MultiRELOAD

DELIVERABLE 2.4: MARKET POTENTIAL ANALYSIS FOR MULTIMODALITY USING IWT

Evaluation of the market potential for multimodal transports along the Danube using IWT

SILVIA DOPLER

VERSION 2.0

20TH FEBRUARY 2024

Funded by the European Union

The project receives funding under the Horizon Europe Call "Safe, Resilient Transport and Smart Mobility services for passengers and goods"
Call ID: HORIZON-CL5-2021-D6-01, Grant ID: 101069796

DOCUMENT ADMINISTRATIVE INFORMATION

Deliverable number	D2.4
Deliverable title	Market Potential Analysis for Multimodality using IWT
Dissemination level	Public
Submission deadline	29/02/2024
Version number	V2
Author	Silvia Dopler (FHOO)
Internal reviewer(s)	Henrike Bauer, Müller Rainer (VIE) Gergely Mezö (RSOE) Bianca Duldner-Borca (FHOO)
Document approval	

LEGAL DISCLAIMER

MultiRELOAD is funded by the European Union's Horizon Europe Research and Innovation programme under Grant Agreement No 101069796. The views represented in this document only reflect the views of the authors and not the views of the European Commission. The dissemination of this document reflects only the author's view, and the European Commission is not responsible for any use that may be made of the information it contains.

Version	Date (DD/MM/YYYY)	Created/amended by	Changes
V1	05/02/2024	Silvia Dopler (FHOO)	Initial version
V2	20/02/2024	Silvia Dopler (FHOO)	Added chapters
	27/02/2024	Henrike Bauer, Rainer Müller (VIE)	Added review comments
	28/02/2024	Gergely Mezö (RSOE)	-
V3	27/02/2024	Silvia Dopler (FHOO)	suggestions for revision implemented
	28/02/2024	Bianca Duldner-Borca (FHOO)	Check for errors
	29/02/2024	Silvia Dopler (FHOO)	Final version
V4			Approved version

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

This report is a contribution to dissemination within the MultiRELOAD project. The results presented here are achievements from the work within **Work Package 2 "Smart Multimodal Logistics"** in the context of **Task 2.3 "From bulk to multimodal for inland waterway transport"** carried out by FHOO. The research in this task is conducted to identify the market potential for increasing the low share of multimodal transport along the Danube corridor based on the learnings from the Rhine corridor and other relevant transport corridors and are disseminated in the Deliverables 2.4 and 2.5.

The content of the present **Deliverable 2.4, Market potential analysis for multimodal transports along the Danube using IWT**, includes:

- Task analysis of the freight mode choice process (Chapter 2)
- Identification of the market potentials by an analysis of available data (Chapter 3)

This Deliverable is accompanied by Deliverable 2.5, Determination of ports' readiness for multimodality, with the following content:

- Evaluation of Barriers on the Danube and Lessons Learned from the Rhine
- Review & Analysis of Ports along Corridors, to identify focal points of industry
- Determination of Ports' Potentials

Work package 2 contributes to the MultiRELOAD **Innovation Area A "Smart multimodal logistics"** and shall facilitate a shift from road to rail and IWT of 5%. The potential of containerized transport on the Danube is evaluated and its quantitative impact will be presented in this report. The expected outcome is defined in the following project goals:

- Facilitate a shift from road to IWT by 5% (by 2025)
- Increase of transported cargo on the Danube by 2%
- Annual modal shift of approx. 52.000 tons of cargo (minus 2.600 trucks on roads annually)

Task 2.3 is linked to the **Demonstrator A2 "Transporting Bulk Cargo in Multimodal Containers"** carried out by TTS. The goal of this demonstrator is introducing a new transport concept for bulk cargo by shifting it to containers who are universally applicable for each mode of transport for flexible and save cargo handling. A description and gap analysis for this Demonstator can be found in the

MultiRELOAD Deliverable 2.1 "Evaluation of feasibility of multimodal transports along the Rhine-Alpine and Rhine-Danube corridors".

2. ANALYSIS OF THE FREIGHT MODE CHOICE PROCESS

Freight mode choice processes and their diverse influencing factors are a broad research field that has been scientifically examined from various perspectives. In general, four mode choice variables are identified to be the most important ones, namely price, transit time, reliability and flexibility (Reis 2014). Often, decision makers are viewed as "homo economicus" assuming a rational behavior as default based on measurable criteria like costs and time; whereas in fact, decisions are often impeded by subjective perception, e.g. reputation of a transport mode or routines (Stockhammer et al. 2021). Hence, mode choice towards inland shipping may be subject to behavioral distortions. This results in the need for a detailed analysis of the (perceived) disadvantages of inland navigation in the modal decision process. This can then help to implement targeted measures to remove the identified barriers. Therefore, in the following subchapters the focus lies on barriers towards IWT in the mode choice process. We aim at evaluating the causes for reluctance to commission inland shipping. On the one hand we conducted a literature review to identify known obstacles and on the other hand we set up an online questionnaire to quantitatively assess these barriers. Those insights facilitate conclusions to be drawn as to which adjustments need to be made in order to strengthen sustainable waterway transport in the long term. Subsequently, in Chapter 2.4 we discuss how containerized IWT may help to overcome barriers towards IWT mode choice. Within Chapter 3 market potentials of IWT are analyzed assuming that these barriers are overcome.

2.1. METHODOLOGY

A literature review of scientific papers and research outcomes of related EU projects was conducted to identify barriers that are hindering gains of inland waterways in the European transport market. This longlist of barriers is summarized into more general categories. The subsequent shortlist of 25 IWT barriers (described in Chapter 2.2 and shown in Table 1) is then evaluated by a standardized online survey. A quantitative assessment of the barriers was conducted using the "Best-Worst Method" (BWM) following the approach of (Rezaei 2016; Rezaei et al. 2018; Mohammadi and Rezaei 2020). Following the methodological considerations of (Rezaei et al. 2018), the 25 barriers have been assigned to content-wise related dimensions. We were able to cluster them into 4 dimensions, which are namely “Investments”, “Framework conditions”, “Market characteristics” and “IWT Infrastructure”.

In order to obtain a consensus of a group of experts on a set of criteria, a tool from the spectrum of Multi Criteria Decision-making Methods (MCDM) is needed. We identified the Best-Worst-Method introduced by Rezaei 2016 and further developed by Mohammadi and Rezaei 2020 as suitable which presents an analytical method without statistical inference. For the results, the quality of answers provided is more important than the quantity (Munim et al. 2022). Moreover, the questionnaire demands concentration of the participants for approximately 25 minutes in our case. Hence, we were aiming to receive a small but highly relevant sample of answers. BWM can be evaluated using different models, e.g. multiple solutions, linear or Bayesian (Mohammadi and Rezaei 2020). The Bayesian BWM is capable of aggregating answers from a group of experts or decision makers, hence we followed the model of (Mohammadi and Rezaei 2020).

To secure highly relevant answers, we added questions where potential respondents were asked to rate themselves in three relevant categories: a) knowledge in IWT, b) knowledge in managing transports, and c) knowledge on decision making processes.

In general, the questionnaire included three main question-bundles: demographic questions, company-specific questions, and a set of questions that are needed to apply the BWM. The BWM bundle of questions is designed to fit the needs of the BWM. As the name already suggests, decision makers are asked to classify criteria as “best” and “worst” is the core of the Best-Worst-Method. Hence, understanding the used wording within this research is very important:

“**BEST**” criterion = **MOST severe/important barrier** towards IWT mode choice

“**WORST**” criterion = **LEAST severe/important barrier** towards IWT mode choice

To avoid confusion on the terms the respondents were not confronted with the wording “best” or “worst” within the questionnaire but always asked on their opinion on which would be the most and least important barrier towards IWT mode choice. The following steps are introduced in the BWM survey section (Mohammadi and Rezaei 2020): First (step 1), the experts are provided with a set of decision criteria (barriers). The participants have to select the most (“best”) and least (“worst”) important barrier towards IWT mode choice of each dimension (step 2). In the next step (step 3), pairwise comparisons are undertaken, which means that the barrier selected as "best" must be compared to the relative importance of each "other" barrier ("best to others") on a scale ranging from 1 to 9:

- 1 - Equally important as
- 2 - Somewhat between Equal and Moderate
- 3 - Moderately more important than
- 4 - Somewhat between Moderate and Strong
- 5 - Strongly more important than
- 6 - Somewhat between Strong and Very strong
- 7 - Very strongly more important than
- 8 - Somewhat between Very strong and Absolute
- 9 - Absolutely more important than

Based on the same concept in step 4, each "other" barrier had to be rated regarding its importance relative to the most important barrier ("others to worst"). This procedure has to be repeated for each of the 4 dimensions. The BWM survey results in two vectors ("Best to others", "Others to worst") that are used to calculate the local weights of each barrier. Moreover, the global weights for all 25 barriers can be calculated since we asked the participants to rank the 4 dimensions regarding their overall importance. This results in step 5, obtaining the optimal weights of each main dimension and all its sub-criteria. Herein, a probabilistic model is used following Mohammadi and Rezaei 2020. In its core, first, each sub-criteria's local weight within its dimension is calculated, which results in a number between 0-1. Summing up the weights of all sub-criteria weights per dimension results in 1. Second, the global weight for each sub-criteria is calculated by multiplying the local weights by the weight of the belonging dimension. After this step all sub-criteria across dimensions are comparable and the sum of all sub-criteria global weights sum up to 1.

Data cleaning steps are needed beforehand the analysis of the survey. First, irrelevant (e.g. respondent is not an expert in the field) or incomplete (e.g. did not finish the whole survey) answers are excluded. Next, the answers are reviewed for incorrect answers (e.g. criteria compared to itself is not "1") or straight lining (the same rating for each criterion in a row). Subsequently, the data is analysed by the means of descriptive statistics and Best-Worst-Method. In total, 18 valid answers from the EU have been received from November 2023 to February 2024. Data cleaning and descriptive statistics analysis are conducted using Microsoft Excel. Some figures are produced within Tableau Desktop software. Bayesian BWM (group decision) evaluation is carried out by re-using and adapting Python code from Github[1] provided by Mohammadi and Rezaei 2020.

2.2. IDENTIFIED BARRIERS TOWARDS IWT MODE CHOICE

A longlist of in total 90 barriers have been identified by literature research. These have been summarized and rephrased as well as assigned to iteratively derived main categories of barriers (dimensions). This process resulted in finally 25 barriers, which are shown Table 1. The longlist of barriers including their literature references can be found in Appendix A.

Table 1: Shortlist and categorization of barriers towards IWT mode choice, including count of references from the longlist (see Appendix A)

Dimension	#	Barrier	No
Investment	1	Low pace of development of the IWT sector in terms of sustainability (alternative engines and fuels, emissions, ...)	2
	2	High initial costs for introducing IWT services (e.g. equipment, compliance with safety regulations, ...)	2
	3	Shortage of vessel and barge building	2
	4	Lack of investments to build/maintain waterway infrastructure	4
Market characteristics	5	Additional costs of transshipment/multimodal transport	4
	6	IWT Services are (perceived as) unreliable	5
	7	Only competitive for high volumes of goods	3
	8	Only suitable/competitive for certain types of goods	2
	9	Transit time takes too long	5
	10	Transport price is too high/not competitive in comparison with other modes	9
	11	Insufficient flexibility of IWT services (e.g. frequency, capacity, vessel or shipment size)	5
Framework conditions	12	Insufficient/varying operating hours of ports, locks, customs, terminals	2
	13	Lack of connection to other modes of transport (insufficient multimodal connections)	2
	14	Lack of qualified personnel	2
	15	Low prioritisation of IWT	5
	16	Decision makers have a lack of knowledge about IWT or are not willing to shift	3
	17	Lack of regulatory frameworks	6
	18	Administrative burden of IWT (e.g. inter-agency coordination, border controls, languages, standardization)	7
IWT Infrastructure	19	Insufficient bridge clearance	2
	20	Insufficient waterway depth	6
	21	Lack of interlinking with other waterbodies	3

[1] https://github.com/Majeed7/BayesianBWM, 09.02.2024

	22	Lack of navigational equipment (e.g. digital navigational charts and river information systems)	1
	23	Lack of terminals and related infrastructure needed for loading/unloading and storage	1
	24	Insufficient location or number of ports/quays	4
	25	Insufficient maintenance, repair and overhaul of infrastructure (ports, vessels, handling facilities)	3

2.3. QUANTITATIVE EVALUATION OF THE BARRIERS

2.3.1. DEMOGRAPHIC STATISTICS AND EXPERT EVALUATION

We received 18 valid responses. The demographic statistics of our sample is presented in Table 2. Regarding gender, we received nearly twice as many answers from males than from females. Countries of the respondents' companies are mainly in Europe and 12 of 18 answers came from Danube riparian countries (see also Figure 1). Various stakeholder types participated in the study spanning logistics service providers, shippers, waterway administrations, vessel owners/operators and experts working in research or in dedicated inland waterway associations (classified as "Other"). Our sample includes companies from size small to large with referring to both, employees and annual turnover.

Table 2: Respondent demographic statistics

Variable	**Category**	**Count**	**Percentage**
Gender	female	6	33.3%
	male	11	61.1%
	no answer	1	5.6%
Country of company headquarter	Algeria	1	5.6%
	Austria	8	44.4%
	Belgium	3	16.7%
	Germany	1	5.6%
	Greece	1	5.6%
	Hungary	2	11.1%
	Italy	1	5.6%
	Serbia	1	5.6%
Stakeholder type	Administration	2	11.1%
	Logistics Service Provider	6	33.3%
	Other	6	33.3%
	Shipper	2	11.1%
	Vessel Owner/Operator	2	11.1%
Employees	Less than 10	5	27.8%
	10-49	5	27.8%
	50-249	4	22.2%

	500 or more	4	22.2%
Annual turnover	Up to 2 million EUR	5	27.8%
	>2 to 10 million EUR	6	33.3%
	>10 to 50 million EUR	3	16.7%
	More than 50 million EUR	4	22.2%

All respondents were asked to rate themselves in three categories of relevant expertise: IWT, managing transports and mode choice processes. Figure 1 shows the "Experts", to what stakeholder type they belong, which job title they have and their self-rating. The scale spans from totally disagree (1) to totally agree (7). If the stakeholders rated themselves in 2/3 categories 3 or higher, we consider their answer as relevant. Hence, none of the 18 respondents was eliminated.

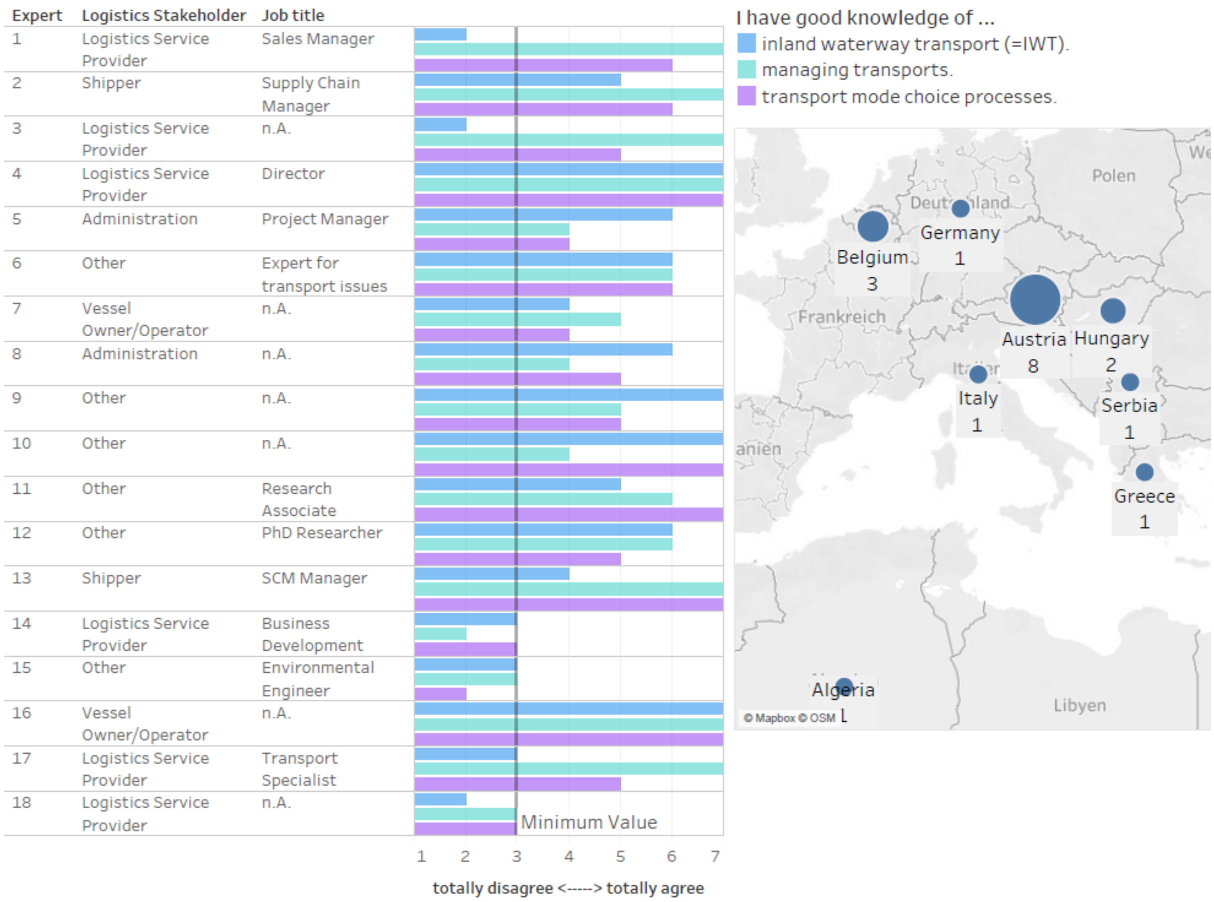

Figure 1: Experts rated their knowledge (left) and indicated their company location (right)

2.3.2. DECISION MAKERS OF MODE CHOICE

Furthermore, we evaluated how the experts assess the decision-making power of which stakeholder is primarily responsible for the modal decision. The largest share, one third, stated that the decision-making power could not be clearly assigned or that they did not know. In sum, 38.9% assigned the modal decision (more often) on the shippers' side, whereas a smaller proportion (22.2%) located it more often on the logistics service providers' side. Hence, based on the expert assessment of our sample, there is a slight tendency for shippers to have more decision-making power in the mode choice process. This outcome is in line with the empirical findings of an Austrian study, which asked a total of 131 logistics stakeholders from Austria, Germany and Benelux countries the same question (Beil et al. 2022).

Table 3: Responses to the question of the decision maker of the transport mode

Answer option	Answered by stakeholder type	#	%
always the Shipper	**total**	**2**	**11.1%**
	Shipper	2	11.1%
more often the Shipper	**total**	**5**	**27.8%**
	Logistics Service Provider	4	22.2%
	Other	1	5.6%
both equally	**total**	**1**	**5.6%**
	Vessel Owner/Operator	1	5.6%
more often the Logistics Service Provider	**total**	**4**	**22.2%**
	Administration	1	5.6%
	Logistics Service Provider	1	5.6%
	Other	2	11.1%
Always the Logistics Service Provider	**Total**	**0**	**0.0%**
Unclear / I do not know	**total**	**6**	**33.3%**
	Administration	1	5.6%
	Logistics Service Provider	1	5.6%
	Other	3	16.7%
	Vessel Owner/Operator	1	5.6%

2.3.3. BEST-WORST ASSESSMENT OF BARRIERS AND DIMENSIONS

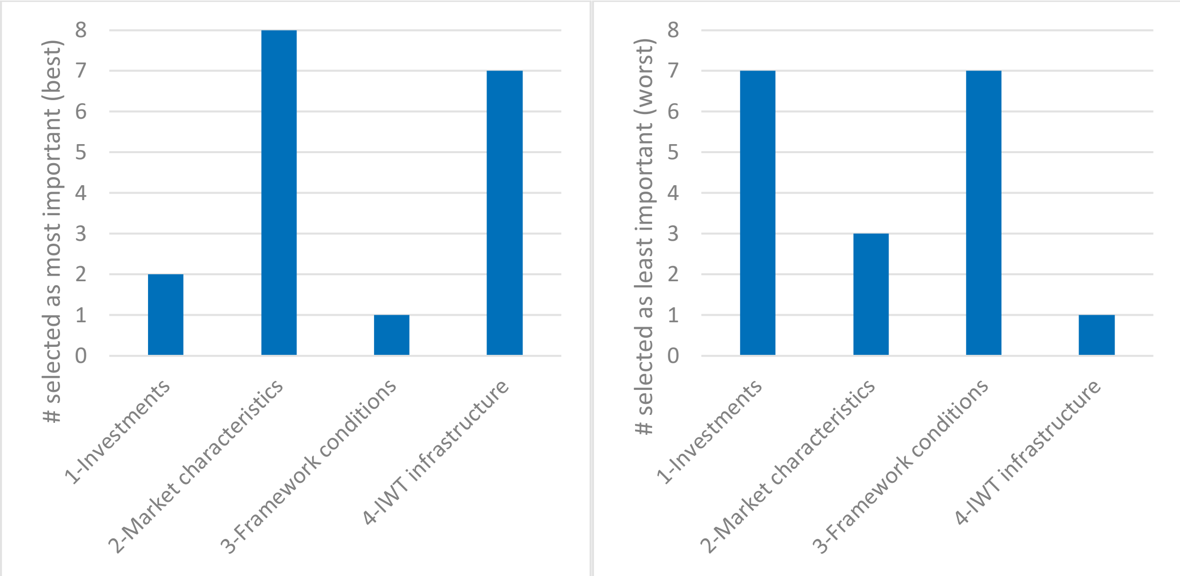

Figure 2: Number of respondents selecting the dimensions as most ("BEST", left) and least ("WORST", right) important.

Figure 2 shows how often the main dimensions have been selected as "best" and "worst" criterion in the overall rating. This bar chart gives a first indication of a preference of "IWT Infrastructure" and "Market characteristics" as the more important barrier dimensions and "Framework conditions" and "Investments" as probably less severe barriers towards IWT in the mode choice decision.

Following the methodological steps of (Mohammadi and Rezaei 2020) we obtained the two vectors "best to others" and "others to worst". As an example, Table 4 and Table 5 shows the vectors of each participant. In the case of the dimension "Investments" a clear preference of sub-criteria "infrastructure investments" is underpinned by 12 out of 18 Experts choosing it as the "Best" a.k.a. most important sub-criteria (locally within the assigned dimension). In contrast to this, the experts were less aligned when it came to choosing the least important criterion among the "Investments" dimension: "sustainability" and "vessel building" were chosen six times each. In the cross-check, only one participant rated "infrastructure investments" as least important and thus controversial to most of the other experts.

Table 4: "Best to Others" vectors of all respondents for the dimension "Investments"

	Selected as "Best"	Rating "Best to Others"

Expert	In "Investments"	*sustainability*	*initial cost*	*vessel building*	*infrastructure investments*
1	initial cost	9	1	8	7
2	infrastructure investments	5	6	7	1
3	initial cost	4	1	8	6
4	infrastructure investments	9	9	9	1
5	infrastructure investments	7	9	7	1
6	infrastructure investments	3	3	3	1
7	vessel building	4	6	1	3
8	sustainability	1	5	5	3
9	infrastructure investments	6	9	9	1
10	infrastructure investments	5	5	6	1
11	infrastructure investments	4	5	8	1
12	infrastructure investments	6	5	6	1
13	infrastructure investments	9	3	5	1
14	initial cost	3	1	1	4
15	infrastructure investments	7	3	3	1
16	vessel building	9	1	1	1
17	infrastructure investments	9	3	2	1
18	infrastructure investments	1	2	1	1

Table 5: "Others to Worst" vectors of all respondents for the dimension "Investments"

Expert	Selected as "Best"	Rating "Others to Worst"			
		sustainability	*initial cost*	*vessel building*	*infrastructure investments*
1	sustainability	1	8	5	8
2	sustainability	1	4	3	5
3	infrastructure investments	7	8	1	1
4	vessel building	1	1	1	9
5	initial cost	5	1	1	5
6	sustainability	1	1	2	3
7	initial cost	4	1	5	9
8	initial cost	2	1	2	2

9	vessel building	5	4	1	9
10	vessel building	6	5	1	6
11	vessel building	5	7	1	8
12	sustainability	1	7	3	8
13	initial cost	3	1	5	5
14	vessel building	5	9	1	9
15	vessel building	3	1	1	3
16	sustainability	1	9	9	9
17	sustainability	1	3	6	5
18	sustainability	1	1	1	6

On the basis of these pairwise comparisons, the optimal weights are calculated for each dimension and local weights for the sub-criteria listed in Table 1. The local weights of the sub-criteria can be found in Appendix C. Finally, global weights are calculated to obtain comparable weights by multiplying the optimal weight of each dimension (see Figure 3) with the local weight of each of their sub-criteria as explained in Equation 1. This results finally, in a global weighing which allows a ranking of all 25 barriers (sub-criteria) as a group decision of all 18 experts. The final weights are depicted and sorted in Figure 4. To interpret the figures correctly, one has to remember the "best" and "worst" definition from the methodology section 2.1 (page 13). The "BEST" criterion corresponded to higher ratings and subsequently higher weights (w*). To put it differently, a **higher weight means that a barrier is more severe/important barrier towards IWT mode choice** than other, lower weighted barriers (dimensions and sub-criteria).

