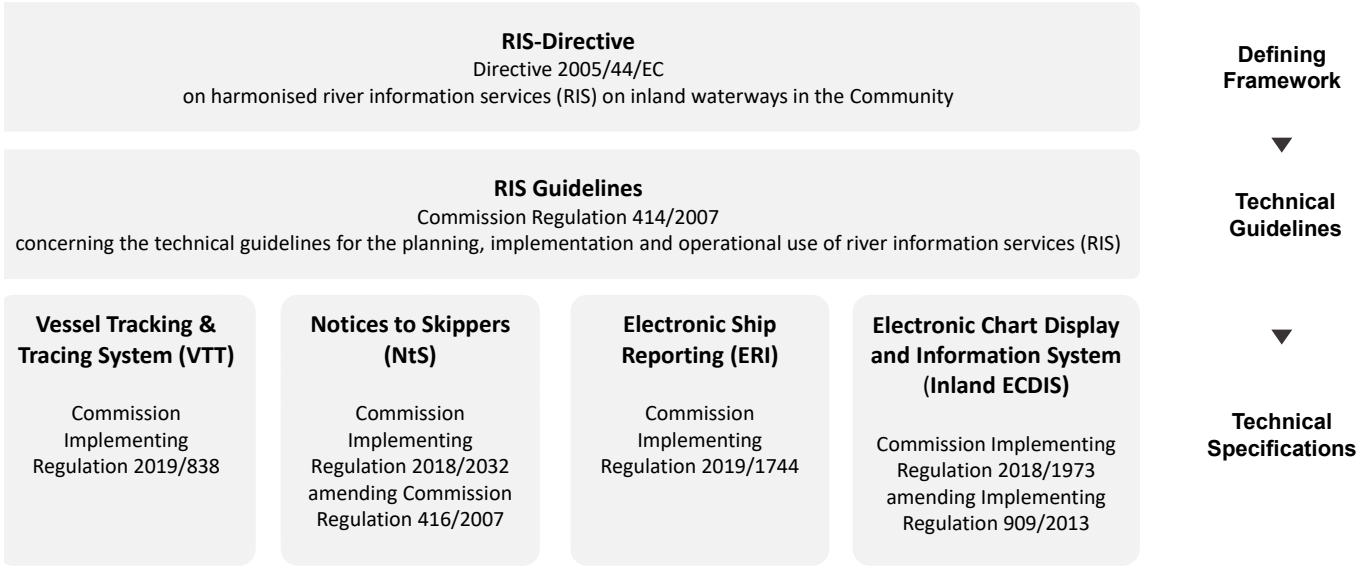

Figure 1. RIS legal framework (own figure, 2021 adapted from [22]).

The technical specifications to these key technologies have been developed by the European RIS expert groups and adopted by the European Commission into a set of directives and regulations [23]. These efforts are now continued under the umbrella of the information technologies working group of CESNI (Comité européen pour l'élaboration de standards dans le domaine de la navigation intérieure), which is the European Committee for proposing standards in the field of inland shipping. The activities of this working group regarding RISs comprise the drafting of proposals for the development and revision of technical standards in the field of RISs, including proposals for the European regulations, the promotion of the proper implementation of standards in the field of RIS, as well as the support of policy initiatives on digitalisation in inland navigation [24]. Ultimately, the implementation of RIS is handled by the designated "competent authorities" within the EU member states [21].

As the DINA (Digital Inland Waterway Area) study commissioned by the European Union has revealed, significant shortcomings of the current RIS standards and related digital services include limited functionalities for continuous and controlled data sharing (especially in a machine-to-machine manner) and a lack of up-to-date information on traffic conditions (bridges, locks, berth allocation) as well as limited system integration between barge operators and logistics stakeholders. The study concludes that the current situation represents a significant impediment towards achieving better competitiveness of IWT [11]. Hence, to allow for more effective digitalisation efforts, it is necessary to define and analyse the needs and requirements of the industry.

2.2. Literature Review on Digital Services in the IWT Domain

In the past, several academic authors analysed the impact of digitalisation in inland waterway transportation. However, the overall body of publications available on the matter is rather limited.

