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INLAND WATERWAYS LOGISTICS

Operational Requirements & Vessels' Characteristics

Master's Thesis in the Master's Programme
Maritime Management

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Abstract

Inland waterway transport (IWT) is a complex system with numerous components and specifications; performance and competitiveness of IWT rely, to a large extent, on the fleet, the vessels' structure and capacity, the vessels' equipment and management. Therefore, it is necessary to analyse and distinguish the fleets according to their performance, equipment and technical parameters. The purpose of this master's thesis is to investigate the operational requirements and vessel characteristics required for the well-functioning IWT in the area of Göta älv - Lake Vänern.

The data for the study was collected through the relevant literature, study visits and interviews as well as cross-referencing them with the authors own experiences. This objective however would have been achievable only by investigating the vessels characteristics, operational features and reasons behind those in Northern Europe's main Inland waterways. The main and dominant of these inland waterways are, the Danube and Rhine; also including some countries on the routes investigated. Sequentially, it follows the general characteristics of inland waterways' vessels in those two routes, the operational features and reasons behind, in the two main dominant Inland waterways. In the same way, operational requirements and conditions of IWT for the area of project have been investigated to find out shortcomings and render a SWOT analysis developed for the presenting of recommendations for the threats and weakness on the bases of key learnings and finding from the Northern Europe Inland waterways vessels characteristics, operational features of vessels and terminals.

Findings on the Rhine and Danube IWT indicate that vessels' characteristics and operational features as well as the ports conditions are regionally different and are affected by various factors such as the locks' allowance, nautical status of waterways, economy of the region, etc.

The recommendations for the promotion of IWT business in the Göta Älv-Lake Vänern are made in the domain of vessels' characteristics and operational features, the facility requirements, such as futures locks' dimensions, lifting gear for the container operation either on the vessels or ports, and the regulations' requirements for the ice and pilotage, etc.

Key words: IWW, IWT, vessels, SWWs, corridor.

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Abbreviations

AEO	Authorized Economic Operator
AGN	European Agreement on Main Inland Waterways of International Importance
ARA	Amsterdam-Rotterdam-Antwerp
CCNR	Central Commission for the Navigation of the Rhine
CCTV	Closed Circuit TV
DWT	Deadweight Tonnage
ETA	Estimated Time of Arrival
Fig	Figure
FRS	Swedish Vessel Reporting System
IWT	Inland Water Transport
IWW	Inland Waterway
KM	Kilometer
LOA	Length Overall
M	Meter
MARPOL	Marine Pollution (One of the important international marine environmental conventions)
NEWS	Next generation European inland Waterway Ship
Res	Resolutions
RPM	Revolution per minutes
RVBR	Rhine Vessels Inspections Regulations
SMA	Swedish Maritime Authority
SOLAS	Safety of Life at Sea
SWW	Small Waterway
TEU	Twenty-foot Equivalent Unit
VTS	Vessel Traffic System
KW	Kilowatt
RSV	River Sea Vessel
RIS	River Sea Information System
Km/h	Kilometre per hour
SSS	Short Sea Shipping
T	Tons
RQ	Research Questions
WBS	Work Breakdown

1- Introduction

Due to the expected trade growth of rail and road in the EU, and limitations to expanding the capacity of rail and road transport, the EU commission has encouraged using multi-modal transports with the aim of shifting transport towards the less congested and more environmentally friendly modes. As a result, the tendency has gone towards a multi-modal approach where IWT is connected to the rail and/or road transports.

The IWT is a complex system with numerous components and specifications. The main hardware components of IWT are vessels, waterways, locks, bridges, ports and ports' facilities. The performance and competitiveness abilities of IWT, to a large extent, rely on the fleet, the vessels' structure and capacity, the vessels' equipment and management. Therefore, it is necessary to analyse and distinguish the fleets according to their performance, equipment and technical parameters which influence their efficiency, competitiveness, traffic safety and service reliability. All the above factors, however, are governed by the costs which impact the different service parameters such as the age of vessels, dimensions of vessels, the capacity and capacity utilization ratio of vessels, the equipment and technologies onboard the vessels, the draft restrictions, operation structure… etc. (buck consultants international et al.,2004)

However, the quality and efficiency of IWT depend on the waterway's infrastructures such as port facilities, dimensions of locks' chambers, numbers of ships in operation and flow of cargo… etc.