Figure 3: Optimum weights (w*) for each dimension

Equation 1: Calculation of global weights (w*) per subcriteria and example.

$$w^*(dimension) * w^*(subcriteria) = global\ w^*(subcriteria)$$

$$Example: w^*(investments) * w^*\ (infra.invest.) = 0.21861110 * 0.404809771 = 0.08849592 = global\ w^*(infra.invest.)$$

As already suspected from Figure 2, the global weights of the four dimensions reveal that “IWT Infrastructure” is rated the most important category of barriers, followed by “Market characteristics”. Thirdly, “Investments” and rated the least important is “Framework conditions”. Despite this ranking of the main dimensions by the experts, a look at the sub-criteria final weights in Figure 4 reveals that the aspect of “infrastructure investments” (Investments) is still the most important barrier among the whole range of obstacles of IWT. It is followed by “waterway depth” (IWT Infrastructure) which is as well far ahead the rest of the sub-criteria list. Table 6 picks up the previous Table 1 with the listing and full names of barriers and indicates their weights with highlighting of the more severe barriers towards IWT mode choice.

Within the dimension “Market Characteristics” the experts' responses were more heterogeneous in this dimension leading to a less distinguished outcome without a clear favorite. The leading aspects “flexibility” and “reliability” are rated almost as equally important. In sum this can be interpreted that, according to the experts, Market characteristics are highly important when (not) choosing IWT, while it does not depend too much on one certain aspect of this dimension. All of them are seen as important, while eventually the slightly stronger weight of flexibility and reliability could indicate that without their perceived presence, IWT is more unlikely to be chosen as a mode of transport.

The dimensions “Framework conditions” was rated as least important compared to the other provided dimensions. The seven barriers within this category are less distinguished as well. Interestingly, the leading barrier within this group is the lack of “priority of IWT” which communicates the consensus of the experts that IWT is neglected by politics and economics which may impair the growth potential. Also, the insufficient “knowledge and willingness” of decision makers as well as the lack of “multimodal connections” underpin the neglect of IWT in mode choice processes. These soft facts seem to be more emphasized as barriers than the hard, measurable facts, e.g. lack of personnel, administrative burden or operating hours of locks.

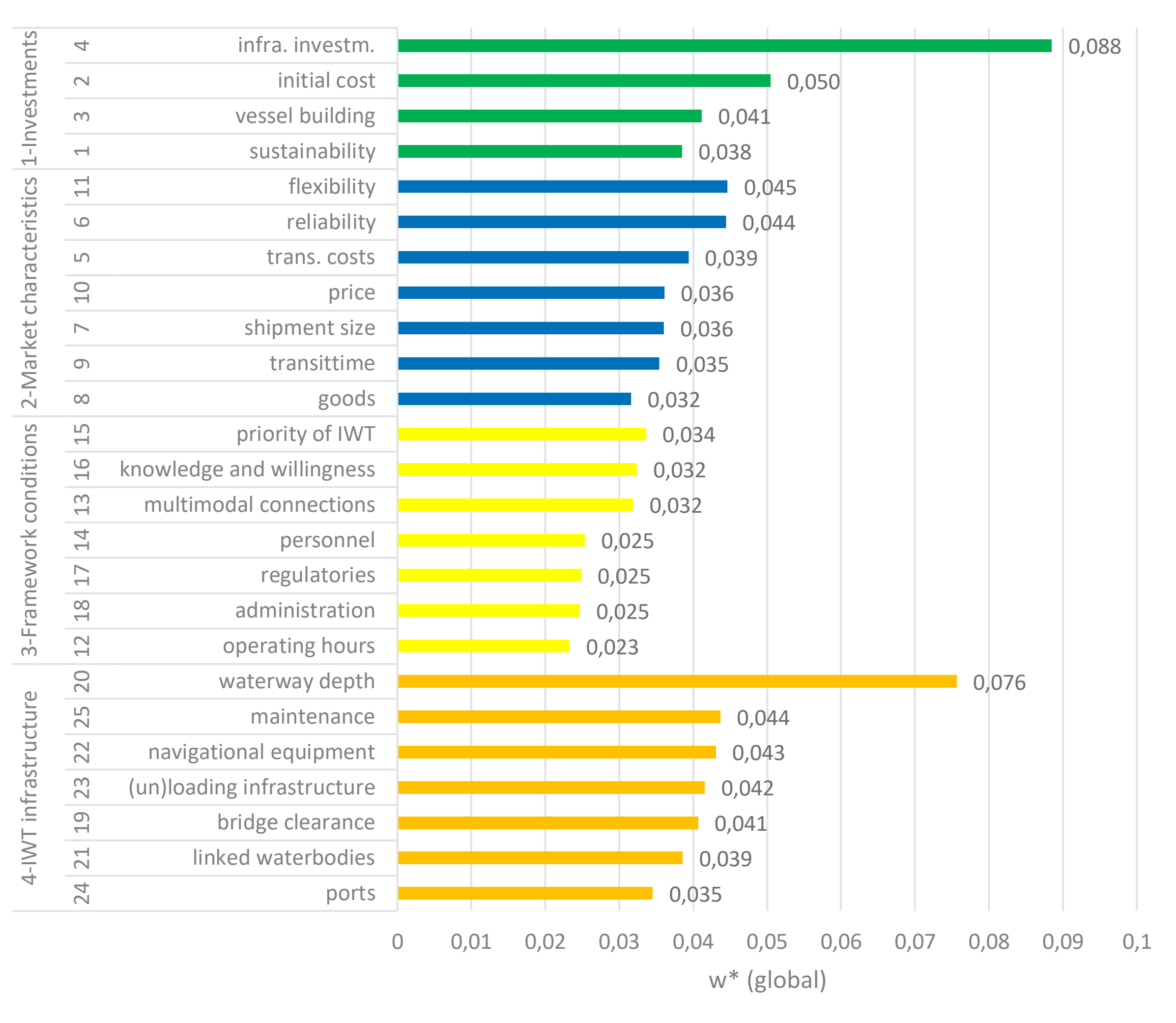

Figure 4: Final (global) weights for all sub-criteria, ranked from most to least important, according to the expert group.

Table 6: List of Barriers and their final weights with highlighted most severe/important barriers within each dimension

Dimension	#	Barrier	weight
Investment	1	Low pace of development of the IWT sector in terms of sustainability (alternative engines and fuels, emissions, …)	0.038
	2	High initial costs for introducing IWT services (e.g. equipment, compliance with safety regulations, …)	0.050
	3	Shortage of vessel and barge building	0.041
	4	**Lack of investments to build/maintain waterway infrastructure**	0.088
Market characteristics	5	Additional costs of transshipment/multimodal transport	0.039
	6	IWT Services are (perceived as) unreliable	0.044
	7	Only competitive for high volumes of goods	0.036

	8	Only suitable/competitive for certain types of goods	0.032
	9	Transit time takes too long	0.035
	10	Transport price is too high/not competitive in comparison with other modes	0.036
	11	**Insufficient flexibility of IWT services (e.g. frequency, capacity, vessel or shipment size)**	0.045
Framework conditions	12	Insufficient/varying operating hours of ports, locks, customs, terminals	0.023
	13	Lack of connection to other modes of transport (insufficient multimodal connections)	0.032
	14	Lack of qualified personnel	0.025
	15	**Low prioritisation of IWT**	0.034
	16	Decision makers have a lack of knowledge about IWT or are not willing to shift	0.032
	17	Lack of regulatory frameworks	0.025
	18	Administrative burden of IWT (e.g. inter-agency coordination, border controls, languages, standardization)	0.025
IWT Infrastructure	19	Insufficient bridge clearance	0.041
	20	**Insufficient waterway depth**	0.076
	21	Lack of interlinking with other waterbodies	0.039
	22	Lack of navigational equipment (e.g. digital navigational charts and river information systems)	0.043
	23	Lack of terminals and related infrastructure needed for loading/unloading and storage	0.042
	24	Insufficient location or number of ports/quays	0.035
	25	Insufficient maintenance, repair and overhaul of infrastructure (ports, vessels, handling facilities)	0.044

2.3.4. ASSESSMENT REGARDING STAKEHOLDER TYPE

The experts were asked to which stakeholder type they assign themselves to and the industry they are working in. As also shown in Table 2, we received 2 answers each from administrative entities, shippers and vessel operators, 6 from logistics service providers, and 6 from other stakeholders like logistics associations or research. In this section we distinguish the responses by type of logistics stakeholder and investigate the differences between their ratings. The following two figures show in principle the same information, once separated on the main axis by stakeholder type (Figure 5) and once by dimension (Figure 6). Figure 7 to Figure 10 reveal the differences of rating of the stakeholders for each of the 25 barriers.

While Administration, Others and Vessel Owners seem to agree on a high importance of Investments, this category has got less of an emphasis by Shippers and logistics service providers (LSP). Regarding Market characteristics (transit time, shipment size, suitable goods for transport etc.), all stakeholders agree on a relatively high rating, except for vessel owners.

The vessel owners tend to put more emphasis on Market characteristics than all other stakeholders. Looking at the sub-criteria figure of Market characteristics (Figure 8) it reveals that shipment size and transit time are viewed as the more severe barriers according to vessel owners. Their opinion on IWT Infrastructure differs in the opposite direction resulting in a much lower rating than from the other groups.

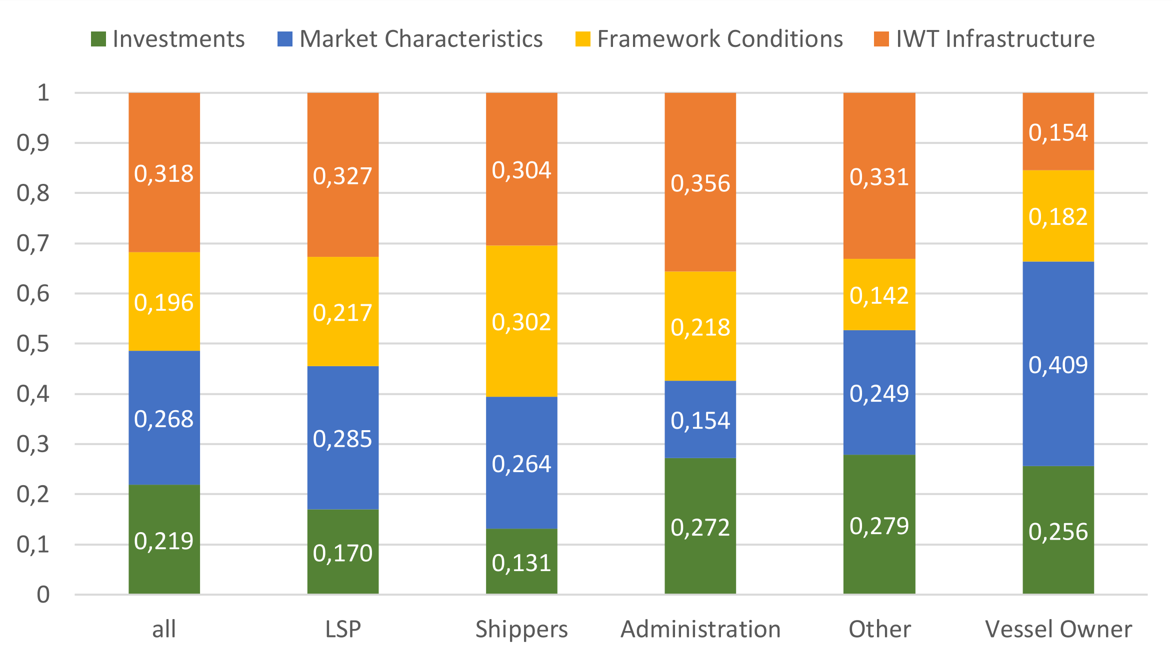

Figure 5: Evaluation of the dimensions (w*) by stakeholder type

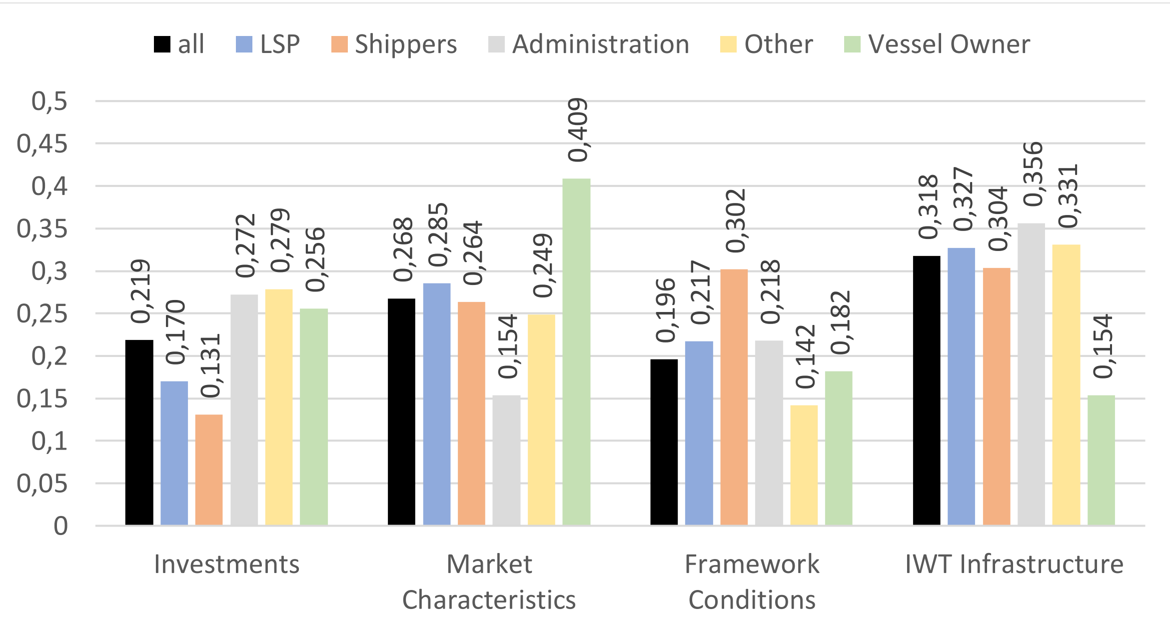

Figure 6: Different views of the stakeholders on the main barrier dimensions (w*)

Figure 7 shows the ratings per stakeholder type within the barrier of the dimension "Investments". It reveals the outlier of Vessel Owners, who see the vessel building capacity as more severe than all other stakeholders. Respondents from Administration stand out for their contrasting opinion on the pace of development of IWT regarding sustainability.

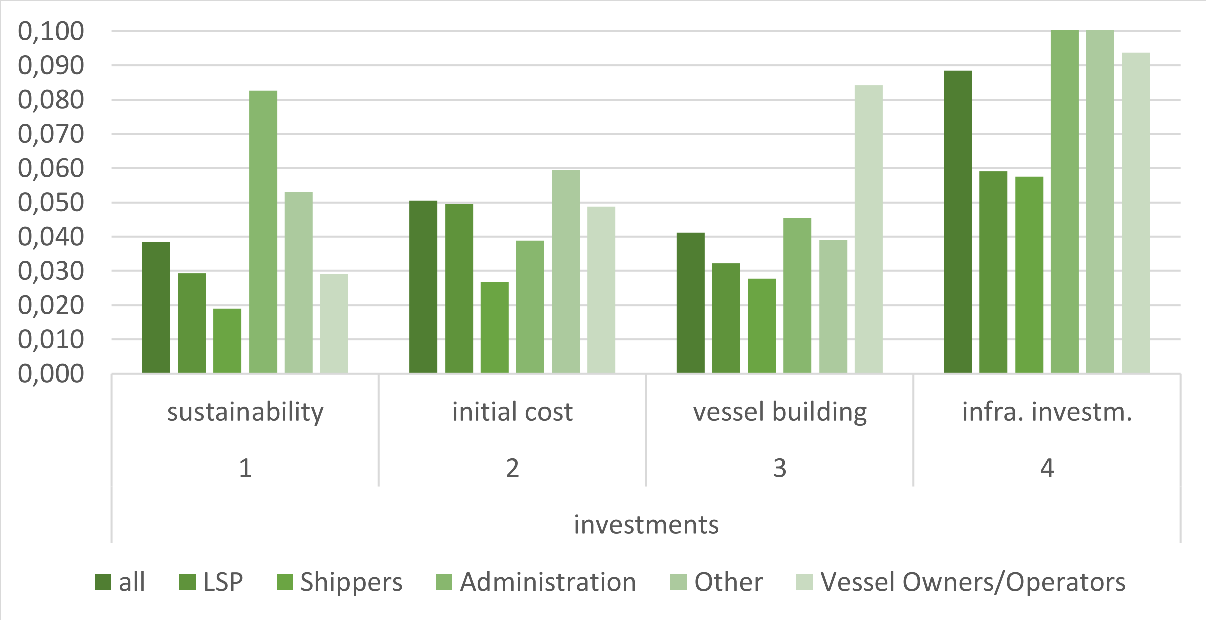

Figure 7: Different views of the stakeholders on the sub-criteria of barrier dimensions "Investments"

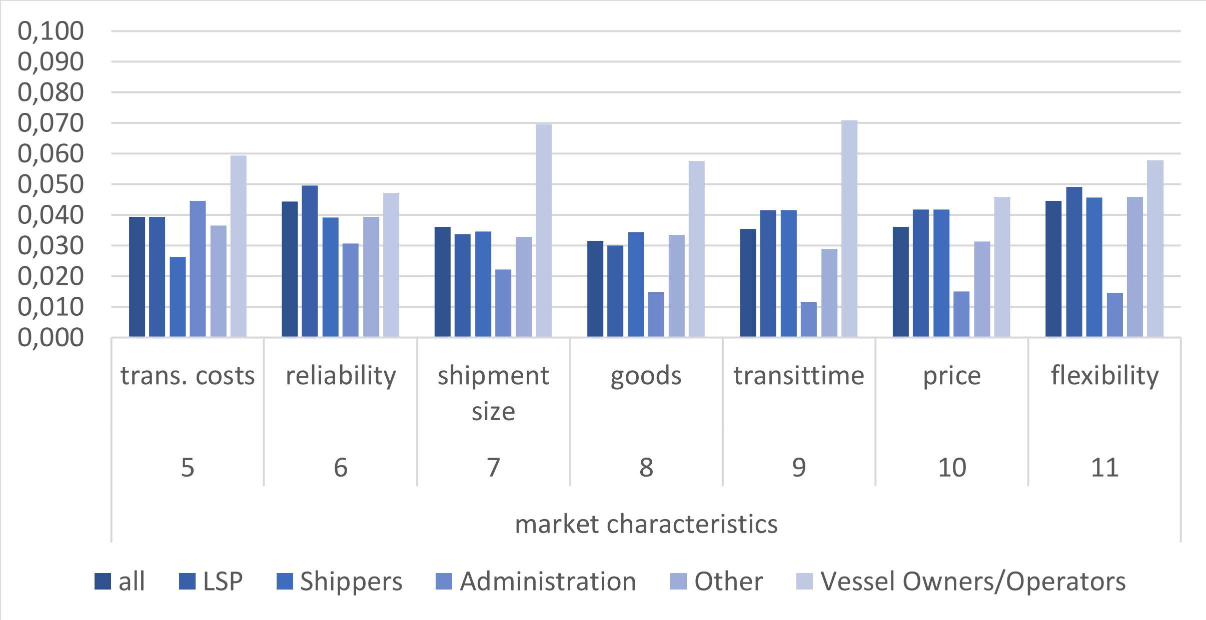

Figure 8: Different views of the stakeholders on the sub-criteria of barrier dimensions "Market characteristics"

Within the Market characteristics barriers (see Figure 8), the vessel owners rate all barriers especially high, and, on the opposite, the administration group rated 6 of 7 sub-criteria much lower. This reflects the overall rating that was given by those two groups and shown in Figure 5. The price of transportation is stated by research and practitioners to be one of the leading mode choice factors (Reis 2014). In the case of IWT it does not appear as a (severe) barrier to mode choice according to all experts. Also the other three "typical" mode choice variables transit time, reliability, flexibility (Reis 2014), which all belong to this barrier dimension, do not stand out as a particular obstacle for IWT mode choice (from decision maker perspective, who are anticipated to be represented by shippers and LSPs). From a theoretical perspective this is good news for IWT in principle but having a sneak peek at Figure 10, all stakeholders are concerned because of waterway depth which might severely impedes the perception of reliability. This underpins that navigability concern (e.g. insufficient waterway depth) is one of the most severe obstacles towards IWT mode choice.

Only shippers rated the Framework conditions as most severe barrier dimension (see Figure 5). Looking at Figure 9 below, this results in higher weights in the shipper's rankings, with the most important obstacle being the lack of knowledge and willingness of decision makers for a shift to IWT. Since the shippers in our study indicated themselves to be the decision maker (see Table 3, page 19), they admitted that they personally or their companies lack enough knowledge and/or willingness for a modal shift to inland waterways. As the second-most severe barrier the lack of multimodal connectivity is mentioned by the shippers. On the third place landed the low prioritisation of IWT in general. The Administration stakeholders rated the Framework conditions also relatively high. They perceive the insufficient priority of IWT as well as the lack of regulatory frameworks as the more severe obstacles within this dimension.