A rather conceptual note is given by Wang and Sun [14]. They outline an intelligent waterway management system based on the use of cutting-edge ICT technologies incorporating advanced sensors and internet of things (IoT), cloud computing capabilities, big data, and artificial intelligence, as well as wireless communication. According to them, an "intelligent waterway" could enable sharing and exchange of waterway-related business data and change the current "'information isolated island situation' through unified data resource planning and standardized data center". Furthermore, the authors claim that waterway planning lacks effective data analysis, while maintenance is lacking fast-tracked feedback. In the context of an "intelligent information service platform", Di et al. [15]

carried out an evaluation of inland waterway information service demands in China. They highlight that the design of inland information services requires a stronger user perspective due to changing needs as well as missing capabilities of technical providers to anticipate the user's requirements.

Other contributions specifically focus on the role of the European river information services for inland waterway transportation. For example, Schilk and Seemann [16] emphasise the role of RISs in the context of transport logistics services. According to them, river information services have extended and will further expand their scope from a primarily navigational function to the whole transportation process lifecycle and will become the backbone of an intelligent transport system (ITS) for inland waterways. As such, they claim, logistics-driven RISs will foster the integration of IWT in multimodal transport chains. In the same context, Niedzielski et al. [8] see great potential of RISs to improve the efficiency and achieve sustainability of inland waterway transport companies. They argued that the immediate impacts of the technology are "intangible and incalculable" but will ultimately contribute to a better financial performance of the sector, affecting the economic aspect of sustainability. This observation is in line with the findings of Verberght et al. [17] who analysed the impact of the RIS Directive on IWT performance in the Antwerp-Rotterdam-Amsterdam-Rhine region, with a special focus on the dry and liquid bulk market. Even though they concluded that the introduction of the RIS Directive had no significant effect on IWT performance in their statistical experiments, they pointed out methodological difficulties in quantifying the effects of RISs. However, they pointed out that even if RISs had no measurable economic effect and do not meet the economic objective, they still serve as core infrastructure for smart shipping solutions.

Other authors specifically focus on new business uses cases that are enabled by RISs. For example, Koralova-Nozharova [18] assessed the impact of digitalisation on cargo flows for forestry products on the Danube waterway and further identified impediments that prevent digitalisation of transportation services. The contribution pointed out a lack of harmonisation with regard to information and communication applications, as well as national legislation of countries that limit sharing of traffic information with third parties, which may prevent sustainable business development. Durajczyk and Drop [19] considered the role of well-established RISs for enabling and supporting the development of IWT business models for urban and interurban freight transport. Among others, they claimed that river information services improve the conditions for IWT operations in urban areas by providing capabilities for optimised route planning, improved coordination and consolidation of cargo flows, and better supervision and control, as well as reduced administrative barriers, ultimately affecting economic (decreased costs, waiting time etc.) and social (efficient use of human resources, etc.) aspects of sustainability.

Analysing the above-mentioned literature, it can be concluded that even though the importance of digitalisation for increased competitiveness and efficiency of inland waterway transport operations is broadly acknowledged, the literature seemingly gives little attention to the functional requirements of the IWT business. However, in order to take full advantage of digitalisation and digital transformation, it seems necessary to apply a user-centric approach [15] and to analyse what digital information services are perceived as important to IWT business stakeholders in detail, in order to achieve sustainable business.

3. Methodology

To understand what digital services are required for improved planning decisions (as perceived by operational IWT decision makers, such as crew members and transport planners) that can, in turn, improve efficiency and lead to a more sustainable IWT business, our research design and course of action in the field was based both on an inductive and qualitative approach as well as a deductive and quantitative approach, thus making up a mixed-method approach [25].

As shown in Figure 2, the course of action started with initial desk research using the existing scientific literature as well as an investigation of other secondary data, such as

the RIS regulations and guidelines (see Section 2.1), websites of the competent waterway authorities, or related projects, such as "RIS COMEX" [26].