This master's thesis in inland waterways transport (IWT) investigates the elements and vessels' characteristics which are required for the well-functioning of IWT in the area of the project, being Göta Älv - Lake vänern.

1.1 Background

According to the European Commission, IWT is an energy efficient and environmentally friendly mode rather than a road transport system (European Commission, 2018). Obviously, while selecting a sustainable and efficient freight mode among different modes, prior to selecting a transport mode, the customer focuses on all the available freight modes, for an evaluation of costs, flexibility, reliability… etc. Normally, road transport is a dominant method which is responsible for the greatest emissions. To improve greener transport, it is necessary to concentrate on cleaner ways of transport along with advancing the improvement of fuel properties, new technologies, and cleaner energy resources. Switching from the road to more sustainable modes with lower environmental impacts is targeted by the EU. In the EU, 33% of long-distance transport freights are carried by road while rail and inland waterways (IWW) contribute less than 20 percent. Clearly, waterborne and rail transports are greener than other approaches especially in medium and long-distance transportation (McKinnon, 2015). Most of the EU countries are naturally provided with inland and short-sea waterways which can facilitate this mode. For instance, in the UK only 24% of the market is covered by rail and inland water transport mode (Partnership, 2018).

There are many advantages for short sea, coastal and IWW transport such as being reliable, environmentally friendly and cheaper in price, because of the greater volume of transport compared to the road per kilometre. Just in Europe, there are 300 major ports (commission ,2018), which just goes to show what great potential still exists for the IWT improvement in this continent?

Clearly, the reasons behind the extensive usage of road transport are flexibility, accessibility, is a convenience for short distance and network. Since 1995 to 2011, road transport rose 3 percent in the EU which had the greatest share among the other modes. However, there is a less positive image for the railway and waterborne transports. Even, the railway was losing the market since before 1995. But, in the same period, IWT had a constant share of 4% (McKinnon, 2015).

Nowadays, unitization has facilitated intermodal freight transport such as containerization. Especially, due to the advantages of fuel efficiency, fewer carbon impacts, reduction in the cost and time of transportation. Obviously, characteristics of various modes are heavily under the influence of freight flow, however not much geared to the volume of cargo in transit. On average, water transport modes have lesser emissions than the other transport modes. For example, figure 1 represents GHG emissions of different modes in the UK which clearly explains that the rail and waterborne modes are more sustainable and have greater competitive advantages than the other modes.

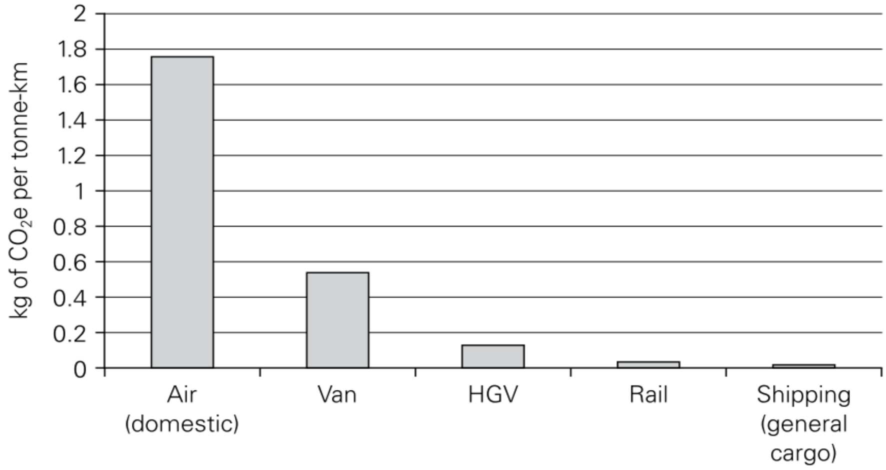


Fig.1 estimated average CO2 intensity values for different freight transport modes (UK) (McKinnon, 2015).