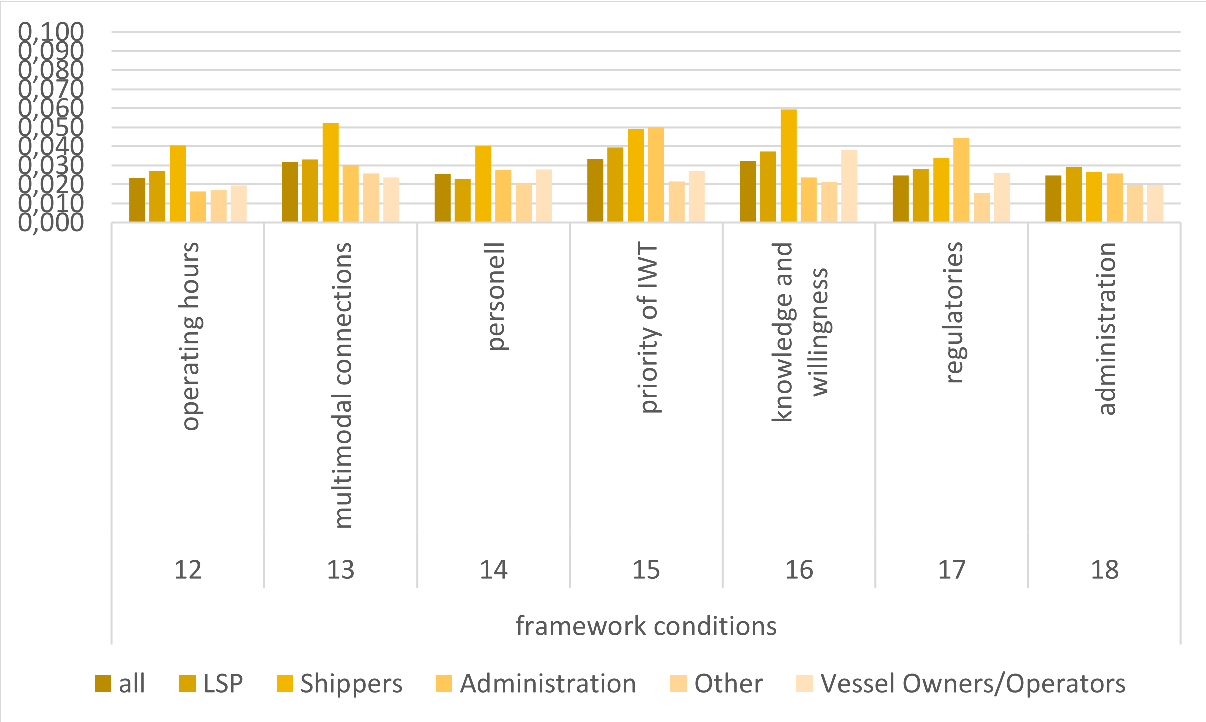

Figure 9: Different views of the stakeholders on the sub-criteria of barrier dimensions “Framework conditions”

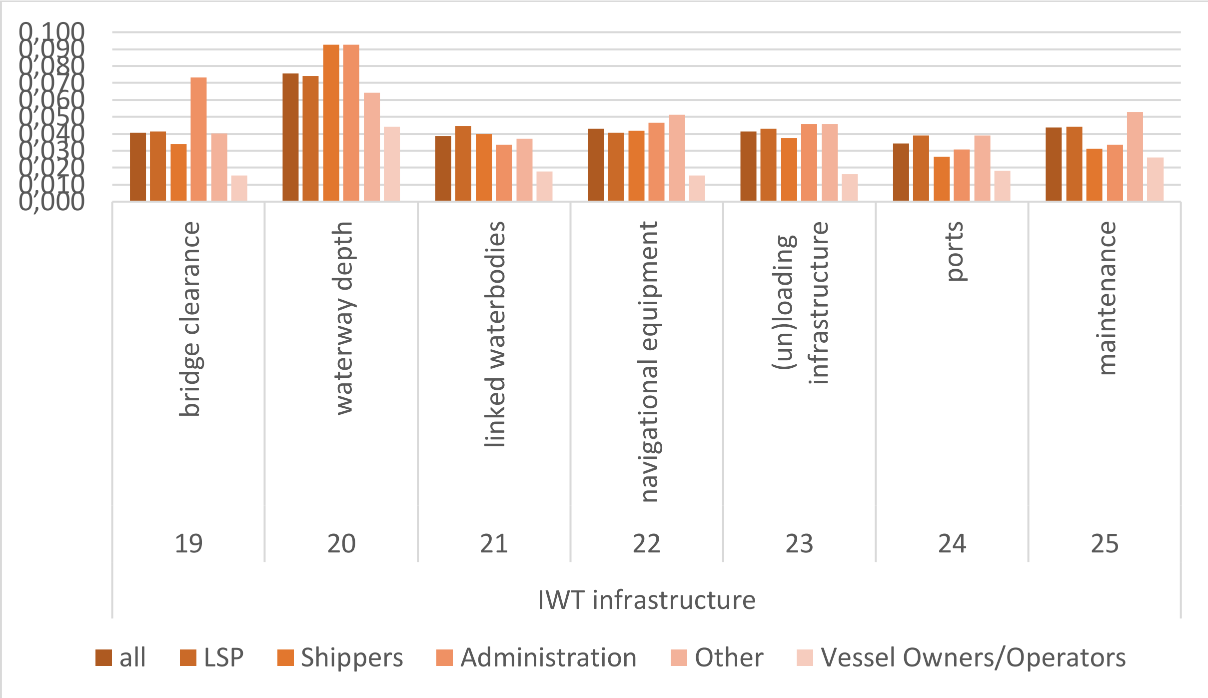

Figure 10: Different views of the stakeholders on the sub-criteria of barrier dimensions "IWT Infrastructure"

2.4. SUMMARY: CONTAINERIZED DANUBE SHIPPING TO OVERCOME PERCEIVED BARRIERS TO THE IWT MARKET

Inland Waterway Transport (IWT) is known for its cost-effectiveness with high payload and low cost per ton (Bu and Nachtmann 2021). The changing landscape of global trade and the need for increased production and distribution flexibility have led to smaller, more frequent freight flows covering longer distances (Hesse and Rodrigue 2004). This shift has impacted the cost-effectiveness of traditional IWT for bulk cargo. Containerization emerges as a promising solution to enhance IWT and address barriers hindering the modal shift, particularly concerning key criteria like costs, transit time, reliability, and flexibility (ITF 2022).

Moreover, research from Belgium revealed that the variable "cargo type" has an influence on mode choice. It indicates that price changes of road transport influences modal shift tendencies towards rail and inland waterways of cargo types containers (+1.2%), pallets (+2.4%), solid bulk (+3.9%) and liquid bulk (+5.9%) (Mommens et al. 2020). These findings are highly relevant and underpin the potential of the efforts to shift various cargo types from road to IWT (in containers). This addresses especially the common barrier of IWT, that it is associated with certain types of cargo, which is also reflected by the identified barrier number 8

"Only suitable/competitive for certain types of goods" (Table 1, Table 7). Our analysis of the freight mode choice process using Best-Worst-Method revealed that this barrier is perceived the highest by vessel owners/operators. But for the designated decision makers, who were identified as mostly shippers, the type of good does not seem to play a big role (Figure 8). More interestingly, the shippers rated the barrier lack of knowledge and willingness to shift to IWT much higher (Figure 9). This presents also an example that some barriers may be caused or supported by behavioral biases as suggested by Stockhammer et al. 2021. Moreover, the stakeholders are all convinced that the low prioritization of IWT also function as an obstacle toward inland shipping. Our quantitative evaluation of the barriers towards IWT mode shift revealed moreover, that two barriers are far ahead all other barriers: Lack of investments in IWT Infrastructure maintenance and waterway depth (see also Table 6).

After quantitatively evaluating obstacles towards IWT mode choice, we aim to shed light on how containerized Danube shipping may qualitatively help to overcome the (perceived) barriers to the IWT market. Above all, containers present the advantage of consolidating diverse goods on a single barge, offering cost efficiencies and enhanced capacity utilization (Bu and Nachtmann 2021). Standardized globally, containers facilitate improved links with pre- and post-haulage by road, promoting seamless multi-modal transport. This bundling approach enhances the flexibility of IWT, reducing dependence on specific vessels and enabling loading adjustments on earlier/later liners. The elimination of transshipment needs during mode changes for pre- and post-carriage contributes to reduced transit times. Installing container handling equipment in all Danube ports further enhances overall reliability, allowing adaptability to low or high water conditions through collaboration between truck and barge carriers for a smooth transition between road and water transport to meet customer delivery timelines.

The barriers towards broader IWT use, discussed and analyzed in Chapter 2, have to be contrasted with the potentials and advantages that lie within containerized IWT. Bu and Nachtmann 2021 identified **15 advantages of container transport on barge** from existing literature. They are listed below and sorted by most often mentioned to least often mentioned:

1. ***Lower transportation cost***
2. Environmentally friendly
3. Road congestion mitigation
4. ***Economies of scale***
5. ***Reliable transport mode***

6. Alternative to road transportation
7. ***River resource utilization***
8. ***Fuel efficiency***
9. ***Empty container repositioning***
10. ***Low infrastructure investment***
11. ***Smaller port network expansion***
12. ***High cargo volume***
13. ***Low maintenance cost***
14. ***Multimodal transport development***
15. ***Flexible terminal dwell time***

Out of the 15 advantages identified by literature listed above, the ones written in bold italic letters have potential to overcome barriers towards IWT mode choice. We identified 9 out of the 25 shortlisted barriers (see Table 1) that can be potentially reduced by those listed advantages of container transport by barge (see Table 7). Using containers allows more flexible utilization of barges, e.g. at low water periods (barrier No. 20, Table 7) only one layer could be loaded per barge and a further barge could be attached (possibility must be checked depending on the Danube section). Another possibility would be to compensate for bottlenecks caused by low water levels by reloading to other modes of transport at short notice. This only becomes possible by close cooperation between the modes and efficient transshipment by containerization. On the other hand, of course, there are still barriers where containerization only cannot play a major role to overcome them. E.g. a structural neglect of the transport mode inland shipping by low prioritization (Barrier #15) or missing investments in IWT Infrastructure (Barrier #4).

Table 7: Containerization potentials out of the 15 advantages of Bu and Nachtmann 2021 to overcome barriers towards IWT mode choice.

Dimension	**No**	**Barrier**	**Potentials of containerization**
Investment	2	High initial costs for introducing IWT services (e.g. equipment, compliance with safety regulations, …)	1, 4, 8, 12, 10, 13
Market characteristics	5	Additional costs of transshipment/multimodal transport	1, 4, 5, 8, 9, 10, 13, 14, 15
	7	Only competitive for high volumes of goods	
	8	Only suitable/competitive for certain types of goods	
	10	Transport price is too high/not competitive in comparison with other modes	
	11	Insufficient flexibility of IWT services (e.g. frequency, capacity, vessel or shipment size)	

Frame-work conditions	13	Lack of connection to other modes of transport (insufficient multimodal connections)	5, 7, 9, 14, 15
IWT Infra-structure	20	Insufficient waterway depth	7, 10, 11
	23	Lack of terminals and related infrastructure needed for loading/unloading and storage	

Multimodal container transport and inland waterway transport play an important role in the transport of goods in Europe. Multimodal transport, i.e. the combination of different modes of transport such as rail, road or ship, enables more flexible and efficient logistics to be achieved. Inland waterway transport represents a significant part of multimodal transport and contributes to relieving the burden on roads and reducing greenhouse gas emissions.

While container usage is well-established along the Rhine, constituting 99.95% of the EU's container transport performance, its adoption on the Danube is minimal (0.05%). In the EU, container transport represents 9.6% of the total IWT performance in tonne-kilometers (136 billion TKM in 2021) (CCNR 2022b). In the INTERREG project DAPhNE the outcome of a market potential analysis forecasted a low feasibility of a full container liner service from Austria to the west via the locks in the Rhine-Main-Danube channel in Germany. But it is underpinned that there is potential in the Danube region downstream from Budapest to Constanta. Nevertheless an empty container liner service is estimated to be profitable between Austria and Germany (DAPhNE 2018). Containerization emerges as a promising market segment for Danube shipping, offering a plethora of advantages and a considerable growth potential due to its underutilization on the Danube[2]. The following chapter aims to evaluate the current market situation of specific product groups transported by road and estimate the share that could potentially transition to multimodal container transport via barges on the Danube.

[2] See also Deliverable 2.5

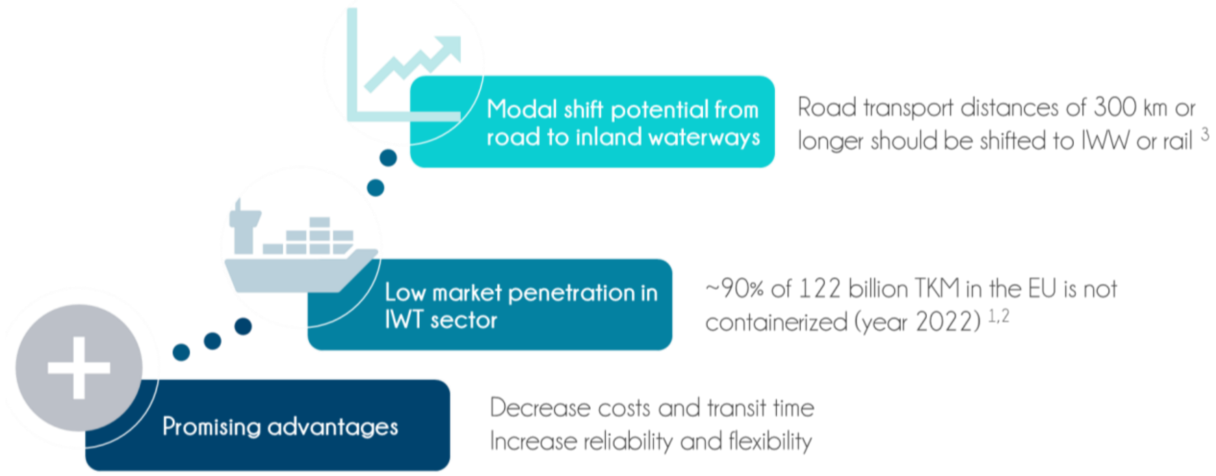

Figure 11: Summary of reasons for fostering containerized Danube shipping ([1] CCNR 2022a, [2] CCNR 2023, [3] Eurostat 2022c)

3. MARKET POTENTIAL ANALYSIS OF CONTAINERIZED DANUBE TRANSPORTATION

Within this chapter, we present the analyses to retrieve the potential volumes (in tons and tonne-kilometers) that could be shifted from road to IWW in the Danube corridor to estimate the market potential for containerization on the Danube by an analysis of available data.[3]

Herein we refer to "market potential" as the potential cargo volume shifted from road to IWW, i.e. modal shift from road to IWW.

Although a substantive shift to more sustainable modes of transport, such as inland waterways, is demanded by the EU (European Commission 2019) the share of IWT has decreased from 7.4% in 2012 to 5.6% in 2021 (Eurostat 2023b). In general, the IWT network in the EU still has available capacities (Federal Ministry of Transport and Digital Infrastructure 2019). Hence, a modal shift to the Danube waterway is desired and possible (Wiegmans and Konings 2016). The present study elaborates on the market potential that containerization on the Danube could have and what proportion of road transport could be shifted to multimodal transport using the Danube waterway.

"Containerization" refers to the practice of transporting goods in standardized containers that can be easily transferred between different transport modes, without the need for unpacking and repacking the cargo.

Eurostat, as the statistical office of the European Union, already provides indicators that relate "the transport of containers over longer distances (more than 300 kilometres) to total road ITU transport and to total road goods transport, providing information for analysis of the potential for transferring such long-distance transport of containers from road to other modes of transport." One indicator is based on tonne-kilometers (TKM) (Eurostat 2022c) and the other one on tonnes (Eurostat 2022b). Figure 12 and Figure 13 show the respective data for some of Danube riparian countries that were available in the datasets. These figures indicate a modal shift potential from road to IWW in principle in the Danube countries, but another indicator on the current state of "Freight unitisation in inland waterways transport" (Eurostat 2022f) shows that only Germany has a 10.2% containerization rate to date (2021).[4] These indicators address the problem of

[3] Sub-Task within Task 2.3: Identification of the market potentials by an analysis of available data
[4] 0.0 % in Bulgaria, Czechia, Croatia, Austria, Romania, Slovakia (year 2021) Eurostat 2022f.

our current study to an insufficient extent, since the indicators provide no information on types of goods that are transported in containers. Moreover, not all countries of interest in the Danube regions are covered by the datasets. Hence, a more detailed approach is needed. We evaluate herein which goods are potentially suitable to be shifted to containerized Danube shipping, and what proportion of the current road transport volumes of those goods in the Danube countries could potentially be shifted to Danube shipping.

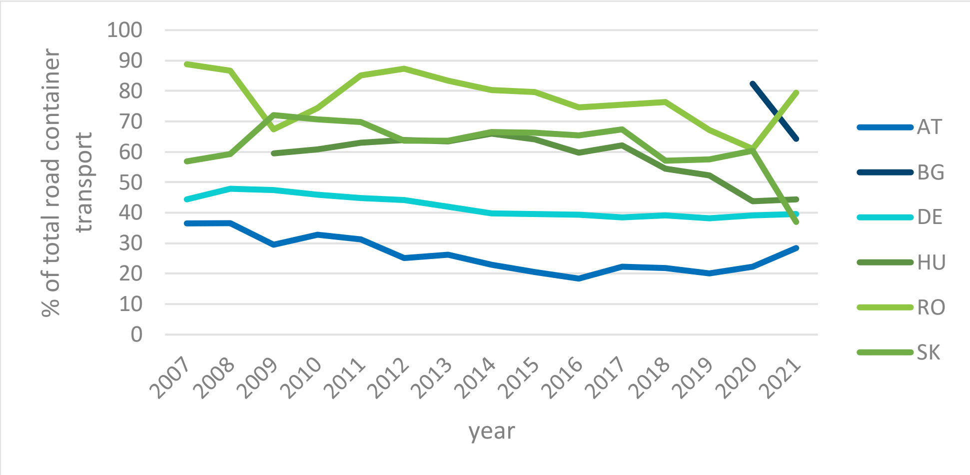

Figure 12: Percent of total road container transport [TKM] of 300 km or more distance in Danube riparian countries, 2007 to 2021 (Eurostat 2022c) (data: tran_im_mosp)

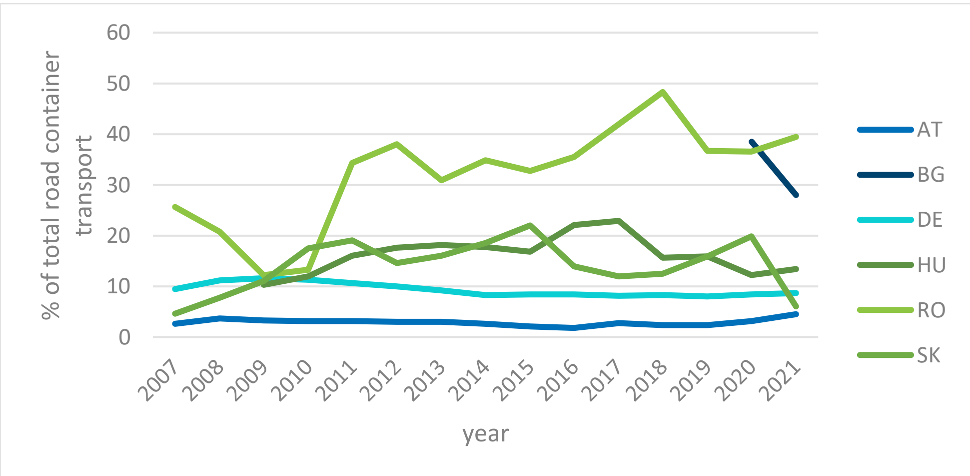

Figure 13: Percent of total road container transport [T] of 300 km or more distance in Danube riparian countries, 2007 to 2021 (Eurostat 2022b) (data: tran_im_mospt)

The methodological steps to determine a potential modal shift volume from road to the Danube waterway are summarized in Figure 14. First, a definition of the spatial study area, namely the “Danube corridor”, needed to be set. This definition builds the baseline for further desk research on available secondary data. In the second pillar, a comprehensive desk research was conducted to identify suitable bulk product groups and cargo types as well as available data sources which provide statistical data on the desired economic figures. EUROSTAT by the European Union was identified as the most appropriate source of statistical information.

Subsequently, in the third process step, the theoretical maximum transport volume in tons and performance in ton-kilometres for a shift from road transport per country was determined. However, as the country level provides very imprecise results, a heuristic approach was developed. With the help of scenarios developed for a modal shift, an attempt was made to derive an approximate realistic result. The individual work steps and threshold values for the scenarios were derived from the findings of the previous process steps.

The three methodological steps were not carried out step by step but repeated iteratively. If new findings emerged, a check was made to see whether an earlier step needed to be adapted. For example, spatial data sets were collected to delineate and map the Danube corridor and compared with the level of detail in which the economic and statistical data on transport goods was available. The original aim was to collect data at NUTS-3 level, but only data at country level was available for the selected product and cargo classes. The remainder of this chapter explains further details of the conducted work and methodology and presents the results of the conducted analyses.

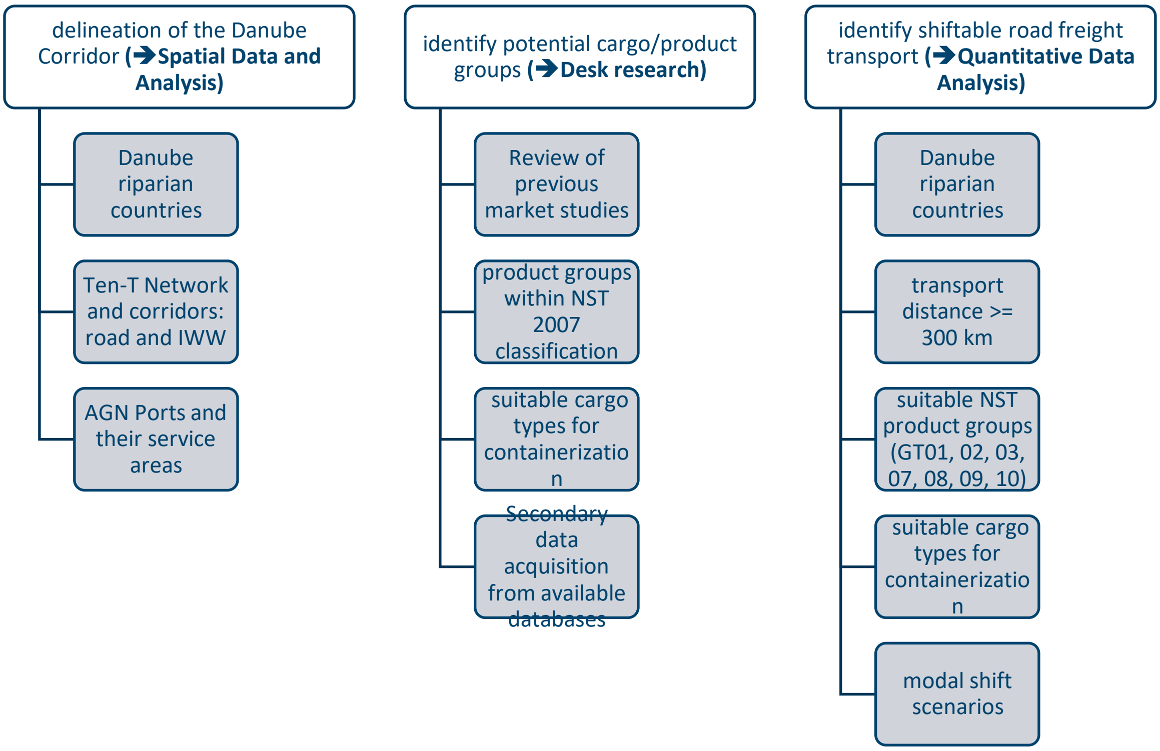

Figure 14: Main process stages to determine the modal shift potential from road to multimodal transport using IWT.

3.1. DEFINITION OF THE STUDY AREA AND DANUBE CORRIDOR

The EU has defined NUTS regions on level 3 (NUTS-3) that are part of the "EU Strategy for the Danube Region of the European Union (EUSDR)" (Danube Strategy Point). They are shown in Figure 15: EU Strategy for the Danube Region of the European Union (EUSDR), included NUTS-3 regions and non-EU regions (Danube Strategy Point). Another view on the definition of the Danube Corridor is provided by the EU's trans-European transport network policy, the TEN-T policy, defining nine core network corridors including the Rhine – Danube Corridor.[5] (European Commission 2023) which is shown in Figure 16

[5] Regulation (EU) No 1315/2013 currently under revision, http://data.europa.eu/eli/reg/2013/1315/oj

Figure 15: EU Strategy for the Danube Region of the European Union (EUSDR), included NUTS-3 regions and non-EU regions (Danube Strategy Point)

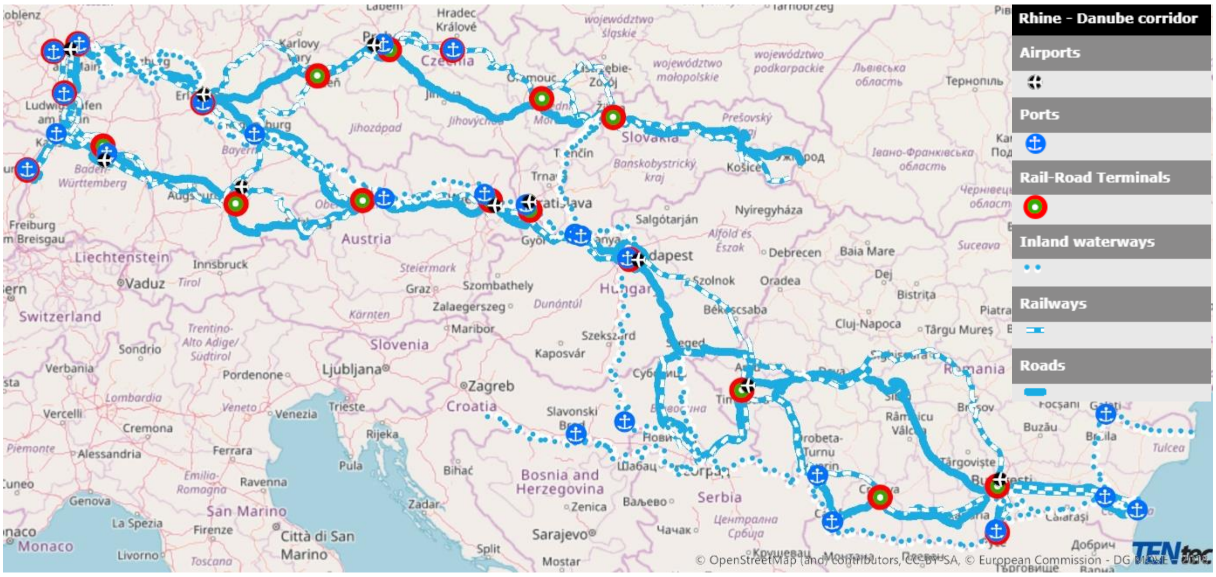

Figure 16: Rhine-Danube corridor according to TENtec Interactive Map Viewer (source: https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/map/maps.html)

This study used the above delineations as starting points but the final study area and level of details of the subsequent analysis results are based on two factors:

1) Data granularity of the available datasets
2) Catchment areas of the Danube ports

Consequently, we receive two delineations of the spatial Danube region under review. On the one hand, the **"Study Area"** is defined as the territories of the EU Member States bordering the Danube, namely Germany, Austria, Slovakia, Hungary, Croatia, Bulgaria and Romania. For some analysis Czechia was added as well, since it lies within vicinity of the Danube and within the catchment area of minimum one Danube port. The map is shown in Figure 17. For non-EU Danube riparian states, no or only sparse data is provided by the main source of information EUROSTAT and hence cannot be fully included. Those comprise Serbia, Moldova and Ukraine. The spatial dataset of the NUTS administrative boundaries is received from European Commission – Eurostat/GISCO. And on the other hand, the **"Danube Corridor"** comprises the areal of the Danube ports' catchment (or service) areas shown in Figure 18. The catchment areas are calculated using ArcGIS Network analyst and is based upon the truck driving distance from each Danube port. A distinction is made between the catchment areas within the lorry driving distances around the ports of 60, 80, 100 and 120 km.