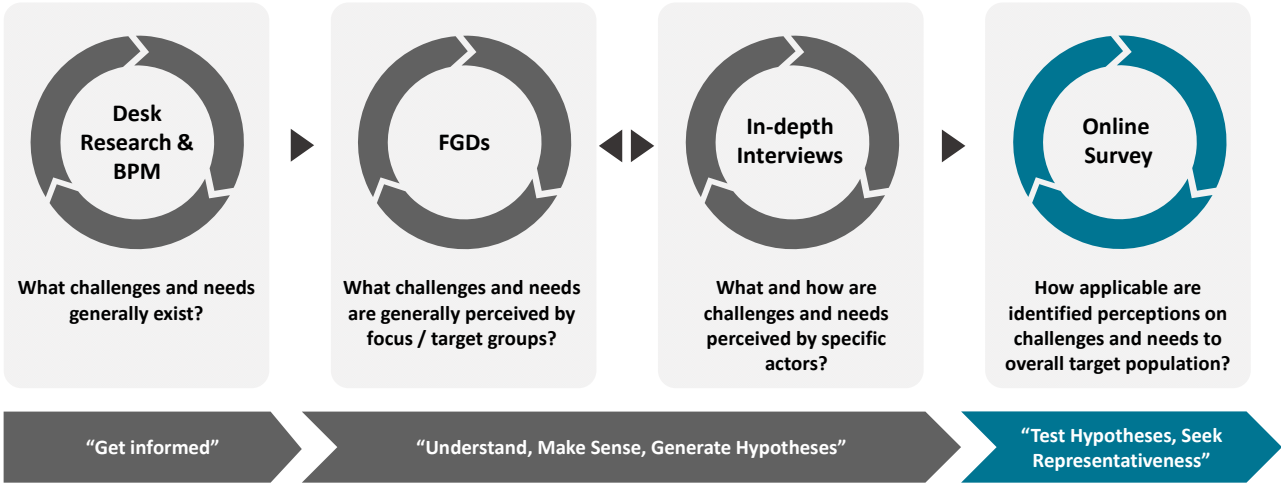

Figure 2. Overall research design and course of action (own figure, 2021).

It was accompanied by modelling and analysis of IWT business processes using the Business Process Model and Notation 2.0 (BPMN) [27] to acquire general information on structural outlines, to get a general understanding of challenges and needs, and to further familiarise with the topic. Next, qualitative research followed through the use of focus group discussion (FDGs) with relevant stakeholder and target groups to deepen understanding, make sense of challenges and needs, and generate initial hypotheses. In-depth, individual interviews were carried out afterwards to lay out hypotheses in more detail, according to specific actors. To then test the generated hypotheses and indicatively understand how far these were applicable to the overall target population, an online survey finalised data collection in the field.

3.1. Qualitative Data Collection: Focus Group Discussions and In-Depth Interviews

Based on previous desk research, expert FGDs (focus group discussions) were used to collect first-hand general information on the perceptions of target groups and identify issues of concern to generate intermediate hypotheses as well as to establish further contact with the participants and to build rapport for the following individual in-depth expert interviews. Furthermore, in-depth interviews provided more detailed information on the individual stakeholders' perceptions and interdependency of problems, thus giving more room for interpretation. The qualitative interviews conducted covered a total of 25 participants and took place from January 2021 to May 2021.

Geographically, for both FGDs and in-depth interviews, the sample of participants was drawn from IWT actors that operate on and along the River Weser, which represents the main waterway hinterland link of the ports Bremerhaven and Bremen in Northern Germany. The set of participants covered actors engaged in infrastructure management, port authorities and public bodies, crew members (skippers, helmsmen, and boatsmen), and administrative staff of IWT operators, hinterland logistics experts, and software developers active in the sector. An interviewee or actor bias had been set consciously. As shown in Table 1, the focus was on infrastructure managers, port authorities, and public officials to maximise compliance with organisational needs, public policies, and regulations, which would, if not thoroughly considered, inhibit implementation of innovations to be developed.

Table 1. Target groups approached for qualitative research.

Target Subgroup	Interviewees (*n*)
Infrastructure managers	9
Port authority/public officials	7
IWT operators	3
Others (software developers, IT experts)	6
Sum	**25**

IWT operators were used to assure a transport operational view of developments. The underrepresentation of this actor group was indirectly accounted for by further surveying it in the course of the quantitative online survey. Others, such as software developers and IT experts, were consulted for further inspiration and to inquire about the various IT systems used in the domain since they were aware of the latest developments in the realm of digital services.