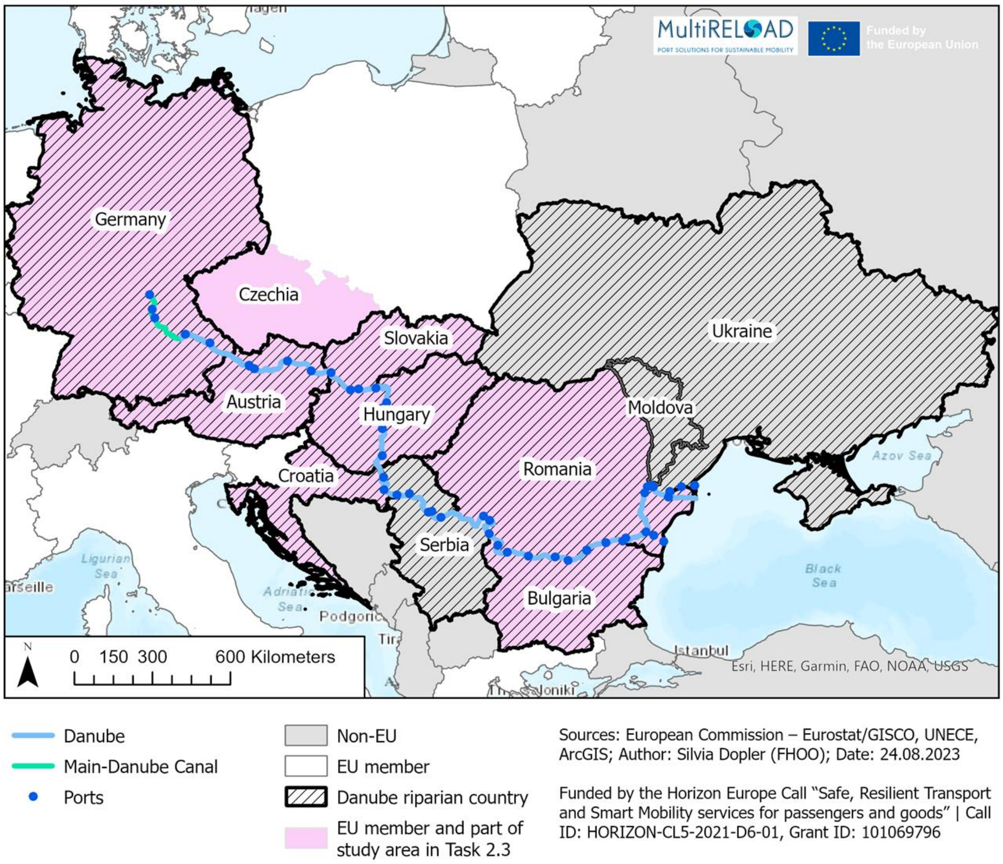

Figure 17: Map of the Danube study area of the market potential analysis (Task 2.3)

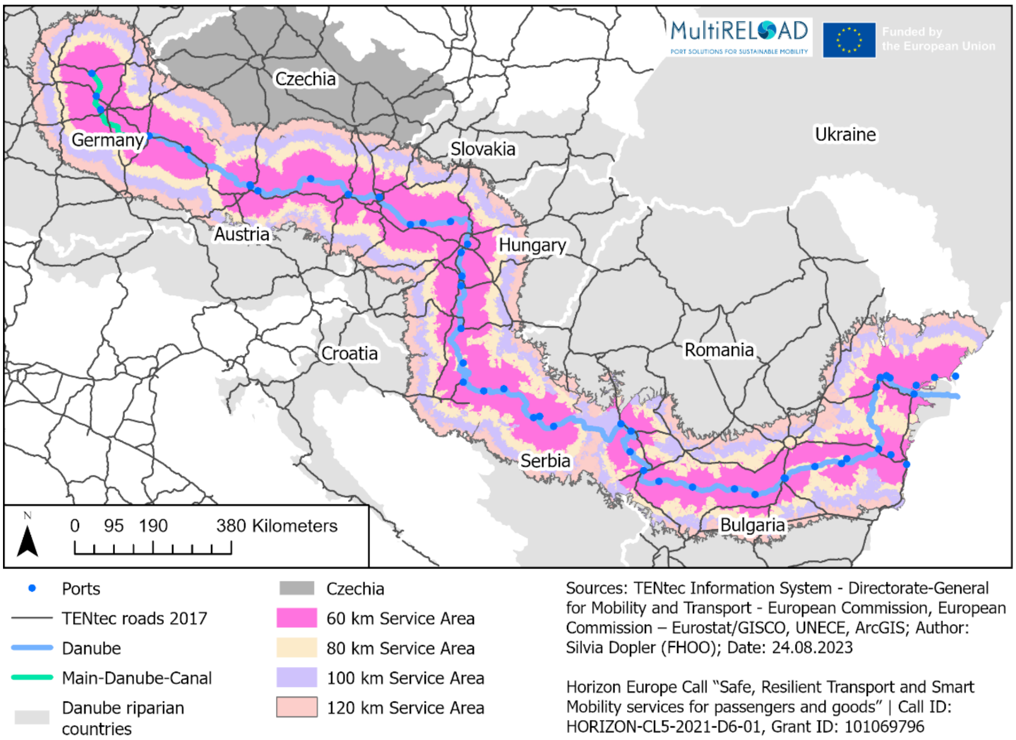

Figure 18: Delineation of the "Danube corridor" by catchment areas of the Danube ports

3.2. IDENTIFIED PRODUCT GROUPS AND CARGO TYPES

By thorough desk research potential product groups and cargo types for containerization and Danube shipping have been identified. Main sources for the identification of well-suited goods for Danube shipping were market observations by the Central Commission for the Navigation of the Rhine (CCNR 2022b) and the Danube Commission (Danube Commission 2022) as well as outcomes of the EU research projects Platina II (Gvozdic et al. 2014), DaHar (Steindl et al. 2014), INWAPO (Dolinsek and Hartl 2012) and IW-NET (IW-NET 2023). Within the task 2.3 "From bulk to multimodal for inland waterway transport" a clear focus lies on bulk products since this is also the aim of the A2 Demonstrator. Nevertheless, one goal of MultiRELOAD is to facilitate a modal shift of 5% from road to multimodal transport using IWT. Hence, we also looked at the broader perspective and decided to include the perspective of cargo types potentially suitable for containerization. The identified product groups and cargo types are presented in the following sub-chapters 3.2.1 and 3.2.2.

3.2.1. BULK PRODUCT GROUPS

Desk research revealed that inland navigation has a significant role in the transport of dry bulk cargo in the Danube region. It emerges that this type of cargo has a high but underutilized potential for IWT in the Danube countries (Gvozdic et al. 2014). The potential can be justified by the fact that these materials can be transported and stored in large quantities due to their characteristics (Martin 2018) and are typically not time-critical (Gvozdic et al. 2014). Eleven potential dry bulk commodities for inland navigation were identified from the main literature source the Platina II "Report on market transfer conditions Market Analysis Danube Corridor" (Gvozdic et al. 2014). The NST 2007 divisions 01, 03, 07 and 08 already have an affinity with IWT, as these are product groups of which high volumes (T and TKM) were transported by inland waterways in the Danube riparian states in 2021 (*iww_go_atygo*). Finished metal items (NST 2007 division 10) are also confirmed by historical transport data to be related to IWT (Danube Commission 2022). Group 09 "Other non-metallic mineral products" has lower transport volumes in tons in the Danube countries but contains the bulk goods cement and used glass, hence is added to the list of potential products for containerization. These divisions are considered to determine a modal shift potential from road to IWT.

The identified goods are assigned to the Standard Goods Classification for Transport Statistics (NST 2007) (shown in Table 8: Identified potential goods and assignment to NST 2007 divisions (Eurostat 2023g)) which is a uniform list of goods specifically developed for the compilation of transport statistics (Eurostat 2023g). The EUROSTAT transport database (Eurostat 2023a) was screened for available datasets on road, inland waterways. Suitable data were collected where transports are classified according to NST 2007, by country and the transport distances. The following datasets are used: *road_go_ta_dctg*, *road_go_ta_tcrg*, *iww_go_atygo*. At the time of evaluation, the most recent year with data available was 2021 and used for the analysis.

Table 8: Identified potential goods and assignment to NST 2007 divisions (Eurostat 2023g)

Identified products	NST 2007	Division description
Wheat, maize, soybeans	GT 01	Products of agriculture, hunting, and forestry; fish and other fishing products
Coal	GT 02	Coal and lignite; crude petroleum and natural gas
Industrial salts	GT 03	Metal ores and other mining and quarrying products; peat; uranium and thorium
Pellets, Coke	GT 07	Coke and refined petroleum products
Urea	GT 08	Chemicals, chemical products, and synthetic fibers; rubber and plastic products; nuclear fuel
Cement, used glass	GT 09	Other non-metallic mineral products

Metal scrap	GT 10	Basic metals; fabricated metal products, except machinery and equipment

The current road transport market size in the Danube countries is extracted as well as the share of transports over 300 km distance, which represents the **maximum that could be shifted** away from road transport countries to IWT on the Danube. The threshold of 300 km is suggested by Eurostat 2023c (see also explanation in chapter 3.3.1, page 47). This is the desired shiftable volume to IWT and rail by the European Commission. Considering the **selected NST 2007 product groups**, this amounts to approximately 156 million tons or 88 billion TKM of the identified bulk goods for the year 2021 shown in Table 9. The Figure 19 shows how the ~156 million tons and ~88 billion TKM are distributed among the NST-2007 product groups.

Table 9: Road transportation of NST-2007 divisions 01, 02, 03, 07, 08, 09, 10, year 2021 (Eurostat 2023e)

	Transport volume [thousand tons]			Transport performance [Million tonne-kilometer]		
Country*	**All distances**	**Long-distance [≥ 300 km]**	**%**	**All distances**	**Long-distance [≥ 300 km]**	**%**
Austria	283 465	7 193	2.5	13 820	3 784	27.4
Bulgaria	112 138	10 370	9.2	12 075	6 970	57.7
Croatia	56 743	5 682	10.0	6 235	3 664	58.8
Czechia	329 155	18 765	5.7	27 502	12 562	45.7
Germany	1 790 646	83 258	4.6	121 375	38 949	32.1
Hungary	79 513	8 243	10.4	10 065	5 029	50.0
Romania	199 716	11 159	5.6	15 583	8 070	51.8
Slovakia	101 082	11 611	11.5	13 228	8 721	65.9
Total / avg. %	2 952 458	156 281	5.3	219 883	87 749	39.9

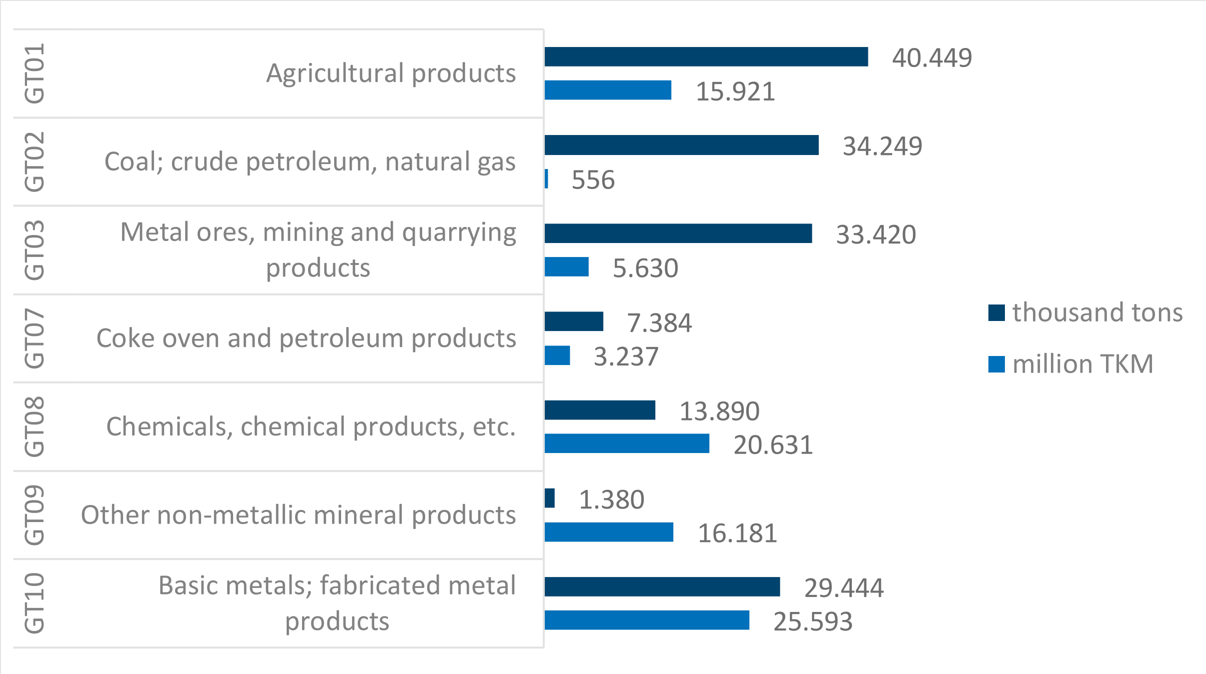

Figure 19: Maximum modal shift volume of the identified product groups that are currently transported ≥300 km by truck (2021)

3.2.2. BROADER PERSPECTIVE: CARGO TYPES

Table 10: Road transportation of products classified as “bulk cargo”, year 2021 (Eurostat 2023f)

	Transport volume [thousand tons]			Transport performance [Million tonne-kilometer]		
Country*	**All dis-tances**	**Long-distance [≥ 300 km]**	**%**	**All dis-tances**	**Long-distance [≥ 300 km]**	**%**
Austria	226 714	4 325	1.9	10 093	2 360	23.4
Bulgaria	105 948	6 006	5.7	8 068	3 620	44.9
Croatia	47 884	2 247	4.7	3 314	1 242	37.5
Czechia	281 015	7 093	2.5	14 705	3 617	24.6
Germany	1 467 686	41 563	2.8	81 758	18 692	22.9
Hungary	130 552	7 974	6.1	11 894	4 496	37.8
Romania	206 040	9 338	4.5	14 037	6 391	45.5
Slovakia	91 607	8 358	9.1	9 867	5 922	60.0
Total / avg. %	2 557 446	86 904	3.4	153 736	46 340	30.1

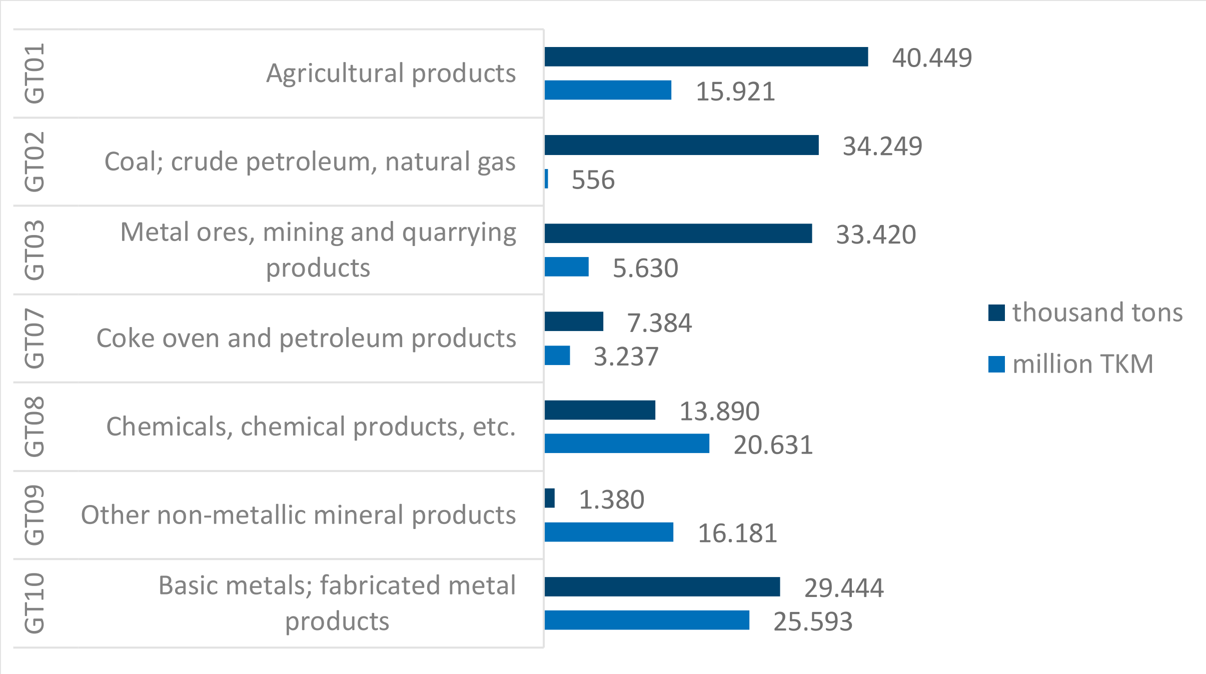

Figure 19: Maximum modal shift volume of the identified product groups that are currently transported ≥300 km by truck (2021)

Table 10 lists the current market potential regarding solely the cargo type (liquid and dry) bulk cargo. If looking at the cargo type **bulk cargo only**, this results in a maximum for a modal shift of approximately 87 million tons or 46 billion TKM, hence, the potential seems to be smaller than indicated by product types in Table 9. The difference can be attributed to the fact that the NST product groups also include other types of goods than just bulk. Since other cargo types could be shifted to containers as well, we introduced a broader perspective of shiftable volumes to the Danube.

Additional to the bulk cargo, it is also possible to use containers for general cargo. Hence, various product groups can be thought of as suitable for IWT. Consequently, different types of cargo can be shipped on one vessel by containerization. Within the EU Horizon project "IW-NET" (IW-NET 2023) 45 ft high-cube and pallet-wide containers were identified to be suitable for containerization on the Danube. By the use of this container type palletized goods can be transported with use of the maximum capacity of the container and ship. Following from this, the successive analysis of EUROSTAT data will collect information about further suitable cargo types (additionally to the identified NST 2007 product groups) for a potential shift from road to IWT. The following cargo type classes from EUROSTAT are investigated. Table 11: Road transportation of LBK, DBK, LCNT, CNT_OTH, PAL, year 2021 (Eurostat 2023f) shows again the transport volume and performance as well as the share of transports over long distances, per Danube riparian country.

- Liquid bulk goods (LBK)
- Dry bulk goods (DBK)
- Large containers (LCNT, starting from 20ft)
- Other containers (CNT_OTH)
- Palletized goods (PAL)

Considering these cargo types for a potential shift from road to containerized IWT, we receive a maximum volume of ~400 million tons and a maximum shiftable transport performance of ~250 billion TKM (see Table 11: Road transportation of LBK, DBK, LCNT, CNT_OTH, PAL, year 2021 (Eurostat 2023f)). Figure 20 shows the distribution of the performance in TKM and volume in tons per cargo type. Compared to the quantity of the selected NST 2007 product groups (~156 million tons, 88 billion TKM), these figures promise a much higher potential for a modal shift.

Table 11: Road transportation of LBK, DBK, LCNT, CNT_OTH, PAL, year 2021 (Eurostat 2023f)

	Transport volume [thousand tons]			**Transport performance [Million tonne-kilometer]**		
Country*	**All distances**	**Long-distance [≥ 300 km]**	**%**	**All distances**	**Long-distance [≥ 300 km]**	**%**
Austria	300 354	13 178	4.4	19 458	7 090	36.4
Bulgaria	152 013	27 949	18.4	31 690	24 341	76.8
Croatia	72 306	10 958	15.2	11 085	7 357	66.4
Czechia	427 411	43 295	10.1	52 424	30 587	58.3
Germany	2 602 894	199 360	7.7	233 672	93 062	39.8
Hungary	207 297	28 509	13.8	30 982	18 250	58.9
Romania	296 161	56 602	19.1	58 982	46 357	78.6
Slovakia	142 979	26 131	18.3	28 104	21 072	75.0
Total / avg. %	4 201 415	405 982	9.7	466 397	248 116	53.2

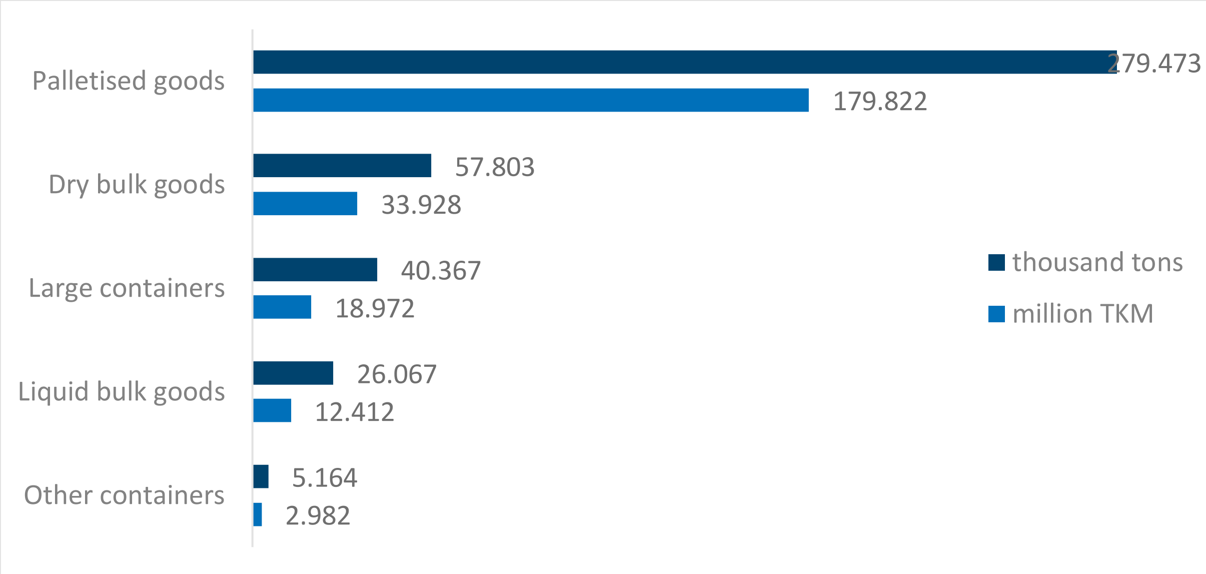

Figure 20: Maximum modal shift volume of the potential cargo types that are currently transported ≥300 km by truck (2021)

3.3. HEURISTIC APPROACH TO DERIVE MODAL SHIFT SCENARIOS

To identify a potential quantity of the selected product groups for a modal shift, an approach based on secondary data oriented on Zimmer and Schmied 2008 was chosen. First, it considers type of goods suitable for a shift which we analysed in Chapter 3.2. Secondly, transport distance plays a vital role which we will discuss in Chapter 3.3.1. Thirdly, supply quality of IWT is anticipated to be satisfied in principle due to containerized transport. Additionally, we consider a short pre and post haulage as factor of supply quality. Transports originated and ending close to a port are more likely to have a chance to be transported by IWW (Borca et al. 2021). Given the available level of detail within the EUROSTAT data there exist some obstacles of estimating a "realistic" or "exact" modal shift potential. The following reasons can be given that we identified during the exploration of the EUROSTAT transport database:

A) Data contain the transport volumes reported by the reporting countries. They do not refer exclusively to their own national territory, but to all transports carried out by domestic companies.
B) There is no information on which or how many of the road transports run "parallel" to the Danube.
C) Shipment size is an important factor for modal shift of certain products and is often mentioned as a market factor of IWT. But this variable is not available within the road transport data sets.