3.2. Quantitative Data Collection: Online Survey

What followed and finalised the gathering of primary data was a quantitative online survey, as a deductive method, to obtain information from a larger sample of the population [28], mostly IWT operators (onboard and land personnel). Furthermore, hypotheses and identified perceptions in terms of representativeness were checked to see if initial, qualitative findings could be supported quantitatively and explore their applicability at a European scale.

The first part of survey results allows an outlining of basic characteristics of the panel, including general information on respondents, such as mother tongue, professional background, routes frequently travelled, and types of cargo they would transport.

Aside from these general classification questions, the second part of the survey was designed to yield quantitative insights. As such, the hypotheses related to perceptions of the importance of stakeholders' needs in terms of digital service functionalities, the appearance of common challenges faced during transport, the importance of information to carry out respective planning tasks, and preferences with regards to access to digital services were translated into closed questions using 4-point Likert-type rating scales. Assuming an equidistant scale, the answers have been coded numerically such that the arithmetic mean ("mean rating") of the perceived responses could be calculated. As the condition of equidistance is not without doubt [29], the presentation of the mean serves illustrative purposes only and is not to be used for parametric statistical analyses.

The survey was carried out from May 2021 to June 2021 using the survey platform "SoSci Survey". Given that the largest IWT volumes in the European Union go to or come from the Netherlands, Germany, Belgium, and France [30], the survey has been conducted in all respective languages of these countries. Participants were gathered through advertisement in selected mailing lists, press releases and the use of social media of partnering IWT associations, corporations and political actors. While this non-probabilistic "convenience sampling" comes with advantages in terms of a good balance of acquisition costs and response rate, it also entails methodological disadvantages. As such, the chosen selection criteria may foster selection bias [31]. It can be assumed, for example, that exclusive use of an online survey will tend to be answered by people who have an affinity for digital information services. Similarly, the selection of available languages will exclude some potential respondents of the respective population.

4. Results of the Online Survey

4.1. General Information on Respondents

The survey attracted a total of 84 respondents, among which the vast majority answered in Dutch (50%), followed by German (26%), English (20%), and French (4%). Most of the respondents indicated a professional background as skippers (whereas 55% are self-employed barge operators and 11% traditionally employed), transport planners (14%),

managing directors (15%), or crew members on inland vessels (2%). Around 12% of the respondents did not fit into the predefined role descriptions. In this context, it should be noted that the respondents could select one or more answers. Accounting for this, around 62% of the respondents can be considered to be crew members, 32% landside staff, and 6% stated to be involved in onboard as well as landside activities.

Corridors frequently used by respondents were the Rhine route (57%), followed by the north-south route (France–Belgium–Netherlands; 44%), the east-west route (North Sea ports–Northern Germany–Eastern Europe; 26%), and the Main-Danube route (24%). Respondents transported various cargo types, mostly bulk material (61%) and/or containers (44%), general cargo (40%), liquid bulk (19%), vehicles (4%), swap bodies (2%), or other cargo (13%).

4.2. Challenges for IWT Operations

To get an understanding of the operational environment of IWT, reasons, and considerations behind digital service needs, the respondents were asked to provide an indication of frequency of commonly faced challenges in the context of their operational activities. The results indicate that most respondents face a lack of available or suitable berths, time-consuming pre-announcement and reporting obligations, lack of information on available services at these berths (e.g., fresh water supply, waste disposal), and a lack of available shore power facilities at these berths. The only situation not observed frequently by more than half of the respondents was a lack of information on local nautical conditions (e.g., depths, currents, dangers), as shown in Table 2.

Table 2. Overall frequency of challenges for IWT operations (own survey, 2021, $n = 84$).

Challenges	"Never" (1)	To		"Always" (4)	Mean Rating
Delays due to unavailable or malfunctioning infrastructure (e.g., locks, signals)	8%	35%	44%	13%	2.62
Lack of available or suitable berths	7%	21%	44%	27%	2.92
Lack of available shore power facilities at berths	13%	24%	36%	27%	2.77
Lack of information on local nautical conditions (e.g., depths, currents, dangers)	21%	50%	24%	5%	2.12
Lack of information on available services at allocated berth (e.g., water supply, waste disposal)	8%	25%	43%	24%	2.82
Lack of information on local points of interest (e.g., health services, shops, post boxes)	21%	26%	25%	27%	2.58
Pre-announcement and reporting obligations are too time-consuming	10%	25%	32%	33%	2.89
Pre-announcement and reporting obligations are too complex or complicated	12%	36%	21%	31%	2.71
Pre-announcement and reporting obligations are not clear	12%	31%	30%	27%	2.73
Too many different means of communication with authorities	11%	32%	30%	27%	2.74
Percentages may not total 100% due to rounding.					