Therefore, heuristics and scenarios are used to approximate quantities for the modal shift. Three heuristics are used to extract a reasonable amount of shiftable goods from road to IWT which are described in the following chapters. Chapter 3.3.4 presents the summarized approach and how different resulting scenarios are calculated to derive a potential modal shift quantity for road to IWT.

3.3.1. H1 TRANSPORT DISTANCE

Heuristic criterion number 1 (H1) is based on the EUROSTAT indicator for potential modal shift in road freight transport. Therein it is anticipated that road freight in containers that is transported over a distance of 300 km or longer, could potentially be shifted to other modes of transport (Eurostat 2023c). Also the European Commission's White paper towards a competitive and resource efficient transport system proposed that "30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050 [...]." (European Commission 2011) In the course of the scenario calculations, we will moreover test a more restrictive shiftable distance of ≥500 km. This distinction is used due to the provided distance classes by EUROSTAT.

A	Less than 50 km
B	From 50 to 149 km
C	From 150 to 299 km
D	From 300 to 499 km
E	From 500 to 999 km
F	From 1 000 to 1 999 km
G	From 2 000 to 5 999 km
H	6 000 km or over

Figure 21: Percentage of transport volume (thousand tons) and performance (million tonne-kilometers) per distance class in the study area (DE, CZ, AT, SK, HU, HR, RO, BG) and selected product groups (GT 1, 2 3, 7, 8, 9, 10), year 2021 (Eurostat 2023e) shows the share of each transport distance class of the total transport volume (in tons) and performance (in ton-kilometers) of the above identified product groups (Chapter 3.2) from the year 2021. It reveals that 5.29% (sum of classes D-G) of the road transport volume of the selected NST 2007 product groups is aimed at for a modal shift (~156 million t, see also Table 9). Looking at the key figure of transport performance, a quantity of 39.91% of the TKM should be shifted to IWT and rail (~88 billion TKM). Figure 22: Percentage of transport volume (thousand tons) and performance (million tonne-kilometers) per distance class in the study area (DE, CZ, AT, SK, HU, HR, RO, BG) and selected

cargo types (DBK, LBK, LCNT, CNT_OTH, PAL) (Eurostat 2023f) reveals the same numbers but regarding the selected cargo types: 9.66% of the road tons (~400 million t) and 53.2% (~250 billion TKM) of the ton-kilometers are to be shifted from road to more sustainable modes of transport (D and E). Based on these insights, we anticipate the actual shiftable volume will be smaller than 9.66% regarding road transport volume and below 53.2% regarding transport performance.

Figure 23: Transported product groups in the Danube riparian countries 2019 – 2022 (Eurostat 2023e) and Figure 24: Transported cargo types in the Danube riparian countries 2019 – 2022 (Eurostat 2023f) are bar charts that depict how much of the product groups and cargo types are transported within each distance class in TKM.

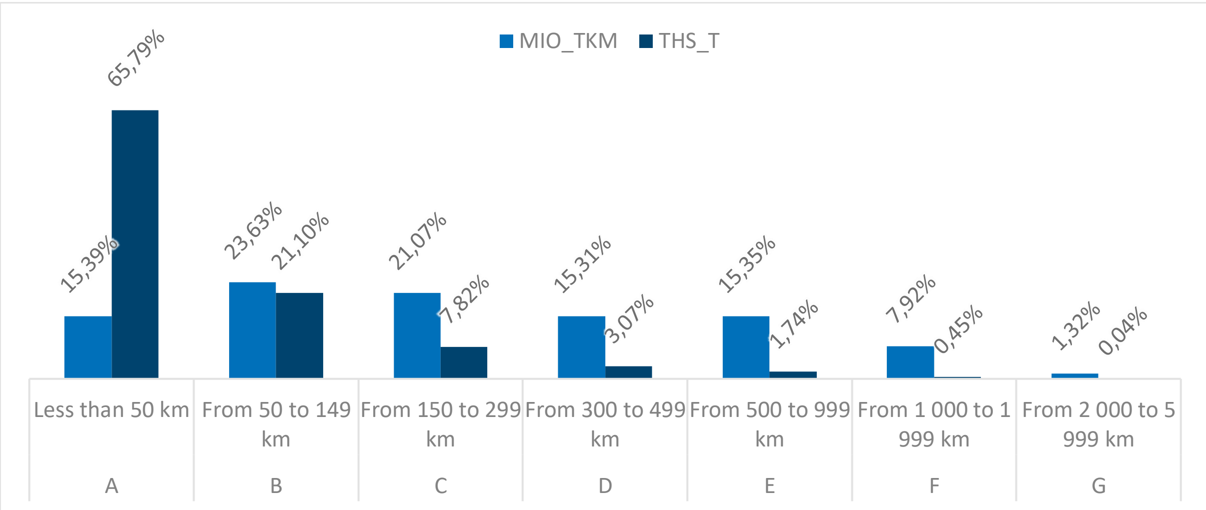

Figure 21: Percentage of transport volume (thousand tons) and performance (million tonne-kilometers) per distance class in the study area (DE, CZ, AT, SK, HU, HR, RO, BG) and selected product groups (GT 1, 2 3, 7, 8, 9, 10), year 2021 (Eurostat 2023e)

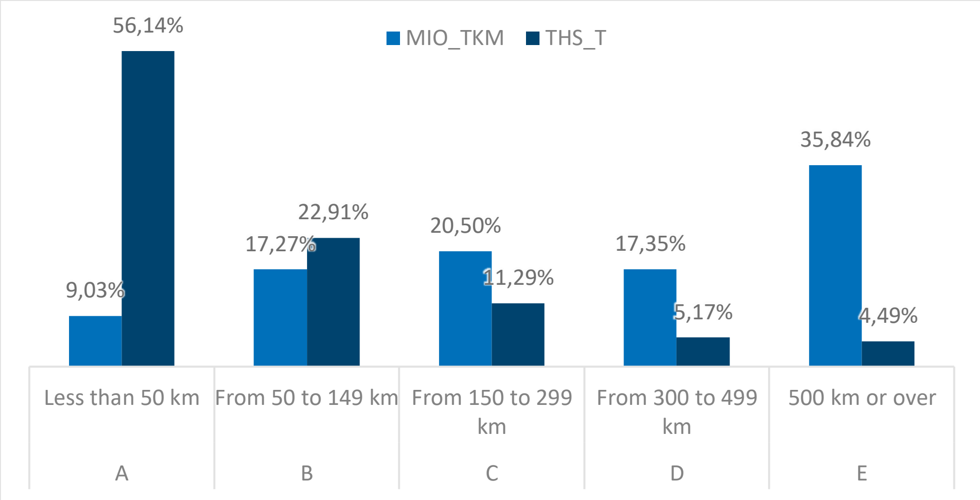

Figure 22: Percentage of transport volume (thousand tons) and performance (million tonne-kilometers) per distance class in the study area (DE, CZ, AT, SK, HU, HR, RO, BG) and selected cargo types (DBK, LBK, LCNT, CNT_OTH, PAL) (Eurostat 2023f)

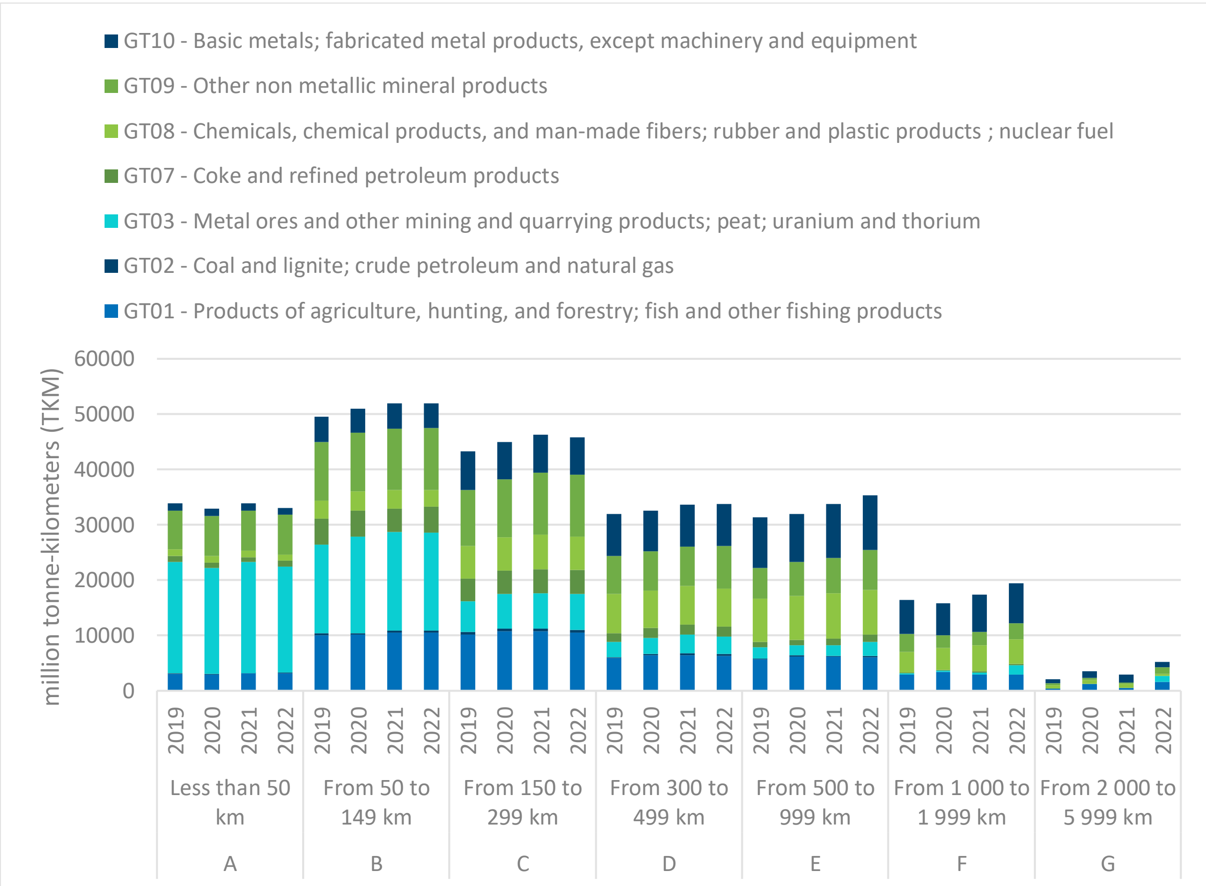

Figure 23: Transported product groups in the Danube riparian countries 2019 – 2022 (Eurostat 2023e)

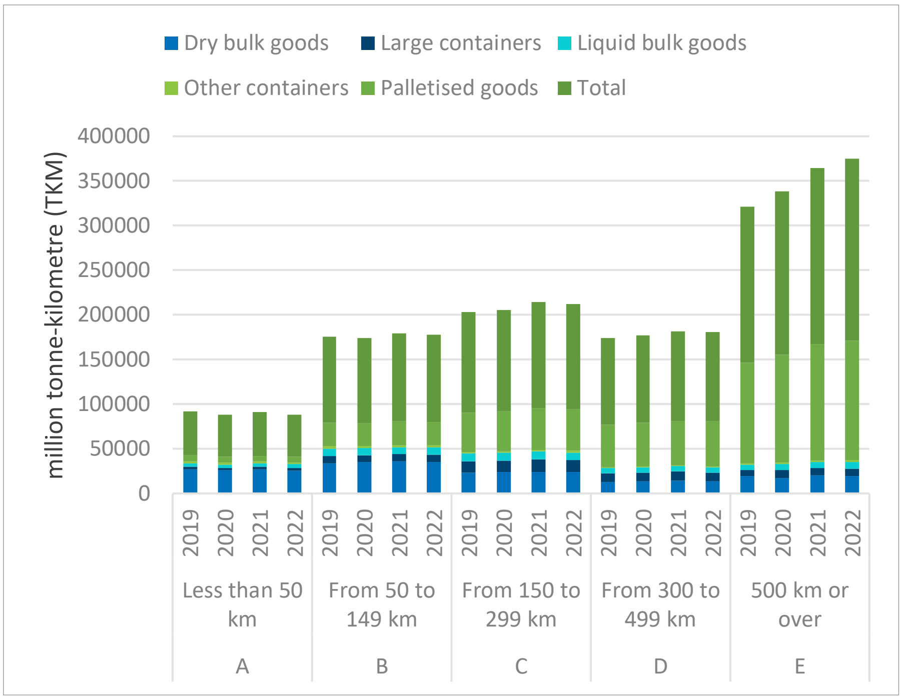

Figure 24: Transported cargo types in the Danube riparian countries 2019 – 2022 (Eurostat 2023f)

3.3.2. H2 TERRITORIALIZATION OF ROAD TRANSPORT

Heuristic criterion number 2 is called "territorialization". As above mentioned, road transport that is reported by a country did not necessarily take place within this country. As shown in the Figure 25 below, only a part of the reported transports took place on national territory. For modal split calculation per country EUROSTAT publishes an annual territorialized road freight transport dataset "road_tert_go" (Eurostat 2022d). This dataset is only available for the unit "TKM", the unit "tonnes" are not territorialized. For our analysis and to derive approximated and territorialized transports for the Danube countries, the volumes of the territorialized (road_tert_go) and the standard dataset on road freight transport (road_go) are compared per country. The percentage deviation between the two data sets is determined and applied to the determined quantities of goods per country (see Table below).

Table 12: Comparison of road TKM reported (road_go) and territorialized (road_tert_go) and their deviations per Danube country

countries	mio. TKM reported	mio. TKM territorialized	difference in %
Austria	26296	49809	+89%
Bulgaria	35176	13267	-62%
Croatia	13632	9302	-32%
Czechia	63892	55108	-14%

Germany	296136	480154	+62%
Hungary	36887	29726	-19%
Romania	61845	26790	-57%
Slovakia	30129	16509	-45%

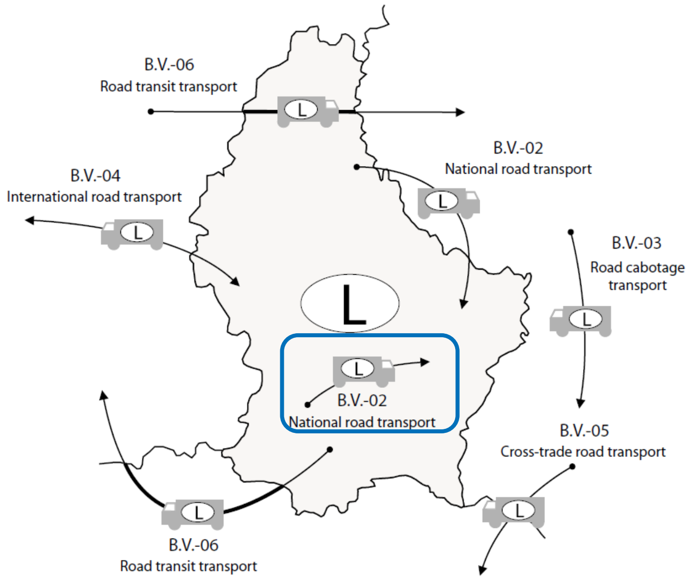

Figure 25: Explanation of transport categories that are reported by the countries and included in EUROSTAT (Adapted from European Commission et al. 2019)

3.3.3. H3 TEN-T ROADS WITHIN PORT SERVICE AREAS

Heuristic criterion number 3 is the catchment or service area of the Danube ports' hinterlands by trucks. Pre- and post-haulage of the multimodal transports are undertaken by trucks. Since transport costs are subject to fluctuations, several geographic extents have been calculated with the ArcGIS Network Analyst tool, ranging from 60 to 120 km transport distance from the port by truck. Lower limit is taken from expert interviews in Borca et al. 2021 and starting from there 20 km steps to the upper limit, which is twice the lower limit. The resulting polygons serve as basis for the geographic definition of "Danube Corridor" within this report (see Figure 18, Chapter 3.1). The port service areas are spatially divided by country and overlayed with the TEN-T road network of the European Commission (see Figure 26). The share of roads within the Danube corridor is calculated for each country. This heuristic anticipates an even distribution of transports on the TEN-T road transport network. Although this approach cannot deliver exact transport volumes within the Danube corridor it is a feasible approximation.

Table 13: Percentage of TEN-T road network kilometre share per service area (SA) cut-off at 120, 100, 80 and 60 truck-distance to ports for each Danube country.

Country	SA120	SA100	SA80	SA60
Austria	47.2%	43.2%	40.0%	33.8%
Bulgaria	39.6%	29.1%	22.5%	16.3%
Czechia	13.7%	7.3%	2.2%	0.6%
Germany	16.0%	12.9%	10.7%	7.2%
Croatia	16.5%	15.2%	13.6%	9.8%
Hungary	65.8%	59.6%	48.6%	38.4%
Romania	41.8%	35.8%	28.2%	21.0%
Slovakia	32.9%	25.2%	21.1%	13.9%

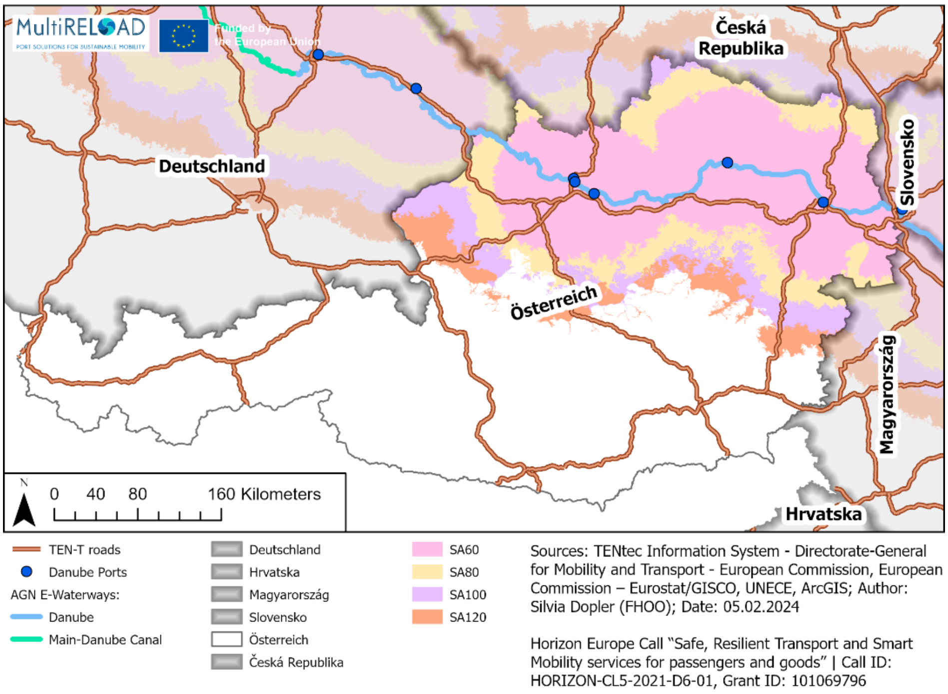

Figure 26: Example of TEN-T roads within Austria and Service Area polygons of ports

3.3.4. MODAL SHIFT SCENARIOS

The following graphic Figure 27 depicts and summarizes the heuristic approach to determine a modal shift potential from road to IWT by using available EUROSTAT statistics data and spatial data on TEN-T roads and waterways and UNECE port and waterway network. Table 14 contains the overview of the derived modal shift scenarios using the increments of H1 and H3.

All 8 scenarios are calculated once based on the dataset classified by NST-2007 product groups (road_go_ta_tcrg) (Eurostat 2023f) and once by the dataset using the variable cargo types (road_go_ta_dctg) (Eurostat 2023e). Finally, Equation 2 presents the calculation of the modal shift potential in mathematical terms. The results are given in the unit tonne-kilometers and presented in the subsequent section 3.4.

Table 14: Scenarios for potential modal shifts from road to inland waterways

shift scenario	**H1: transport distance (H1)**	**H3: share of TEN-T roads within service areas of port hinterlands by trucks (**Table 13**)**
300_120	≥ 300 km	120 km
300_100	≥ 300 km	100 km
300_80	≥ 300 km	80 km
300_60	≥ 300 km	60 km
500_120	≥ 500 km	120 km
500_100	≥ 500 km	100 km
500_80	≥ 500 km	80 km
500_60	≥ 500 km	60 km

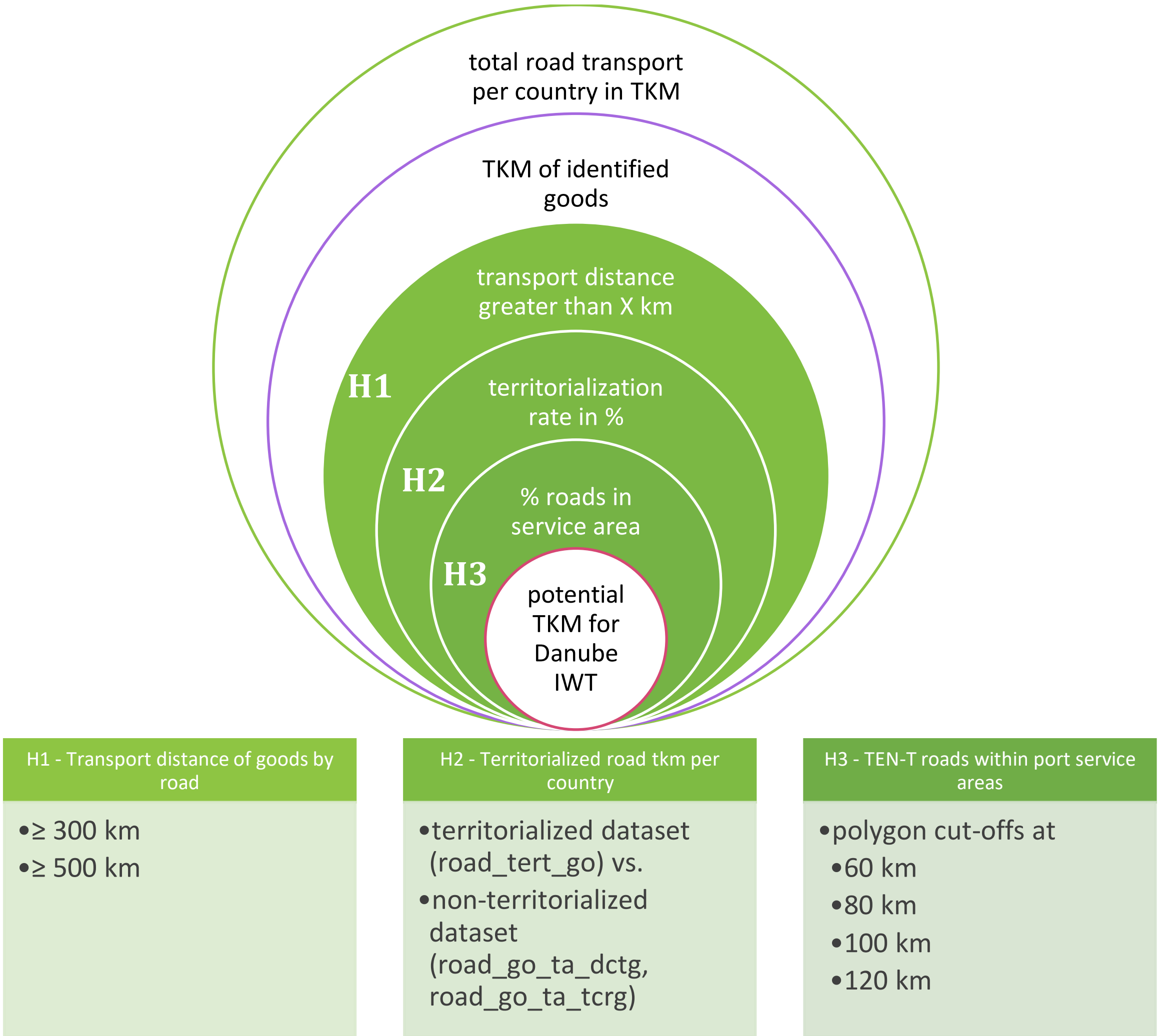

Figure 27: Heuristic approach within this study to determine a modal shift potential from road to inland waterway transport

Equation 2: Formula for modal shift scenario calculation in tonne-kilometers per country

$$S_C = \sum_{i \geq a}^{1\ldots n} \left(x_{1,i}^{C}, \ldots, x_{n,i}^{C} \right) * \propto_C * \beta_C$$

S_C	modal shift potential from road transport to IWW in [tonne-kilometers]
C	country
i	transport distance in km
a	$a = 300 \vee 500$
$x_{1,i\ldots n,i}^{C}$	selected NST 2007 product groups OR cargo types (1…n) transported i km per country
$\propto_C$	territorialization rate of the country
β_C	rate of roads within the defined Danube corridor in the respective country

3.4. POTENTIAL MODAL SHIFT

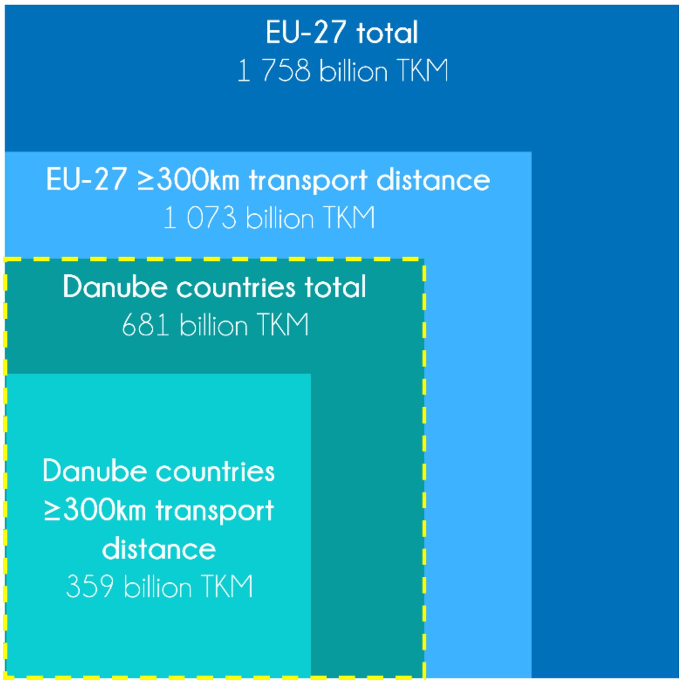

Figure 28: Basic volume of road transport from which a modal shift to Danube shipping is aimed for in this study, indicated by the yellow dashed line, territorialized TKM, year 2021 (Eurostat 2023e, 2022d)

The basic quantity from which a potential modal shift is to be calculated is delimited and numbered in Figure 28. The squares sizes are proportional to the quantity they represent. Each square represents a partial volume of the superior square. In the whole EU territory 1 758 TKM were transported in 2021, of which 1 073 billion TKM were transported over a distance of 300 km or longer. 681 billion TKM of the total EU transports was reported in Danube countries, of which about a half was carried over a distance of 300 km or longer. In the subsequent sections, the derived percentages and volumes for modal shift are sub-quantities of the total road transports within the Danube countries, outlined by the yellow dashed line in the figure above.

As outlined in the introduction chapter, MultiRELOAD aims at facilitating a modal shift of 5% from road to inland waterways to 2025. Measured against the basic quantity of ~681 billion TKM (Figure 28), **5% equal ~34 billion TKM**. The current inland waterway volumes per Danube countries are depicted in Figure 29. In total, ~73 billion TKM have been transported over waterways in the study area countries. Germany is far ahead all other countries, but this is because also volumes from the Rhine shipping are included here.[6] Increases of IWT by the modal shift from road are added to these numbers. The 5% modal shift from road to IWT would cause an increase of IWT transport performance in the Danube countries by 47%. The second goal of MultiRELOAD's Innovation Area A aims at an increase of transported cargo on the Danube by 2%, which corresponds to ~5.5 million tons. Consequently, if goal number two is met, the target three, which aims at an annual modal shift of 52 thousand tons of cargo, is fulfilled as well.

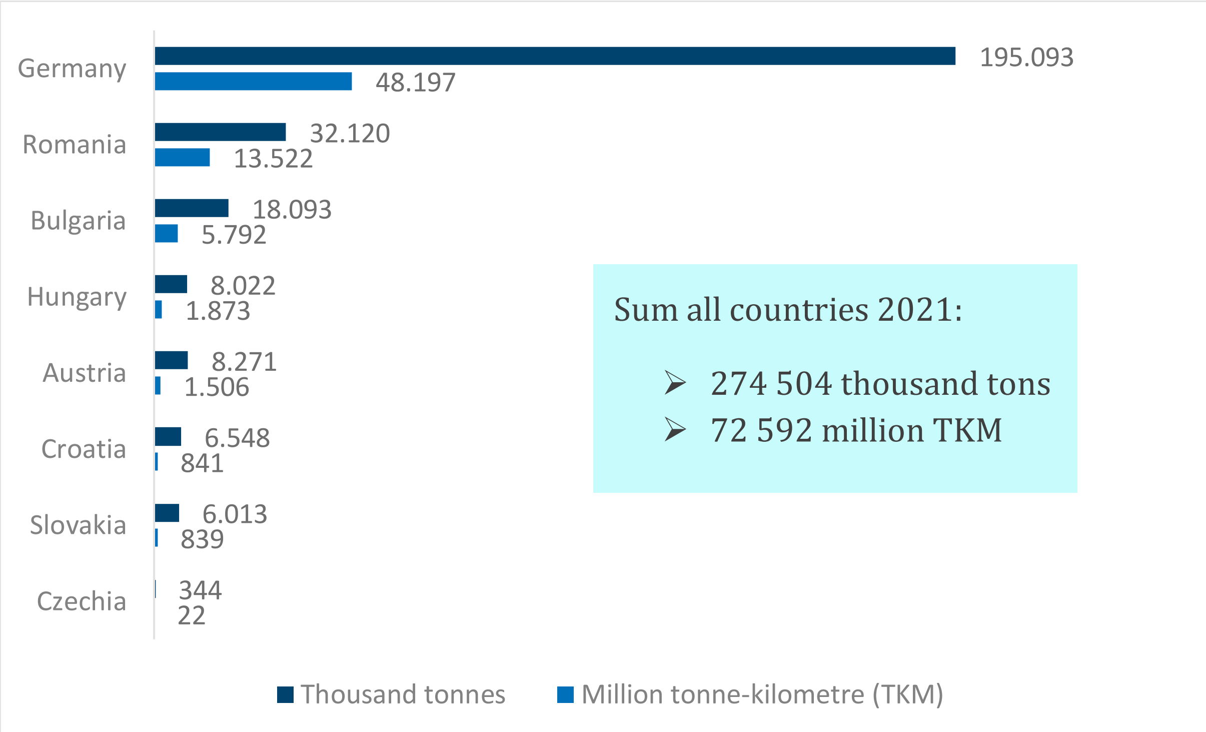

Figure 29: Inland waterway transport performance and volume per Danube country in 2021 (Eurostat 2022e)

3.4.1. REGARDING PRODUCT GROUPS

Applying Equation 2 (page 54) on the dataset of road freight transport by distance class and type of goods (Eurostat 2023e) leads to the potential modal shift volumes in TKM summarized for all countries shown in Table 15. The anticipated modal shift volume of 5% (~34 billion TKM) cannot be reached in either of the 8 scenarios. Even the least restrictive scenario "300_120" delivers only ~22 billion TKM. This would result in +30% transport performance for Danube shipping.

[6] Eurostat does not distinguish between different waterways in the IWW database.

Table 15: Results of modal shift scenarios regarding NST 2007 product types (GT 01, 02, 03, 07, 08, 09, 10)

Modal shift scenario	**shift from road mio. TKM**	**New IWT mio. TKM**	**% + for IWT**
300_120	22 123.44	94 715.44	30%
300_100	18 040.40	90 632.40	25%
300_80	14 750.93	87 342.93	20%
300_60	10 652.78	83 244.78	15%
500_120	13 872.96	86 464.96	19%
500_100	11 172.86	83 764.86	15%
500_80	9 009.92	81 601.92	12%
500_60	6 522.64	79 114.64	9%

~~In addition to Eurostat, the Danube Commission publishes annual figures on transport volumes on the Danube as well. They disseminate them per NST-2007 groups and therefore can be compared to Eurostat IWW data in thousand tons.~~

~~To understand to what extent the maximum potential volume of the selected NST 2007 divisions would enlarge the volume of transported goods via IWT on the Danube, the sum of all countries per NST 2007 class is presented in Fehler! Verweisquelle konnte nicht gefunden werden. and compared to the cargo handling volume at the Danube ports of the year 2021. The classes with the highest shiftable volumes are GT10 (finished metal items) and GT08 (chemicals) which account for almost half of the total shiftable road volume. In 2021, a small amount of these product groups was handled at Danube ports (GT10: 6%, GT08: 7.4%). If the full potential of all product groups could be utilized, the total amount of handled cargo would double with an increase factor of 2.1.~~

~~Table 16. potential shift from road volume (=SV, tsd. t) to IWT in 2021 per NST 2007 division (Eurostat 2023e) and comparison with handled cargo (=DV, tsd. t) at Danube ports in 2021 (Donaukommission 2021)~~

~~In thousand tons~~	~~GT 01~~	~~GT 02~~	~~GT 03~~	~~GT 07~~	~~GT 08~~	~~GT 09~~	~~GT 10~~	~~Total~~
~~Shift volume (SV)~~	~~26 303~~	~~1 011~~	~~10 644~~	~~6 452~~	~~31 303~~	~~27 205~~	~~34 598~~	~~**137 516**~~
~~*% of total SV*~~	~~*19.1*~~	~~*0.7*~~	~~*7.7*~~	~~*4.7*~~	~~*22.8*~~	~~*19.8*~~	~~*25.2*~~	~~***100***~~
~~Danube volume (DV)~~	~~44 785~~	~~14 202~~	~~32 585~~	~~13 067~~	~~9 192~~	~~2 325~~	~~7 465~~	~~**123 621**~~
~~*% of total DV*~~	~~*36.2*~~	~~*11.5*~~	~~*26.4*~~	~~*10.6*~~	~~*7.4*~~	~~*1.9*~~	~~*6.0*~~	~~***100***~~
~~SV + DV~~	~~71 088~~	~~15 213~~	~~43 229~~	~~19 519~~	~~40 495~~	~~29 530~~	~~42 063~~	~~**261 137**~~
~~*% of total SV+DV*~~	~~*27.2*~~	~~*5.8*~~	~~*16.6*~~	~~*7.5*~~	~~*15.5*~~	~~*11.3*~~	~~*16.1*~~	~~***100***~~
~~Increase factor~~	~~1.6~~	~~1.1~~	~~1.3~~	~~1.5~~	~~4.4~~	~~12.7~~	~~5.6~~	~~2.1~~

3.4.2. REGARDING CARGO TYPES

Applying Equation 2 (page 54) on the dataset of road freight transport by distance class and type of goods (Eurostat 2023f) leads to the potential modal shift volumes in TKM summarized for all countries shown in Table 17. Values marked in green fulfill and exceed the 5% target of modal shift volumes within MultiRELOAD, as outlined in the introductory chapter. The scenario that is most restrictive while fulfilling the target is "300_80". Figure 30 shows the results of this scenario per country and compares the quantities for IWT before and after the modal shift. If scenario "300_80" can be realized, this means an increase in IWT performance of 55%.

Table 17: Results of modal shift scenarios regarding cargo types (LBK, DBK, LCNT, CNT_OTH, PAL), values in green exceed the 5% target for modal shift

Modal shift scenario	shift from road mio. TKM	New IWT mio. TKM	% + for IWT
300_120	60 425.29	133 017.29	83%
300_100	49 471.11	122 063.11	68%
300_80	40 081.14	112 673.14	55%
300_60	29 003.01	101 595.01	40%
500_120	40 194.40	112 786.40	55%
500_100	32 897.16	105 489.16	45%
500_80	26 389.93	98 981.93	36%
500_60	19 248.20	91 840.20	27%

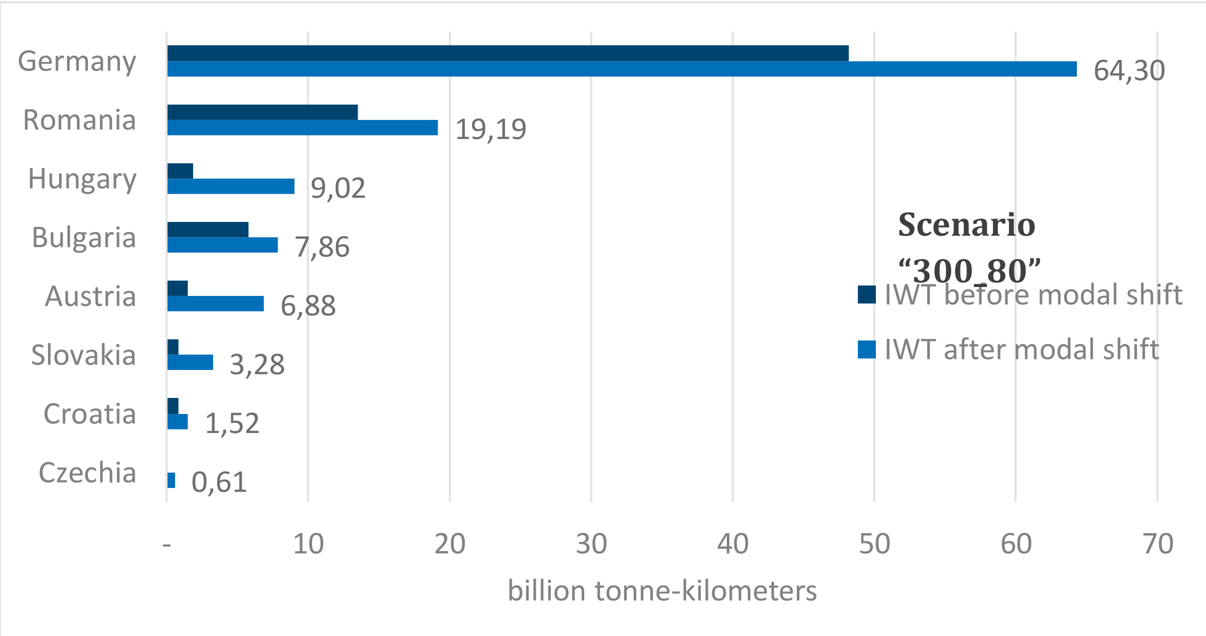

Figure 30: Scenario "300_80" – Inland waterway transport performance in billion TKM before and after modal shift from road (base year 2021)

3.5. SUMMARY

The main outcomes of the scenarios of the market potential analysis are summarised in the following points:

- If "bulk goods only" are considered, it is too small a quantity to achieve the ambitious objectives of MultiRELOAD's Innovation Area A in terms of modal shift quantity in TKM from road to IWT of 5%.
- Considering a broader definition of goods that could be containerized AND shifted from road to IWT (such as palletised goods and general cargo, as well as goods that are already transported in containers but by road) results in modal shift volumes that could potentially fulfill the Innovation Area A target. Table 17 shows that 4 out of 8 scenarios expect a modal shift volume of over 34 billion TKM.
- Scenarios "300_80" and "500_120" are the most restrictive scenarios while delivering the targeted modal shift potential. "300_80" is more restrictive regarding the catchment area to ports, "500_120" is narrower regarding the minimum distance definition of shiftable transports. Discussion among practitioners and maybe empirical evaluation could validate the chosen criteria for the scenarios.
- The developed 8 modal shift scenarios can support future discussions on "realistic" modal shift volumes from road to IWT. E.g. in depth analysis and evaluation of the breadth of the catchment areas of ports is needed.
- The herein developed heuristic approach to estimate the quantity of road transport for a modal shift to IWT is a viable methodology for EUROSTAT data. Nevertheless, more detailed data (e.g. on NUTS-3 level, classification of transports regarding NST-2007 AND cargo types) could help to extract more exact results.

Figure 31 shows finally the summary of the scenario outcome of the most restrictive scenario, namely "300_80", while promising quantities to reach the 5% modal shift goal. Scenario "500_100" returns almost the same percentages. The total values in TKM are drawn from the previous interim results of the territorialized road transports (see H2), Figure 28 on the total amount of transports in the Danube countries, Table 15 on the scenario results of NST-2007 product types, and Table 17 showing scenario results regarding cargo types.

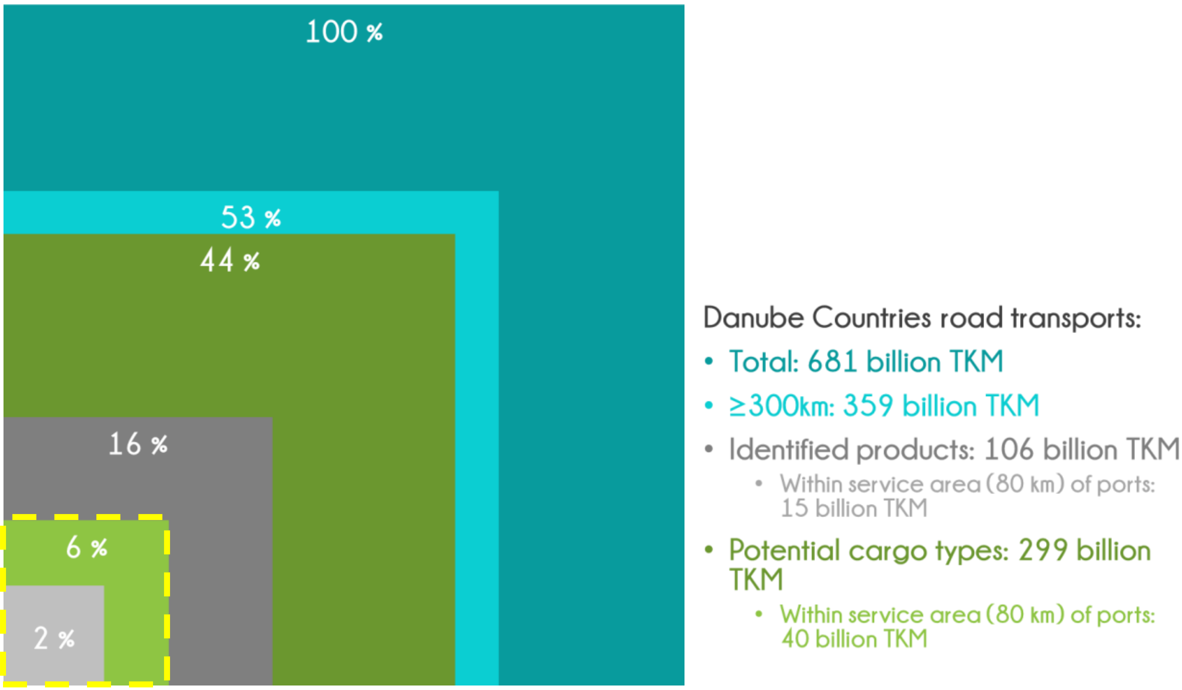

Figure 31: Modal shift potential in percent of product groups and cargo types of scenario “300_80” (yellow, dashed square)

4. CONCLUSIONS

As outlined in the Introduction chapter, the overarching goal of Innovation Area A within the MultiRELOAD project includes a 5% modal shift from the road transport to the more sustainable Inland Waterway transport. After reviewing and analysing the EUROSTAT data, this goal can be put differently in terms of quantitative figures. Looking at the EU countries bordering the Danube, shifting just 5% of their tonne-kilometers (TKM) of the year 2021 from road to inland waterways would result in an increase of Danube freight transport by 47% (see Figure 32). In total numbers 5% means approximately 34 billion TKM of road transports.[7] If comparing road and inland waterway transports regarding their emissions, it becomes evident that the modal shift would have a positive effect on emission reduction (see Figure 33). Containerized IWT causes approximately only one third of the emissions compared to transport by truck.[8] Finally, the analyzed 5% modal shift from road target is put into another commonly used figure: the "modal split" of transported goods. Subtracting the ~34 billion TKM from the road TKM share and adding them to the IWT TKM, results in an increased modal split share of IWT from 7.6% status Quo as of 2021 to 11.1% for the target year 2025. These numbers are depicted in Figure 34 below.

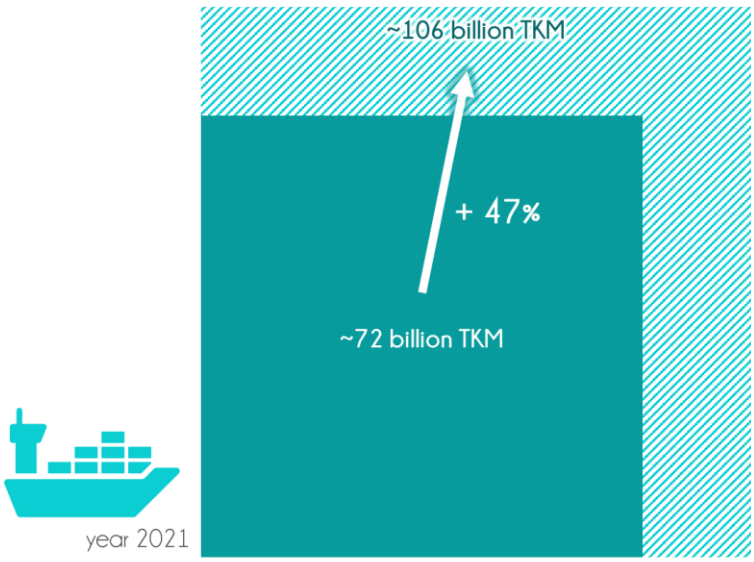

Figure 32: Transport performance of IWT in the Danube countries if 5% modal shift from road to IWT was reached 2021 (Eurostat 2022e)

[7] Measured from the territorialized dataset Eurostat 2022d.
[8] Based on emission intensities of the GLEC framework v2.0, Greene and Lewis 2019.

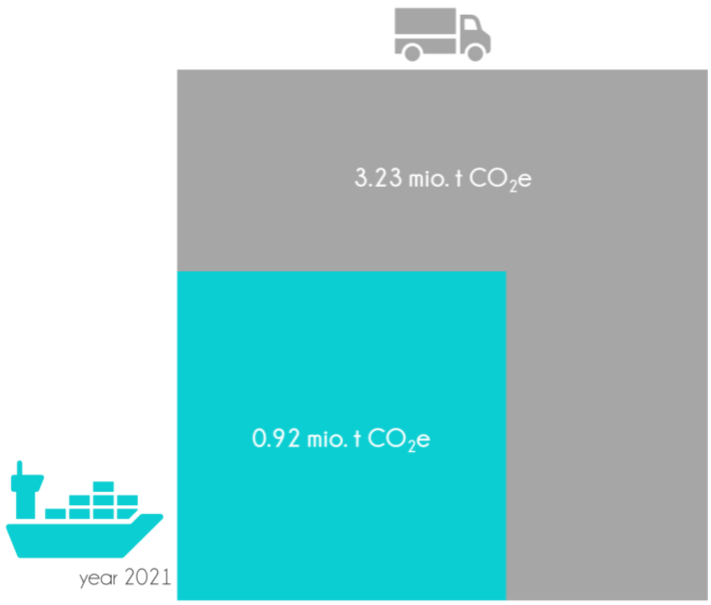

Figure 33: Cut of $CO2_e$ emissions if ~34 billion TKM would be shifted from road to inland waterway transport (=5% of road in 2021) (Greene and Lewis 2019)

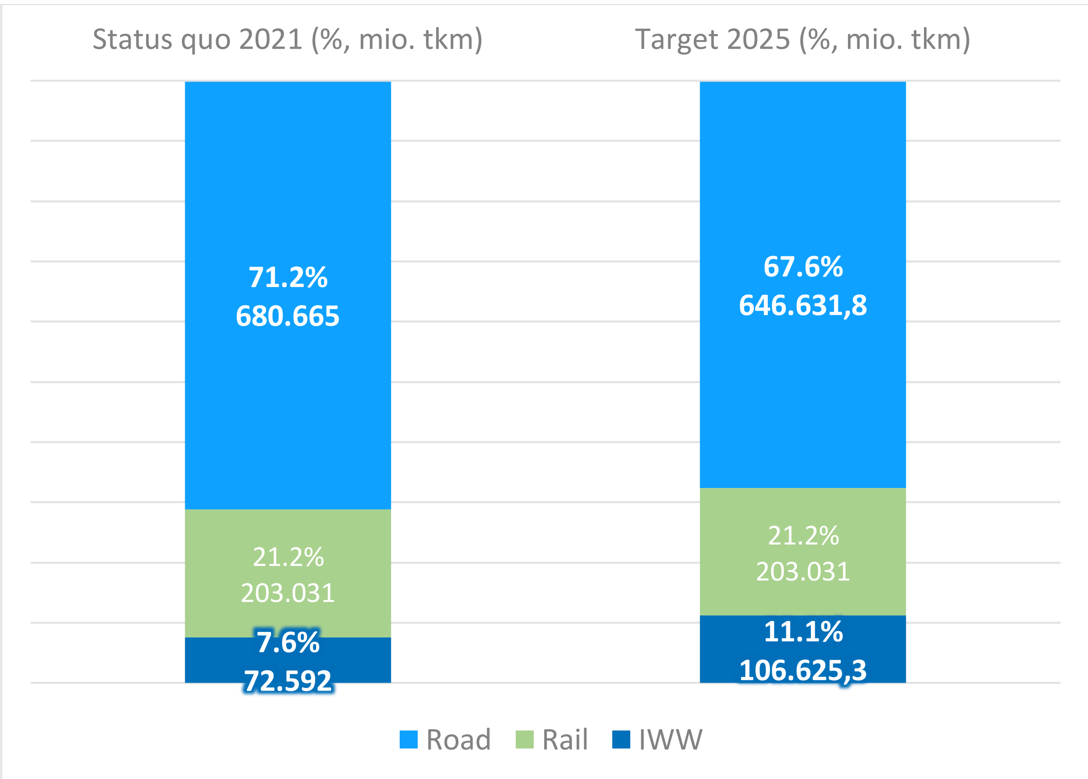

Figure 34: Modal split of inland freight transport in the Danube countries 2021 and target 2025 by MultiRELOAD (Eurostat 2022d, 2022e, 2022a, 2023d)

In order to facilitate reaching this ambitious goal of MultiRELOAD, this study identified on the one hand barriers towards IWT mode choice that have to be tackled (Chapter 2), and on the other hand, promising bulk product groups suitable for containerization to leverage a modal shift from road to the Danube waterway (Chapter 3.2). Our research revealed that there existing transport volumes of suitable products that could potentially be shifted to the Danube waterway if containerized transports are offered as a service.