The comparison between respondents having stated a position onboard and those working in landside positions indicate that the challenges laid out in the survey are generally more relevant for operations onboard vessels. The most significant differences can be

found regarding the "lack of available or suitable berths" (mean rating for onboard = 3.13; onshore = 2.50) as well as the "lack of information on available services at allocated berth" (mean rating for onboard = 3.02; onshore = 2.43). Almost equal importance by both groups is given to the challenge of lacking shore power facilities and too many different means of communication with authorities.

Since the respondents had the possibility to state additional challenges they face (which were not mentioned in the survey), one of them mentioned language issues in VHF communications. Furthermore, two of them stated that the increasing number of incompatible electronic announcement procedures results in extra administrative burden.

4.3. Importance of Information to Carry out the Respective Planning Tasks

Assuming that the operational planning challenges induce a need for certain information from decision makers, additional emphasis was given to gain further insight into the importance of the respective information types. Based on the expert interviews, different information types were clustered into "berth-related", "lock-related", "waterway-related" and "destination-related" information types (see Tables 3–6).

Table 3. Importance of berth-related information to carry out planning tasks (own survey, 2021, *n* = 84).

Information	"Unimportant" (1)	To		"Important" (4)	Mean Rating
Availability of berths	8%	4%	12%	76%	3.56
Availability of shore power facilities	13%	15%	31%	40%	2.99
Availability of fresh water supply	6%	14%	24%	56%	3.30
Availability of waste disposal	8%	5%	29%	58%	3.37
Possibility to unload own vehicle	10%	12%	15%	63%	3.32
Landside access information	5%	15%	21%	58%	3.33
Percentages may not total 100% due to rounding.					

Table 4. Importance of lock-related information to carry out planning tasks (own survey, 2021, *n* = 84).

Information	"Unimportant" (1)	To		"Important" (4)	Mean Rating
Opening hours	6%	11%	20%	63%	3.40
Expected lockage time	7%	13%	29%	51%	3.24
Average waiting times	11%	11%	29%	50%	3.18
Contact information	10%	19%	21%	50%	3.12
Percentages may not total 100% due to rounding.					

Table 5. Importance of waterway-related information to carry out planning tasks (own survey, 2021, *n* = 84).

Information	"Unimportant" (1)	To		"Important" (4)	Mean Rating
Water levels	4%	8%	18%	70%	3.55
Bridge clearance heights	4%	4%	12%	81%	3.70
Bridge status (open/closed)	6%	15%	18%	61%	3.33
Malfunctions and infrastructure maintenance works	4%	6%	7%	83%	3.70
Percentages may not total 100% due to rounding.					

Table 6. Importance of location-related information to carry out planning tasks (own survey, 2021, $n = 84$).

Information	"Unimportant" (1)	To		"Important" (4)	Mean Rating
Shopping facilities	24%	29%	24%	24%	2.48
Public transport/taxicabs	32%	29%	23%	17%	2.24
Delivery services (e.g., groceries or food)	26%	31%	21%	21%	2.38
Repair services	19%	15%	36%	30%	2.76
Health services	19%	15%	21%	44%	2.90
Post offices	35%	38%	21%	6%	1.99
Public facilities	29%	32%	27%	12%	2.23
Sports facilities	52%	32%	12%	4%	1.67
ATMs	32%	26%	25%	17%	2.26
Bunker services	13%	17%	31%	39%	2.96
Percentages may not total 100% due to rounding.					

As can be seen in the results, waterway-related information, which can also be described as nautical information, is of high significance to the full panel, especially for onboard personnel. Unlike in road transportation, IW networks do not allow for spontaneous detours or turns, which make route planning especially critical. Information on bridge clearance heights as well as on malfunctions or ongoing and future maintenance works have received the highest ratings of all information types for the whole panel as well as for the single user groups. However, the individual preferences may differ along the corridors due to different nautical conditions. As an example, the data shows that water level information is perceived as comparably lower in significance by respondents that operate in the north-south route, which is predominantly covered by water-regulated canals. Additionally, the need for information on bridge clearance heights was stated to be especially important by respondents operating in the east-west route, which is known for low vertical clearance while oftentimes possessing high water levels (e.g., River Weser).

Also associated with voyage planning decisions is information about berths, which represent opportunities for the crew to rest and revictual. Of most importance in this regard is information on the availability of berths. Remarkably, respondents held different views on the information on the "possibility to unload own vehicle" (mean rating for onboard = 3.59; onshore = 2.79) as well as "landside access information" (mean rating for onboard = 3.5; onshore = 3.00), receiving fairly high importance ratings by onboard staff while being perceived as the least important berth-related information type by the other group. Whether shore power facilities are available at berth is rated comparatively low, which can be assumed to be the case due to the fact that the adoption of shore power for inland navigation is still low in most European corridors and ports. With respect to locks, which may represent bottlenecks along the journey, participants would most likely need to receive information during opening hours. In this category, the east-west corridor spanning from the North Sea ports to Eastern Europe shows a significantly high demand for information on "average waiting times" for locks, while the Main-Danube subgroup states a need for information on "opening hours" of locks. A weak link between operational planning and the group of location-related information can be deduced by comparatively low importance ratings for the respective items. Information on bunker and health services are of the highest significance.

Over all information categories, onboard personnel stated higher importance for the selected items.

4.4. Needs in Terms of Digital Service Functionalities

Since digital services represent a means to cope with existing operational challenges and provide relevant and necessary information for planning decisions in IWT, respondents were asked to indicate how important they perceive certain functionalities that were suggested in the qualitative research phase to be made available to IWT operators.

As shown in Table 7, the results show that the survey panel generally supported the predefined functionalities to be important. On average, all proposed functionalities received higher importance ratings by landside personnel (mean rating onboard = 2.83; landside = 3.24). High importance, especially by crew members, is given to the provision of real-time information on bridge clearance heights (mean rating onboard = 3.45; landside = 3.41), while the possibility to announce port visits electronically receives the highest importance ratings by landside staff (mean rating onboard = 3; landside = 3.57). Concerning locks, the respondents, especially the landside group, see the importance of allowing for lockage synchronisation in the case where a number of locks in a row need to be passed over the possibility to book slots for single locks (mean rating onboard = 2.98; landside = 3.44). The largest gap between onboard and landside respondents can be found with respect to chat functionalities to allow for communication with port offices (mean rating onboard = 2.38; landside = 2.96) as well as "ETA predictions" (mean rating onboard = 2.71; landside = 3.22). A functionality to access news feeds was found to be rather not important for both groups (mean rating onboard = 2.38; landside = 2.74).

Table 7. Overall perceived importance of potential functionalities of digital services (own survey, 2021, *n* = 84).

Functionalities	"Unimportant" (1)	To		"Important" (4)	Mean Rating
Electronic port announcement	11%	11%	27%	51%	3.19
Online port customer services (e.g., billing)	7%	23%	32%	38%	3.01
Booking of specific berths	10%	24%	23%	44%	3.01
Lockage slot booking	17%	24%	20%	39%	2.82
Lockage synchronisation ("green wave")	11%	17%	20%	51%	3.13
ETA predictions	13%	21%	29%	36%	2.88
Push notifications for notices to skippers (NtS)	11%	14%	30%	44%	3.08
Chat functionalities with port office	17%	36%	23%	24%	2.54
Real time bridge clearance view	4%	12%	21%	62%	3.43
News feed	23%	27%	26%	23%	2.49
Percentages may not total 100% due to rounding.					

4.5. Preference for Access to Digital Services

Studies on technology acceptance indicate that the end-user's "intention to use" digital services on adequate channels or devices may represent an important success factor. Therefore, the respondents were asked about their preference to access digital services.

As shown in Table 8, most respondents would primarily like to access information using a web browser on their laptop or desktop computer. A significant acceptance can be assumed when providing services by integration into existing navigation systems onboard or via mobile apps on smartphones or tablets. However, in the qualitative stage as well as in the comment section of the survey, respondents commented that they see inflation of different native apps to be installed as a serious problem. This can be approached by offering mobile applications within a mobile browser without having the need for installation. The

comparison of user groups within the panel shows that personnel onboard vessels rank access via mobile devices more favourable than landside staff (mean rating onboard = 3.3; landside staff = 2.96).