Unimodal road transport volumes suitable for shifting to multimodal transport using barges and trucks have been identified (Chapter 3.4). IWT already has a traditional share of bulk cargo transport. Nevertheless, the analysis of road data reveals that there exist higher volumes that have potential for a shift to Danube shipping. In order to overcome the barriers to IWT, the criteria for mode choice must be addressed (Chapter 2.3). Containerization could potentially support a modal shift through lower costs, plannable transit time, increased flexibility and improved reliability.

Overall, the use of containers is a promising way to make existing IWT more efficient in the future. We propose that IWT affine commodity groups should be focused for shifting first to provide positive examples. On the long run, Danube IWT shall seek to gain shares in other commodity groups as well. The analysis could be extended to other commodities, as containers can be used across many industries (Wiegmans and Konings 2017). Our method delivered a theoretical modal shift potential from road to IWT and revealed quantities that should be shifted from road in the Danube states to other modes of transport due to the transport distances and catchment areas of ports.

Although we have outlined the advantages and potential of containerized transport on the Danube (Chapter 2.4), market take-up in the Danube region still needs to be promoted, together with the continuous development of port and waterway infrastructure and the development of optimized vessel types for container transport. Cooperation between barge and truck operators is strongly recommended to realize the full potential of multimodal transport in the Danube region.

5. PUBLICATION BIBLIOGRAPHY

Beil, Denise; Matzner, Bettina; Putz-Egger, Lisa-Maria (2022): Modalentscheidungen im Güterverkehr. Ergebnisse der Umfrage zum Thema Verkehrsverlagerungsmaßnahmen und der Einfluss auf Modalentscheidungen. FH Oberösterreich; via donau. Steyr. Available online at https://www.rewway.at/files/a407d1d722e04d2e8d4734c60729f3ab/, checked on 5/15/2023.

Bloemhof, J. M.; van der Laan, E. A.; Beijer, C. (2011): Sustainable Inland Transportation. In *International Journal of Business Insights and Transformation* 3 (3), pp. 26–33.

Borca, Bianca; Putz, Lisa-Maria; Schreiner, Tim (2021): Identifying the modal shift potential of fully assembled cars for inland waterway transport. In : ITS World Congress. ITS World Congress. Hamburg. Available online at https://pure.fh-ooe.at/files/35021281/Borca_Putz_Schreiner_Identifying_the_modal_shift_potential_of_fully_assembled_cars_using_inland_waterway_transport.pdf.

Bu, Fan; Nachtmann, Heather (2021): Literature review and comparative analysis of inland waterways transport: "Container on Barge". In *Marit Econ Logist* 25 (1), pp. 140–173. DOI: 10.1057/s41278-021-00195-6.

Caris, An; Limbourg, Sabine; Macharis, Cathy; Van Lier, Tom; Cools, Mario (2014): Integration of inland waterway transport in the intermodal supply chain: a taxonomy of research challenges. In *Journal of Transport Geography* 41, pp. 126–136. DOI: 10.1016/j.jtrangeo.2014.08.022.

CCNR (2022a): Annual Report 2022. Inland Navigation in Europe market observation. ZKR; CCNR; Central Commission for Navigation on the Rhine. Straßburg, checked on 12/22/2022.

CCNR (2022b): Market Observation Inland Navigation in Europe. Container transport per Country in Europe. CCNR. Available online at https://inland-navigation-market.org/chapitre/2-freight-transport-on-inland-waterways-2/?lang=en, checked on 04.2023.

CCNR (2023): Market observation inland navigation in europe. Freight transport on inland waterway. Central Commission for the Navigation of the Rhine (CCNR). Available online at https://inland-navigation-market.org/chapitre/2-freight-transport-on-inland-waterways-2/?lang=en, updated on 2022, checked on 1/25/2023.

Danube Commission (2022): Market observation for Danube navigation: Results in 2021. Budapest. Available online at https://www.danubecommission.org/dc/en/danube-navigation/market-observation-for-danube-navigation/market-observation-for-danube-navigation-results-in-2021/, checked on 9/6/2023.

Danube Strategy Point: About EUSDR. What is the EUSDR? Available online at https://danube-region.eu/about/, checked on 1/22/2024.

DAPhNE (2018): Container Market Report. D.5.4.3. Final Report. Ennshafen. Available online at http://www.interreg-danube.eu/uploads/media/approved_project_public/0001/27/4de36ced26e9abb44bf1ce89536e2178c4ed0bfe.pdf, checked on 10/14/2021.

Dolinsek, Maja; Hartl, Simon (2012): SWP 5.2.2. Market review analysis – national level. INWAPO Project. via donau. Vienna.

Donaukommission (2021): Statistisches Jahrbuch der Donaukommission 2021. Edited by Donaukommission. Donaukommission. Budapest, Hungary. Available online at https://www.danubecommission.org/uploads/doc/2023/Stat_2021/de_stat_2021.pdf, checked on 2/26/2024.

European Commission (2011): White Paper - Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system. European Commission. Brussels (COM(2011) 144). Available online at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0144&from=EN, checked on 2/27/2023.

European Commission (2019): The European Green Deal. European Commission. Bruxelles (COM(2019) 640). Available online at https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF, checked on 1/27/2023.

European Commission (2023): Mobility and Transport. Trans-European Transport Network (TEN-T). Brüssel. Available online at https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/trans-european-transport-network-ten-t_en, updated on 2023, checked on 1/7/2023.

European Commission; OECD; United Nations (2019): Glossary for transport statistics. 5th. Luxemburg: Publications Office of the European Union (Manuals and guidelines). Available online at https://ec.europa.eu/eurostat/web/products-manuals-and-guidelines/-/KS-GQ-19-

004?inheritRedirect=true&redirect=%2Feurostat%2Fpublications%2Fmanuals-and-guidelines, checked on 2/20/2024.

European Commission – Eurostat/GISCO: NUTS 2021. © EuroGeographics, © TurkStat. Available online at https://ec.europa.eu/eurostat/web/gisco/geo-data/reference-data/administrative-units-statistical-units/nuts, checked on 2/20/2024.

Eurostat (2022a): Goods transported by group of goods - from 2008 onwards based on NST 2007.

Eurostat (2022b): Modal shift potential of long-distance road freight in containers - tonne.

Eurostat (2022c): Modal shift potential of long-distance road freight in containers - tonne-kilometre.

Eurostat (2022d): Territorialised road freight transport, by transport coverage – annual data.

Eurostat (2022e): Transport by type of good (from 2007 onwards with NST2007).

Eurostat (2022f): Unitisation in inland waterways freight transport - tonne-kilometre for gross-gross weight of goods, checked on 2/20/2024.

Eurostat (2023a): Database. Transport. Edited by Eurostat. Luxemburg. Available online at https://ec.europa.eu/eurostat/web/transport/data/database, updated on 2023, checked on 4/4/2023.

Eurostat (2023b): Freight transport statistics: Data Browser. Modal split of inland freight transport, EU-27. Available online at https://ec.europa.eu/eurostat/databrowser/view/tran_hv_frmod/default/bar?lang=en, checked on 3/28/2023.

Eurostat (2023c): Intermodal transport. Unitisation in freight transport. Luxemburg. Available online at https://ec.europa.eu/eurostat/cache/metadata/en/tran_im_esms.htm, updated on 2023, checked on 4/24/2023.

Eurostat (2023d): Répartition modale du transport intérieur de fret.

Eurostat (2023e): Road freight transport by distance class and type of goods (t, tkm, vehicle-km, basic transport operations) - annual data (from 2008 onwards).

Eurostat (2023f): Road freight transport by type of cargo and distance class (t, tkm, vehicle-km, basic transport operations) - annual data.

Eurostat (2023g): Statistics Explained. Glossary:Standard goods classification for transport statistics (NST). Available online at https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Standard_goods_classification_for_transport_statistics_(NST), checked on 9/5/2023.

Federal Ministry of Transport and Digital Infrastructure (2019): Inland Waterway Transport Masterplan. Available online at https://bmdv.bund.de/SharedDocs/DE/Artikel/WS/masterplan-binnenschifffahrt.html, checked on 9/5/2023.

Greene, Suzanne; Lewis, Alan (2019): Global Logistics Emissions Council framework for logistics emissions accounting and reporting. version 2.0. Smart Freight Centre. Amsterdam. Available online at https://www.feport.eu/images/downloads/glec-framework-20.pdf, checked on 8/8/2022.

Gvozdic, Milica; Hartl, Simon; Meinel, Ulf (2014): D 1.7: Report on market transfer conditions Market Analysis Danube Corridor. WP 1: Markets & Awareness. Platina II. Edited by via donau. Platform for the implementation of naides II. Rotterdam.

Hesse, Markus; Rodrigue, Jean-Paul (2004): The transport geography of logistics and freight distribution. In *J. Transp. Geogr.* 12 (3), pp. 171–184. DOI: 10.1016/j.jtrangeo.2003.12.004.

ITF (2022): Mode Choice in Freight Transport. OECD Publishing, Paris (ITF Research Reports).

IW-NET (2023): D3.2 – New design options for barges with improved navigability. Ref. Ares(2023)3020157 - 28/04/2023. Available online at https://www.iw-net.eu/wp-content/uploads/2023/08/IW-NET-New-design-options-for-barges-with-improved-navigability.pdf, checked on 1/22/2024.

Konings, J. W. (2009): Intermodal barge transport. Network design, nodes and competitiveness. Delft, The Netherlands: Netherlands TRAIL Research School (TRAIL thesis series, T2009/11).

Konings, Rob (2004): Development of Container Barge Transport on Small Waterways: From Increasing Scale to Increasing Scope. In *Transportation Research Record* 1871 (1), pp. 24–32. DOI: 10.3141/1871-04.

Kotowska, Izabela; Mańkowska, Marta; Pluciński, Michał (2018): Inland Shipping to Serve the Hinterland: The Challenge for Seaport Authorities. In *Sustainability* 10 (10), p. 3468. DOI: 10.3390/su10103468.

Martin, Heinrich (2018): Warehousing and transportation logistics. Systems,planning, application and cost effectiveness. London, England: Kogan Page. Available online at https://permalink.obvsg.at/.

Meers, Dries; Macharis, Cathy; Vermeiren, Tom; Van Lier, Tom (2017): Modal choice preferences in short-distance hinterland container transport. In *Research in Transportation Business & Management* 23, pp. 46–53. DOI: 10.1016/j.rtbm.2017.02.011.

Mihic, Svetlana; Golusin, Mirjana; Mihajlovic, Milan (2011): Policy and promotion of sustainable inland waterway transport in Europe – Danube River. In *Renewable and Sustainable Energy Reviews* 15 (4), pp. 1801–1809. DOI: 10.1016/j.rser.2010.11.033.

Mircetic, Dejan; Nikolicic, Svetlana; Bojic, Sanja; Maslaric, Marinko (2017): Identifying the Barriers for Development of Inland Waterway Transport: a Case Study. In *MATEC Web Conf.* 134, p. 39. DOI: 10.1051/matecconf/201713400039.

Mohammadi, Majid; Rezaei, Jafar (2020): Bayesian best-worst method: A probabilistic group decision making model. In *Omega* 96, p. 102075. DOI: 10.1016/j.omega.2019.06.001.

Mommens, Koen; Macharis, Cathy (2014): Location analysis for the modal shift of palletized building materials. In *J. Transp. Geogr.* 34, pp. 44–53. DOI: 10.1016/j.jtrangeo.2013.11.001.

Mommens, Koen; Van Lier, Tom; Macharis, Cathy (2020): Multimodal choice possibilities for different cargo types: Application to Belgium. In *Research in Transportation Business & Management*, p. 100528. DOI: 10.1016/j.rtbm.2020.100528.

Munim, Ziaul Haque; Saha, Rana; Schøyen, Halvor; Ng, Adolf K. Y.; Notteboom, Theo E. (2022): Autonomous ships for container shipping in the Arctic routes. In *J Mar Sci Technol* 27 (1), pp. 320–334. DOI: 10.1007/s00773-021-00836-8.

Pfoser, Sarah; Jung, Eva; Putz, Lisa-Maria (2018): Same river same rules? – Administrative barriers in the Danube countries. In *J. sustain. dev. transp. logist.* 3 (3), pp. 27–37. DOI: 10.14254/jsdtl.2018.3-3.2.

Praveen, S.; Jegan, J. (2015): Key issues & challenges for inland water transportation network in India. In *Int J Sci Res Dev* 3 (10), 2321-0613.

Rangaraj, Narayan; Raghuram, G. (2007): Viability of Inland Water Transport in India. Asian Development Bank. New Delhi (INRM Policy Brief Series, 13). Available online at https://www.adb.org/sites/default/files/publication/30113/inrm13.pdf, checked on 1/12/2024.

Reis, Vasco (2014): Analysis of mode choice variables in short-distance intermodal freight transport using an agent-based model. In *Transportation Research Part A: Policy and Practice* 61, pp. 100–120. DOI: 10.1016/j.tra.2014.01.002.

Rezaei, Jafar (2016): Best-worst multi-criteria decision-making method: Some properties and a linear model. In *Omega* 64, pp. 126–130. DOI: 10.1016/j.omega.2015.12.001.

Rezaei, Jafar; Kothadiya, Oshan; Tavasszy, Lori; Kroesen, Maarten (2018): Quality assessment of airline baggage handling systems using SERVQUAL and BWM. In *Tourism Management* 66, pp. 85–93. DOI: 10.1016/j.tourman.2017.11.009.

Rogerson, Sara; Santén, Vendela; Svanberg, Martin; Williamsson, Jon; Woxenius, Johan (2020): Modal shift to inland waterways: dealing with barriers in two Swedish cases. In *International Journal of Logistics Research and Applications* 23 (2), pp. 195–210. DOI: 10.1080/13675567.2019.1640665.

Samanta, Pradeepta Kumar (2019): Opportunities and Challenges in Developing Inland Waterways Transport in India. In *Orissa Journal of Commerce* (III), pp. 97–107. Available online at https://ojcoca.org/july-2019.pdf#page=101, checked on 1/12/2024.

Sriraman, S. (2010): Long term perspectives on inland water transport in India. In *RITES Journal* 12 (1), 18-1. Available online at http://indiaenvironmentportal.org.in/files/Inland%20Water%20Transport.pdf, checked on 1/12/2024.

Steindl, Christian; Kainzinger, Karin; Traxl, Claudia (2014): Master Plan TG3. TG 3 Liner Services. DaHar - Danube Inland Harbour Development. Ennshafen.

Stockhammer, Verena Maria; Pfoser, Sarah; Markvica, Karin; Zajicek, Jürgen; Prandtstetter, Matthias (2021): Behavioural bases distorting the demand for environmentally friendly freight transport fodes: An overview and potential measures. In *Sustainability* 13 (21), p. 11783. DOI: 10.3390/su132111783.

Toma, Janeta; Delmeire, Nik; Matzalik-Florescu, Ruxanda; Rafael, Robert; Quispel, Martin (2023): Platina 3 D1.4 Report on economic barriers to modal shift: challenges & best practices; recommendations. Available online at https://www.danubecommission.org/uploads/doc/Platina3/01_Market/D1.4-economic-barriers-to-modal-shift-disclaimer.pdf, checked on 10/17/2023.

Trivedi, Ashish; Jakhar, Suresh Kumar; Sinha, Daneshwar (2021): Analyzing Barriers to Inland Waterways as a Sustainable Transportation Mode in India: A dematel-ISM based approach. In *Journal of Cleaner Production* 295, p. 126301. DOI: 10.1016/j.jclepro.2021.126301.

Vierth, Inge; Mellin, Anna; Hyl\'e; n, Bertil; Karlsson, Jenny; Karlsson, Rune; Johansson, Magnus (2012): Kartläggning av godstransporterna i Sverige. In *0347-6030* (752). Available online at https://vti.diva-portal.org/smash/get/diva2:670620/FULLTEXT01.pdf, checked on 1/12/2024.

Wiegmans, Bart; Konings, J. W. (2016): Inland waterway transport. Challenges and prospects. London, New York: Routledge Taylor & Francis Group.

Wiegmans, Bart; Konings, Rob (2015): Intermodal Inland Waterway Transport: Modelling Conditions Influencing Its Cost Competitiveness. In *The Asian Journal of Shipping and Logistics* 31 (2), pp. 273–294. DOI: 10.1016/j.ajsl.2015.06.006.

Wiegmans, Bart; Konings, Rob (Eds.) (2017): Inland waterway transport. Challenges and prospects. London, New York: Routledge.

Zimmer, Wiebke; Schmied, Martin (2008): Potentials for a modal shift from road to rail and ship. A methodological approach. European Topic Centre on Air and Climate Change. Berlin.

Garberg, B. (2016). Regeringsuppdrag: Analys av utvecklingspotentialen för inlands- och kustsjöfart i Sverige (Government investigation - Analysis of the potential for inland and coastal shipping in Sweden). Norrköping: Swedish Maritime Administration.

Treiber, Angelika, and Peter Bark. 2018. Förutsättningar för ökad inlandsvattensjöfart i sjöar, skärgårdar och kustområden [Conditions for Increased Inland Shipping in Lakes, Archipelagoes and Coastal Areas]. Stockholm: TFK.

APPENDIX A – LONGLIST OF IWT BARRIERS

Table 18: Longlist of IWT barriers

Original barrier name	primary source(s)	secondary source(s)	Assigned to new barrier name
Administration	(Pfoser et al. 2018; Kotowska et al. 2018)	(Rogerson et al. 2020)	Administrative burden of IWT (e.g. inter-agency coordination, border controls, languages, standardization)
Border Controls	(Pfoser et al. 2018)		Administrative burden of IWT (e.g. inter-agency coordination, border controls, languages, standardization)
Charges & fees	(Pfoser et al. 2018)		Administrative burden of IWT (e.g. inter-agency coordination, border controls, languages, standardization)
Working hours of ports & customs	(Pfoser et al. 2018)		Administrative burden of IWT (e.g. inter-agency coordination, border controls, languages, standardization)
Languages	(Pfoser et al. 2018)		Administrative burden of IWT (e.g. inter-agency coordination, border controls, languages, standardization)
Lack of standardization	(Toma et al. 2023)		Administrative burden of IWT (e.g. inter-agency coordination, border controls, languages, standardization)
Inter-agency coordination	(Rangaraj and Raghuram 2007; Samanta 2019)	(Trivedi et al. 2021)	Administrative burden of IWT (e.g. inter-agency coordination, border controls, languages, standardization)
(Lack of) promotion initiatives	(Kotowska et al. 2018)	(Rogerson et al. 2020)	Decision makers have a lack of knowledge about IWT or are not willing to shift
Information gaps	(Pfoser et al. 2018)		Decision makers have a lack of knowledge about IWT or are not willing to shift
Resistance to change	Garberg (2016), (Meers et al. 2017; Vierth et al. 2012)	(Rogerson et al. 2020)	Decision makers have a lack of knowledge about IWT or are not willing to shift
Physical drop of rivers	(Rangaraj and Raghuram 2007)	(Trivedi et al. 2021)	Insufficient/varying operating hours of ports, locks, customs, terminals
Working hours of ports & customs	(Pfoser et al. 2018)		Insufficient/varying operating hours of ports, locks, customs, terminals
Modal integration	(Praveen and Jegan 2015; Samanta 2019)	(Trivedi et al. 2021)	Lack of connection to other modes of transport (insufficient multimodal connections)
Limited intermodal options	(Toma et al. 2023)		Lack of connection to other modes of transport (insufficient multimodal connections)
Staff shortage	(Pfoser et al. 2018)		Lack of qualified personell
Qualification, education & skills	(Pfoser et al. 2018)		Lack of qualified personell
Legal Issues	(Praveen and Jegan 2015)	(Trivedi et al. 2021)	Lack of regulatory frameworks
Regulations for other modes	Garberg (2016)	(Rogerson et al. 2020)	Lack of regulatory frameworks
Uncertainty re: regulations	Garberg (2016)	(Rogerson et al. 2020)	Lack of regulatory frameworks

Cabotage	Garberg (2016)	(Rogerson et al. 2020)	Lack of regulatory frameworks
Personnel requirements	Treiber and Bark (2018)	(Rogerson et al. 2020)	Lack of regulatory frameworks
Lack of standardization	(Toma et al. 2023)		Lack of regulatory frameworks
Policy Parity	(Rangaraj and Raghuram 2007; Samanta 2019; Praveen and Jegan 2015)	(Trivedi et al. 2021)	Low prioritisation of IWT
Prioritisation between traffic on land and water at bridges	Garberg (2016)	(Rogerson et al. 2020)	Low prioritisation of IWT
Lack of Government Support	(Toma et al. 2023)		Low prioritisation of IWT
Competitive situation versus other modes	(Vierth et al. 2012), Garberg (2016)	(Rogerson et al. 2020)	Low prioritisation of IWT
Market Distortions	(Toma et al. 2023)		Low prioritisation of IWT
Capital requirements	(Rangaraj and Raghuram 2007; Samanta 2019; Praveen and Jegan 2015)	(Trivedi et al. 2021)	Lack of investments to build/maintain waterway infrastructure
High infrastructure costs	(Toma et al. 2023)		Lack of investments to build/maintain waterway infrastructure
Infrastructure Costs	(Toma et al. 2023)		Lack of investments to build/maintain waterway infrastructure
Equipment Costs	(Toma et al. 2023)		Lack of investments to build/maintain waterway infrastructure
Capital costs	(Toma et al. 2023)		High initial costs for introducing IWT services (e.g. equipment, compliance with safety regulations, ...)
Regulatory Costs	(Toma et al. 2023)		High initial costs for introducing IWT services (e.g. equipment, compliance with safety regulations, ...)
Environmental concerns	(Caris et al. 2014; Vierth et al. 2012)	(Rogerson et al. 2020)	Low pace of development of the IWT sector in terms of sustainability (alternative engines and fuels, emissions,...)
Fleet composition	(Mihic et al. 2011)	(Rogerson et al. 2020)	Low pace of development of the IWT sector in terms of sustainability (alternative engines and fuels, emissions,...)
Shortage of vessels	(Rangaraj and Raghuram 2007; Samanta 2019; Praveen and Jegan 2015)	(Trivedi et al. 2021)	Shortage of vessel and barge building
Scale of investment	(Bloemhof et al. 2011)	(Rogerson et al. 2020)	Shortage of vessel and barge building
Inadequate air draft	(Rangaraj and Raghuram 2007; Samanta 2019; Praveen and Jegan 2015; Sriraman 2010)	(Trivedi et al. 2021)	Insufficient bridge clearance

Condition of waterways (ice, water levels, height of bridges)	(Konings 2009; Vierth et al. 2012), Garberg (2016)	(Rogerson et al. 2020)	Insufficient bridge clearance
Location of ports/quays	(Mommens and Macharis 2014)	(Rogerson et al. 2020)	Insufficient location or number of ports/quays
Potential locations of inland ports may vanish	Garberg (2016)	(Rogerson et al. 2020)	Insufficient location or number of ports/quays
Limited access and connectivity	(Toma et al. 2023)		Insufficient location or number of ports/quays
Lack of infrastructure in inland areas	(Toma et al. 2023)		Insufficient location or number of ports/quays
Shortage of MRO facilities	(Praveen and Jegan 2015)	(Trivedi et al. 2021)	Insufficient maintenance, repair and overhaul of infrastructure (ports, vessels, handling facilities)
Infrastructure maintenance	(Mihic et al. 2011),(Kotowska et al. 2018)	(Rogerson et al. 2020)	Insufficient maintenance, repair and overhaul of infrastructure (ports, vessels, handling facilities)
Insufficient infrastructure & equipment	(Pfoser et al. 2018)		Insufficient maintenance, repair and overhaul of infrastructure (ports, vessels, handling facilities)
Inadequate Depth	(Rangaraj and Raghuram 2007; Samanta 2019; Praveen and Jegan 2015)	(Trivedi et al. 2021)	Insufficient waterway depth
Integration of rivers	(Praveen and Jegan 2015)	(Trivedi et al. 2021)	Insufficient waterway depth
Excessive siltation	(Praveen and Jegan 2015; Samanta 2019; Sriraman 2010)	(Trivedi et al. 2021)	Insufficient waterway depth
Condition of waterways (ice, water levels, height of bridges)	(Vierth et al. 2012; Konings 2009), Garberg (2016)	(Rogerson et al. 2020)	Insufficient waterway depth
Insufficient fairway conditions	(Pfoser et al. 2018)		Insufficient waterway depth
Cross structures	(Praveen and Jegan 2015)	(Trivedi et al. 2021)	Insufficient waterway depth
Interlinking of rivers	(Praveen and Jegan 2015)	(Trivedi et al. 2021)	Lack of interlinking with other waterbodies
Integration of rivers	(Praveen and Jegan 2015)	(Trivedi et al. 2021)	Lack of interlinking with other waterbodies
Limited access and connectivity	(Toma et al. 2023)		Lack of interlinking with other waterbodies
Lack of night navigational equipment	(Rangaraj and Raghuram 2007; Praveen and Jegan 2015; Sriraman 2010)	(Trivedi et al. 2021)	Lack of navigational equipment (e.g. digital navigational charts and river information systems)
Lack of terminals	(Sriraman 2010; Praveen and Jegan 2015)	(Trivedi et al. 2021)	Lack of terminals and related infrastructure needed for loading/unloading and storage
Stevedore agreements	Garberg (2016)	(Rogerson et al. 2020)	Additional costs of transshipment/multimodal transport
Cost of pre/post-haulage	(Wiegmans and Konings 2015; Konings	(Rogerson et al. 2020)	Additional costs of transshipment/multimodal transport

	2009; Vierth et al. 2012)		
Additional handling costs	(Wiegmans and Konings 2015; Konings 2009; Vierth et al. 2012)	(Rogerson et al. 2020)	Additional costs of transshipment/multimodal transport
Intermodal Costs	(Toma et al. 2023)		Additional costs of transshipment/multimodal transport
Frequency	(Meers et al. 2017; Konings 2009)	(Rogerson et al. 2020)	Insufficient flexibility of IWT services (e.g. frequency, capacity, vessel or shipment size)
Vessel size	(Vierth et al. 2012)	(Rogerson et al. 2020)	Insufficient flexibility of IWT services (e.g. frequency, capacity, vessel or shipment size)
Limited capacity	(Toma et al. 2023)		Insufficient flexibility of IWT services (e.g. frequency, capacity, vessel or shipment size)
Reliability	(Kotowska et al. 2018)	(Rogerson et al. 2020)	IWT Services are (perceived as) unreliable
Condition of waterways (ice, water levels, height of bridges)	(Konings 2009; Vierth et al. 2012), Garberg (2016)	(Rogerson et al. 2020)	IWT Services are (perceived as) unreliable
Prioritisation of loading/unloading in ports	(Vierth et al. 2012; Konings 2009)	(Rogerson et al. 2020)	IWT Services are (perceived as) unreliable
Uncertainty and risk	(Toma et al. 2023)		IWT Services are (perceived as) unreliable
Perception of unreliability	(Toma et al. 2023)		IWT Services are (perceived as) unreliable
Inflexibility of specialised vessels	(Vierth et al. 2012)	(Rogerson et al. 2020)	Insufficient flexibility of IWT services (e.g. frequency, capacity, vessel or shipment size)
Frequency	(Meers et al. 2017; Konings 2009)	(Rogerson et al. 2020)	Insufficient flexibility of IWT services (e.g. frequency, capacity, vessel or shipment size)
Volume	(Konings 2004)	(Rogerson et al. 2020)	Only competitive for high volumes of goods
Goods that can carry extra cost of handling	Garberg (2016)	(Rogerson et al. 2020)	Only competitive for high volumes of goods
Vessel size	(Vierth et al. 2012)	(Rogerson et al. 2020)	Only competitive for high volumes of goods
Volume	(Konings 2004)	(Rogerson et al. 2020)	Only suitable/competitive for certain types of goods
Inflexibility of specialised vessels	(Vierth et al. 2012)	(Rogerson et al. 2020)	Only suitable/competitive for certain types of goods
Time	(Kotowska et al. 2018; Meers et al. 2017; Konings 2009; Vierth et al. 2012)	(Rogerson et al. 2020)	Transit time takes too long
Time for loading/unloading	(Konings 2009)	(Rogerson et al. 2020)	Transit time takes too long
Matching schedules with crane availability	(Konings 2009)	(Rogerson et al. 2020)	Transit time takes too long
Working hours	(Pfoser et al. 2018)	(Rogerson et al. 2020)	Transit time takes too long

Alignment of lock planning and quay handling	(Caris et al. 2014)	(Rogerson et al. 2020)	Transit time takes too long
Cost of pre/post-haulage	(Wiegmans and Konings 2015; Vierth et al. 2012; Konings 2009)	(Rogerson et al. 2020)	Transport price is too high/not competitive in comparison with other modes
Additional handling costs	(Wiegmans and Konings 2015; Konings 2009; Vierth et al. 2012)	(Rogerson et al. 2020)	Transport price is too high/not competitive in comparison with other modes
Port charges	Garberg (2016), (Mircetic et al. 2017)	(Rogerson et al. 2020)	Transport price is too high/not competitive in comparison with other modes
Fairway dues	Garberg (2016)	(Rogerson et al. 2020)	Transport price is too high/not competitive in comparison with other modes
Piloting fees	Garberg (2016)	(Rogerson et al. 2020)	Transport price is too high/not competitive in comparison with other modes
Fee structures of other modes	(Vierth et al. 2012; Konings 2009)	(Rogerson et al. 2020)	Transport price is too high/not competitive in comparison with other modes
Personnel costs	(Vierth et al. 2012)	(Rogerson et al. 2020)	Transport price is too high/not competitive in comparison with other modes
Stevedore agreements	Garberg (2016)	(Rogerson et al. 2020)	Transport price is too high/not competitive in comparison with other modes
Price competition from other modes	(Toma et al. 2023)		Transport price is too high/not competitive in comparison with other modes

APPENDIX B – IWT BARRIERS QUESTIONNAIRE (BWM)

Table 19: Questionnaire on barriers of IWT mode choice using Best-Worst-Method

ID	Question (group)	(sub) question	Answer
v_73	Country of company headquarter		select from list
v_2	What type of logistics stakeholder is your company?		select from list
v_3	Please select the industry your company is associated to	Industry type ISIC Rev. 4	select from list
v_4	Please further specify the economic activity of your company (optional)		text
v_74	How much do you agree with the given statements below?	I have good knowledge of managing transports.	likert scale 1 (totally disagree) to 7 (totally agree)

v_75		I have good knowledge of inland waterway transport (=IWT).	likert scale 1 (totally disagree) to 7 (totally agree)
v_76		I have good knowledge of transport mode choice processes.	likert scale 1 (totally disagree) to 7 (totally agree)
v_330	How often do you use the modes of transport mentioned below?	Air	percent slider
v_331		Road	percent slider
v_332		Rail	percent slider
v_333		Inland waterways	percent slider
v_334		Short Sea shipping	percent slider
v_335		Maritime shipping	percent slider
v_336		other	percent slider
v_339	What transport distances are covered to what extent?	shorter than 50 km	percent slider
v_340		50 to 150 km	percent slider
v_341		150 to 300 km	percent slider
v_346		300 to 500 km	percent slider
v_347		longer than 500 km	percent slider
v_428	In your opinion, how important is it to increase the modal share of inland waterway transports?		likert scale 1 (not important at all) to 7 (very important)
v_587	Why is it (not) important to increase the modal share of IWT? (optional)		text
v_509	Please select for each category which barrier towards IWT is " the most " and " the least " important one.	The MOST important barrier is... (Investments)	select from list
v_513		The LEAST important barrier is... (Investments)	select from list
v_518		The MOST important barrier is... (Market characteristics)	select from list
v_522		The LEAST important barrier is... (Market characteristics)	select from list
v_527		The MOST important barrier is... (Framework conditions)	select from list
v_531		The LEAST important barrier is... (Framework conditions)	select from list
v_536		The MOST important barrier is... (IWT Infrastructure)	select from list
v_540		The LEAST important barrier is... (IWT Infrastructure)	select from list
v_499	Which of the 4 main categories is the most important one, and which one the least?	The MOST important is... (please select)	select from list
v_501		The LEAST important is... (please select)	select from list

v_588	Investments	#v_509# is ... as/than Low pace of development of the IWT sector in terms of sustainability (alternative engines and fuels, emissions,...)	likert scale 1 (equally important) to 9 (absolutely more important)
v_589		#v_509# is ... as/than High initial costs for introducing IWT services (e.g. equipment, compliance with safety regulations, ...)	likert scale 1 (equally important) to 9 (absolutely more important)
v_590		#v_509# is ... as/than Shortage of vessel and barge building	likert scale 1 (equally important) to 9 (absolutely more important)
v_591		#v_509# is ... as/than Lack of investments to build/maintain waterway infrastructure	likert scale 1 (equally important) to 9 (absolutely more important)
v_592		Low pace of development of the IWT sector in terms of sustainability (alternative engines and fuels, emissions,...) is ... as/than #v_513#	likert scale 1 (equally important) to 9 (absolutely more important)
v_593		High initial costs for introducing IWT services (e.g. equipment, compliance with safety regulations, ...) is ... as/than #v_513#	likert scale 1 (equally important) to 9 (absolutely more important)
v_594		Shortage of vessel and barge building is ... as/than #v_513#	likert scale 1 (equally important) to 9 (absolutely more important)
v_595		Lack of investments to build/maintain waterway infrastructure is ... as/than #v_513#	likert scale 1 (equally important) to 9 (absolutely more important)
v_596	Market characteristics	#v_518# is ... as/than Additional costs of transshipment/multimodal transport	likert scale 1 (equally important) to 9 (absolutely more important)
v_597		#v_518# is ... as/than IWT Services are (perceived as) unreliable	likert scale 1 (equally important) to 9 (absolutely more important)
v_598		#v_518# is ... as/than Only competitive for high volumes of goods	likert scale 1 (equally important) to 9 (absolutely more important)
v_599		#v_518# is ... as/than Only suitable/competitive for certain types of goods	likert scale 1 (equally important) to 9 (absolutely more important)
v_600		#v_518# is ... as/than Transit time takes too long	likert scale 1 (equally important) to 9 (absolutely more important)
v_601		#v_518# is ... as/than Transport price is too high/not competitive in comparison with other modes	likert scale 1 (equally important) to 9 (absolutely more important)
v_602		#v_518# is ... as/than Insufficient flexibility of IWT services (e.g. frequency, capacity, vessel or shipment size)	likert scale 1 (equally important) to 9 (absolutely more important)
v_603		Additional costs of transshipment/multimodal transport is ... as/than #v_522#	likert scale 1 (equally important) to 9 (absolutely more important)
v_604		IWT Services are (perceived as) unreliable is ... as/than #v_522#	likert scale 1 (equally important) to 9 (absolutely more important)

v_605		Only competitive for high volumes of goods is … as/than #v_522#	likert scale 1 (equally important) to 9 (absolutely more important)
v_606		Only suitable/competitive for certain types of goods is … as/than #v_522#	likert scale 1 (equally important) to 9 (absolutely more important)
v_607		Transit time takes too long is … as/than #v_522#	likert scale 1 (equally important) to 9 (absolutely more important)
v_608		Transport price is too high/not competitive in comparison with other modes is … as/than #v_522#	likert scale 1 (equally important) to 9 (absolutely more important)
v_609		Insufficient flexibility of IWT services (e.g. frequency, capacity, vessel or shipment size) is … as/than #v_522#	likert scale 1 (equally important) to 9 (absolutely more important)
v_610	Framework conditions	#v_527# is ... as/than Insufficient/varying operating hours of ports, locks, customs, terminals	likert scale 1 (equally important) to 9 (absolutely more important)
v_611		#v_527# is ... as/than Lack of connection to other modes of transport (insufficient multimodal connections)	likert scale 1 (equally important) to 9 (absolutely more important)
v_612		#v_527# is ... as/than Lack of qualified personell	likert scale 1 (equally important) to 9 (absolutely more important)
v_613		#v_527# is ... as/than Low prioritisation of IWT	likert scale 1 (equally important) to 9 (absolutely more important)
v_614		#v_527# is ... as/than Decision makers have a lack of knowledge about IWT or are not willing to shift	likert scale 1 (equally important) to 9 (absolutely more important)
v_615		#v_527# is ... as/than Lack of regulatory frameworks	likert scale 1 (equally important) to 9 (absolutely more important)
v_616		#v_527# is ... as/than Administrative burden of IWT (e.g. inter-agency coordination, border controls, languages, standardization)	likert scale 1 (equally important) to 9 (absolutely more important)
v_617		Insufficient/varying operating hours of ports, locks, customs, terminals is … as/than #v_531#	likert scale 1 (equally important) to 9 (absolutely more important)
v_618		Lack of connection to other modes of transport (insufficient multimodal connections) is … as/than #v_531#	likert scale 1 (equally important) to 9 (absolutely more important)
v_619		Lack of qualified personell is … as/than #v_531#	likert scale 1 (equally important) to 9 (absolutely more important)
v_620		Low prioritisation of IWT is … as/than #v_531#	likert scale 1 (equally important) to 9 (absolutely more important)
v_621		Decision makers have a lack of knowledge about IWT or are not willing to shift is … as/than #v_531#	likert scale 1 (equally important) to 9 (absolutely more important)

v_622		Lack of regulatory frameworks is … as/than #v_531#	likert scale 1 (equally important) to 9 (absolutely more important)
v_623		Administrative burden of IWT (e.g. inter-agency coordination, border controls, languages, standardization) is … as/than #v_531#	likert scale 1 (equally important) to 9 (absolutely more important)
v_624	IWT Infrastructure	#v_536# is ... as/than Insufficient bridge clearance	likert scale 1 (equally important) to 9 (absolutely more important)
v_625		#v_536# is ... as/than Insufficient waterway depth	likert scale 1 (equally important) to 9 (absolutely more important)
v_626		#v_536# is ... as/than Lack of interlinking with other waterbodies	likert scale 1 (equally important) to 9 (absolutely more important)
v_627		#v_536# is ... as/than Lack of navigational equipment (e.g. digital navigational charts and river information systems)	likert scale 1 (equally important) to 9 (absolutely more important)
v_628		#v_536# is ... as/than Lack of terminals and related infrastructure needed for loading/unloading and storage	likert scale 1 (equally important) to 9 (absolutely more important)
v_629		#v_536# is ... as/than Insufficient location or number of ports/quays	likert scale 1 (equally important) to 9 (absolutely more important)
v_630		#v_536# is ... as/than Insufficient maintenance, repair and overhaul of infrastructure (ports, vessels, handling facilities)	likert scale 1 (equally important) to 9 (absolutely more important)
v_631		Insufficient bridge clearance is … as/than #v_540#	likert scale 1 (equally important) to 9 (absolutely more important)
v_632		Insufficient waterway depth is … as/than #v_540#	likert scale 1 (equally important) to 9 (absolutely more important)
v_633		Lack of interlinking with other waterbodies is … as/than #v_540#	likert scale 1 (equally important) to 9 (absolutely more important)
v_634		Lack of navigational equipment (e.g. digital navigational charts and river information systems) is … as/than #v_540#	likert scale 1 (equally important) to 9 (absolutely more important)
v_635		Lack of terminals and related infrastructure needed for loading/unloading and storage is … as/than #v_540#	likert scale 1 (equally important) to 9 (absolutely more important)
v_636		Insufficient location or number of ports/quays is … as/than #v_540#	likert scale 1 (equally important) to 9 (absolutely more important)
v_637		Insufficient maintenance, repair and overhaul of infrastructure (ports, vessels, handling facilities) is … as/than #v_540#	likert scale 1 (equally important) to 9 (absolutely more important)
v_555	Overall category rating	#v_499# is ... as/than Investments	likert scale 1 (equally important) to 9 (absolutely more important)

v_556		#v_499# is ... as/than Market characteristics	likert scale 1 (equally important) to 9 (absolutely more important)
v_557		#v_499# is ... as/than Framework conditions	likert scale 1 (equally important) to 9 (absolutely more important)
v_558		#v_499# is ... as/than IWT infrastructure	likert scale 1 (equally important) to 9 (absolutely more important)
v_559		Investments is ... as/than #v_501#	likert scale 1 (equally important) to 9 (absolutely more important)
v_560		Market characteristics is ... as/than #v_501#	likert scale 1 (equally important) to 9 (absolutely more important)
v_561		Framework conditions is ... as/than #v_501#	likert scale 1 (equally important) to 9 (absolutely more important)
v_562		IWT investments is ... as/than #v_501#	likert scale 1 (equally important) to 9 (absolutely more important)
v_67	Please select your gender	Gender	select from list
v_403	Your job title (optional)	Job title of respondent	text
v_71	Number of employees in your company:	Employees	select from list
v_72	Annual turnover of your company:	Annual turnover	select from list
v_337	When it comes to choosing a transport mode, who is the main decision maker?	Decision maker	select from list
v_338		Other? Please specify:	text
v_357	Please rank the mode choice criteria according to their importance.	Transport price	rank 1-4
v_358		Reliability	rank 1-4
v_359		Flexibility	rank 1-4
v_360		Transit time	rank 1-4
v_498	Is there anything you would like to tell us? (optional)	Comments	text

APPENDIX C – WHEIGHTS OF IWT BARRIERS (BWM)

Table 20: Local weights of IWT Barriers among the dimension "Investments"

	all	LSP	Shippers	Administration	Other	Vessel Owners
sustainability	0.17605139	0.17268463	0.14510559	0.30358596	0.19065244	0.11399607
initial cost	0.23089005	0.29124415	0.20405841	0.14280837	0.21376928	0.19046281
vessel building	0.18824879	0.18896923	0.21237054	0.16675575	0.13993848	0.32909006
infra. investm.	0.40480977	0.34710199	0.43846546	0.38684992	0.45563980	0.36645106

Table 21: Local weights of IWT Barriers among the dimension "Market characteristics"

	all	LSP	Shippers	Administration	Other	Vessel Owners
trans. costs	0.14706929	0.13811436	0.09970659	0.29053874	0.14733085	0.14532645
reliability	0.16601796	0.17399765	0.14848215	0.19978699	0.15824949	0.11574921
shipment size	0.13462874	0.11797969	0.13134752	0.14430041	0.13242211	0.17049245
goods	0.11810395	0.10562987	0.13068412	0.09702617	0.13503961	0.14092511
transit time	0.13247073	0.14531304	0.15758280	0.07551137	0.11636117	0.17330286
price	0.13488545	0.14658372	0.15869081	0.09755950	0.12616752	0.11262182
flexibility	0.16682388	0.17238167	0.17350601	0.09527681	0.18442924	0.14158209

Table 22: Local weights of IWT Barriers among the dimension "Framework conditions"

	all	LSP	Shippers	Administration	Other	Vessel Owners
operating hours	0.11881285	0.12431657	0.13444960	0.07553564	0.12037878	0.10647363
multimodal connections	0.16255520	0.15247955	0.17305138	0.13835195	0.18107857	0.12935463
personnel	0.12923151	0.10607999	0.13252070	0.12571567	0.14567463	0.15375291
priority of IWT	0.17151546	0.18071424	0.16346694	0.22948089	0.15187389	0.14848967
knowledge and willingness	0.16511905	0.17120461	0.19658784	0.10887716	0.15040195	0.20948048
regulatories	0.12683509	0.13011317	0.11208520	0.20357003	0.11099014	0.14389725
administration	0.12593084	0.13509187	0.08783836	0.11846866	0.13960204	0.10855143

Table 23: Local weights of IWT Barriers among the dimension "IWT Infrastructure"

	all	LSP	Shippers	Administration	Other	Vessel Owners
bridge clearance	0.12799103	0.12682538	0.11215543	0.20632319	0.12209609	0.10109185
waterway depth	0.23801643	0.22690343	0.30512660	0.25982870	0.19427412	0.28816993
linked waterbodies	0.12144779	0.13630562	0.13077835	0.09436552	0.11257606	0.11537591
navigational equipment	0.13553660	0.12461639	0.13768064	0.13088392	0.15520874	0.10162957
(un)loading infrastructure	0.13084882	0.13174185	0.12344205	0.12807748	0.13782385	0.10603362
ports	0.10869021	0.11901233	0.08766353	0.08648944	0.11795047	0.11760972
maintenance	0.13746912	0.13459501	0.10315341	0.09403175	0.16007067	0.17008939

Table 24: Results of the Best-Worst-Method - normalized global weights per dimension and sub-criteria.

dimension	**sub-criteria**	**all**	**LSP**	**Shippers**	**Administration**	**Other**	**Vessel Owners**
Investments	sustainability	0.038751	0.038954	0.032613	0.064719	0.041375	0.02478
	initial cost	0.050381	0.062885	0.04584	0.031495	0.047791	0.042915
	vessel building	0.041421	0.041904	0.044632	0.036784	0.031298	0.075006
	infra. investm.	0.089143	0.075953	0.096611	0.086698	0.099232	0.076996
Market characteristics	trans. costs	0.039143	0.036932	0.025009	0.07527	0.038055	0.037522
	reliability	0.04386	0.045666	0.041233	0.057892	0.040825	0.031747
	shipment size	0.035586	0.031412	0.035321	0.035803	0.034538	0.046482
	goods	0.032107	0.027703	0.033036	0.024747	0.036023	0.037864
	transit time	0.034465	0.03831	0.040747	0.019992	0.031751	0.044764
	price	0.035496	0.038613	0.042068	0.025219	0.033809	0.030296
	flexibility	0.044236	0.046258	0.04748	0.025971	0.049893	0.036219
Frame-work condi-	operating hours	0.023205	0.025119	0.027857	0.015601	0.024245	0.021415
	multimodal connections	0.03246	0.029462	0.033009	0.028173	0.036947	0.024694

	personnel	0.025747	0.021013	0.027751	0.025532	0.029097	0.02901
	priority of IWT	0.034769	0.035499	0.03352	0.045264	0.03041	0.030335
	knowledge and willing-ness	0.032472	0.035303	0.038623	0.021447	0.028822	0.042545
	regulatories	0.025697	0.026147	0.022309	0.038614	0.021794	0.029734
	administration	0.025214	0.027021	0.016495	0.024933	0.02825	0.021832
IWT infrastructure	bridge clearance	0.040044	0.040643	0.036224	0.066013	0.037718	0.031893
	waterway depth	0.075589	0.072622	0.098423	0.083189	0.060614	0.089036
	linked waterbodies	0.038063	0.042525	0.043017	0.029676	0.035783	0.036781
	navigational equipment	0.043135	0.038962	0.041504	0.04134	0.050438	0.032597
	(un)loading infrastruc-ture	0.041723	0.04081	0.036978	0.039677	0.043454	0.034057
	ports	0.034199	0.037492	0.026423	0.026254	0.037545	0.03904
	maintenance	0.043093	0.042791	0.033277	0.029696	0.050294	0.052441