Table 8. Preference for access to digital services (own survey, 2021, *n* = 84).

Access to Digital Services	"Strongly Oppose" (1)	To		"Strongly Favour" (4)	Mean Rating
Mobile app (smartphone/tablet)	10%	13%	26%	51%	3.19
Web browser (laptop/desktop computer)	6%	7%	35%	52%	3.33
Integration into existing software (e.g., transport management system)	20%	23%	26%	31%	2.68
Integration into navigation systems on board	7%	18%	24%	51%	3.19
Percentages may not total 100% due to rounding.					

Comparatively few respondents seek integration into existing systems, such as transport management systems. This might be due to the fact that the share of landside personnel made up less than half of the panel.

5. Discussion and Conclusions

The purpose of our research was to gain insight into what digital services are required for improved planning decisions by IWT operators, to allow for a more sustainable IWT business. After reviewing the existing literature, it can be concluded that the importance of digitalisation in IWT is recognised, especially with respect to the competitiveness and efficiency of inland waterway transport. However, a deeper understanding of the challenges and functional requirements of the IWT business, which is vital to take full advantage of digitalisation and digital transformation and enable sustainable business, is missing. The results of the study fill this research gap and extend the body of knowledge in the field of digital services in European IWT.

While the RIS Directive represents an elaborate framework for legislation of harmonised IWT information services in Europe, studies show some conceptual shortcomings. The results of our investigation support this notion by highlighting digital service functionalities that go beyond the scope of the current RIS framework.

Our findings elucidate that the IWT community faces a number of various planning and decision challenges that can be improved by better supply with information. As such, it has been confirmed that a lack of available or suitable berths as well as time-consuming preannouncement and reporting obligations are apparently common. Additionally, IWT operators do not have sufficient insight into the extent of information on available services at these berths (e.g., fresh water supply, waste disposal) as well as a lack of available shore power facilities. In our panel, those challenges seem more apparent to persons working onboard rather than those on land.

With regard to the importance of specific information for planning purposes, our results show a high relevance of information by onboard as well as landside respondents that can be used for decisions related to voyage planning. This includes waterway-related information, such as bridge clearance heights or water levels and lock-related information as well as berth-related information. In comparison, the proposed location-related information types are of little demand and received lower importance ratings, which may reflect a weak interdependency with operational planning.

Most of the proposed functionalities that address these planning issues receive strong support by the respondents, while the provision of real-time bridge clearance information as well as electronic port announcements have been stated as most important. Surprisingly,

even though the demand for information was found to be generally higher by onboard personnel, the proposed functionalities have been more appreciated by landside personnel. This may refer to the notion that some onboard respondents want to keep their focus on navigation and vessel operation rather than engaging with administrative activities. Therefore, we conclude that user centricity, which includes ease of use and orientation on functional needs, is key when offering new digital information services.

This also incorporates the use of suitable access channels to those services. Our results show no clear preference on single access types. Mobile devices such as smartphones and tablets as well as laptops and desktop computers are generally perceived to be equally appropriate, while crew members' demonstrate a higher attraction to mobile use. However, to avoid an inflation of installable apps and being able to equally support onboard and landside personnel, responsive web applications may become the most adopted choice. In addition, the integration into navigational systems was evaluated as favourable.

Limitations of the study arise from the low number of survey participants. To put this in perspective, in Germany alone, 6805 people worked as skippers for inland waterway transports in 2017 [32]. Assuming a somewhat similar number for the year 2021, confidence levels and ranges reached in analysis do not at all meet scientific criteria commonly applied for representativeness [33]. Further shortcomings arise from the characteristics of the participant panel. With the survey having taken place online only, a certain degree of familiarisation with the use of digital services must be attested. Additionally, the research is focused only on the European level, which does not allow a direct inference to other important IWT areas in the world. Additionally, a language barrier may have partly existed, as the survey was not translated into all languages spoken in the European Union. It can therefore be concluded that the results give a profound initial insight into the requirements and demands for digital services for sustainable inland waterway transport but must be treated with caution for the limitations imposed by the applied methods. Nevertheless, we believe that the survey, together with the previous qualitative research phase, still gives a good indication and summary of perceptions in terms of information needs with regards to digital services for a sustainable IWT business. From a managerial standpoint, the results of this research can contribute to future adaptions of the RIS standards and guidelines by the CESNI working groups but may also serve as a benchmark for competent waterway authorities that seek to provide additional digital services to the IWT community. A possible way to prioritise the results and derive future avenues is given in Figure 3. As such, it could be claimed that future digital services for inland waterway transport should put a stronger focus on the "integration of port processes" as well as on "real-time data sharing and coordination".

Further research should also continue to analyse these directions and thereby support legislative steps. Furthermore, our approach should be applied to other important IWT corridors in the world, to allow for comparative analyses. In addition, this study does not allow for an evaluation of the usefulness of currently implemented and available digital services from an IWT operator perspective, such as the core RIS technologies provided by the competent authorities in the European Union. Further research would be useful in this context as well. It would also be necessary to further investigate concepts on how to integrate the set of useful functionalities into user workflows, such as voyage planning or the process of managing a whole port call lifecycle.

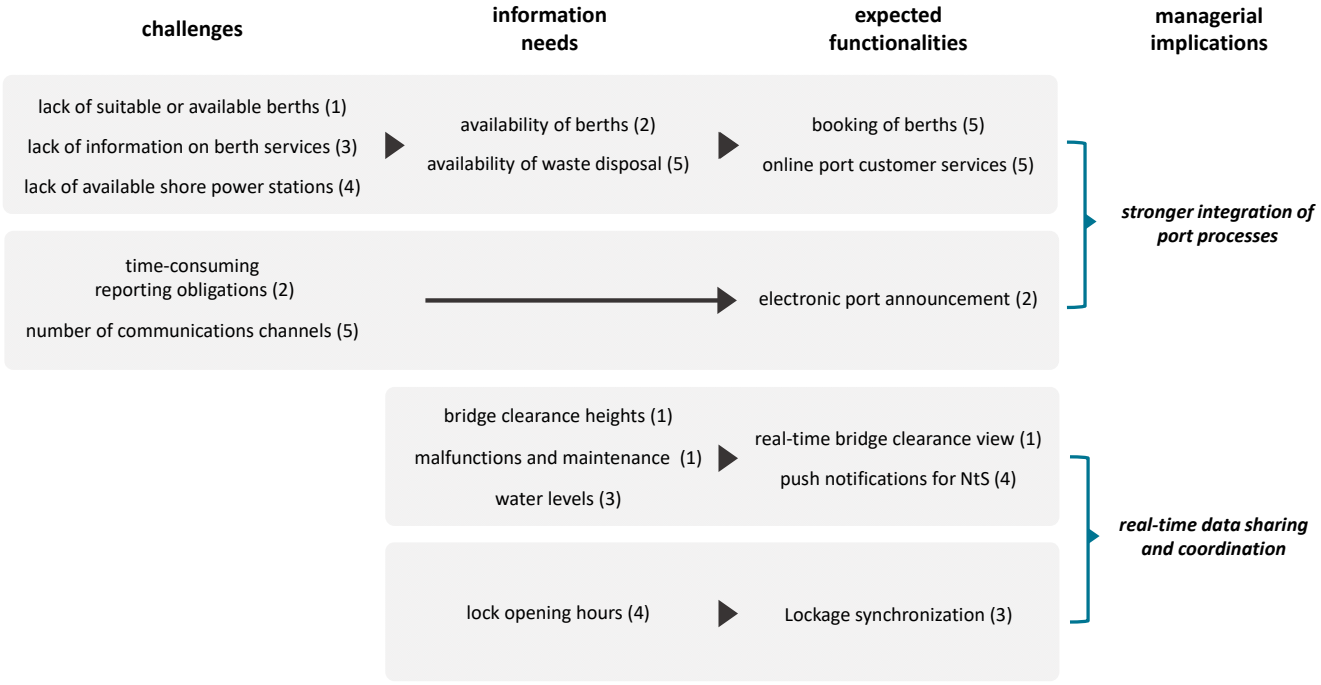

Figure 3. Model to derive managerial implications based on the top 5 rated challenges, information needs, and expected functionalities of IWT operators (own figure, 2021).

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