It is evident that road and rail transports can hardly deal with the increase in the volume of transport. Usually, just grey energy consumption of the IWT mode is considered in comparison to the energy consumption of road and rail transport. But, by considering the whole life cycle of the vessels from building to disposal, the inland waterways vessels are even more cost-efficient than the other two modes of transport. Additionally, the external costs such as climate gasses, accidents, noise, air pollutions of the IWT have a lower rate than rail and road transport.
Unfortunately, when it comes to covering a small distance IWT does not compete with the other transport modes. This is mostly because the final legs of deliveries are not reachable by the ships. A comparison study over a 100 km distance shows that IWT costs compared to other modes of transport gained one in a scale of five, the rail obtained three from five and road secured 3.4 from five (Verheij et al., 2008). In contrast, and in addition to high handling costs in short distances, in the door-to- door transport, IWT loses the competition to the road mode (Verheij et al., 2008). In general, IWT is a slow mode however with the advantage of enjoying high payloads which make it a suitable model for transporting massive cargoes such as the liquid or dry bulk cargo. The special advantage of IWT, however, is safety in transport of hazardous cargoes compared to other modes. In the EU, particularly by considering the main backbone of IWT which is natural existing rivers, in contrast to the required infrastructures for the road and rail transport, IWT seems more reasonable in terms of required infrastructures. From an economic view, the maintenance and running costs of the relevant infrastructure are also lower than other modes of transport.
One of the IWT drawbacks is inflexibility, compared to the other modes. it simply cannot accommodate seasonal peaks easily. The vessels in IWT cannot be re-routed too, due to the vessels' customization for specific regions (Buck consultants international et al.,2004). In this regard, an innovative approach could be focusing on the concept of the vessels which are involved in the IWT in other European countries for better piloting in such countries like Sweden where the IWT share is not promising yet. A part of this thesis is to better understand the concept and characteristics of the IWT vessels in other European countries and then using the key learnings as a pilot for Sweden.

Inland shipping is widely different from country to country or region to region. But there are some common principles in all regions. The least expensive mode of transport will mostly be a winner in the region and will be used widely in that area. Obviously, IWT to a large extent relies on geographical location. For instance, 45% of the Netherlands' cargo ton per km, both that of the national and international, are transported by water mode. The same in Germany is 14% and in Belgium it is 14% (Verheij et al., 2008). Furthermore, the Netherlands uses IWT transport by 18% (Statistiek, 2018). The Below table provides the percentage of cargo transported by different modes in the Netherlands, which indicates that IWT has a promising share. This is at a time when Sweden uses 0.7 % of IWT mode for the movement of goods (Vierth, 2012).

Modality	National cargo transport	International cargo transport
Road transport	77 %	35 %
Inland navigation	22 %	60 %
Rail transport	1 %	5 %
total	100 %	100 %

Table .1 The cargo transport by Dutch companies in 1997 (tons) (Verheij et al., 2008)

As a result, by knowing that Sweden has about 60,000 KM of rivers and that 10 of those rivers are more than 400 km long and that 27 of those rivers are longer than 100 km (organization, 2018), it goes without saying that some of these rivers and lakes have the ability for freight transport. This means that IWT has not been considered seriously enough as a means of freight transport in Sweden yet. That also means that there is a large potential for Sweden to increase its share of the IWT mode.

1.2 Purpose and objectives

IWT is a complex system with numerus components and specifications. The main hardware components of IWT are vessels, waterways and ports. For the efficient operation of IWT, the vessels and infrastructures need to be well synchronized with regional requirements and demands. In Sweden and specifically in Göta Älv – Lake Vänern, the IWT has not yet been developed to gain its due share of transportation in the local market.

The purpose of this master's thesis is to investigate the operational requirements and vessels' characteristics required for the well-functioning of IWT in the area of the project, being Göta älv - Lake Vänern.

1.3 Research questions

To understand the challenges and reach out to the aims in an academic way, the following questions are developed as fundamental points of this thesis:

RQ 1: What are the characteristics of well-functioning IWT in Northern Europe?
a) What are the vessel characteristics?
b) What are the operational features of the vessels?
c) What are the reasons for using these vessel characteristics and operational features under IWT in Northern Europe?
In the first research question, the characteristics of well-functioning vessels involved in river-sea transport and IWT in the North European region is studied. Furthermore, the reasons behind those features are also studied, in order to understand the relation between those conditions and the characteristics.
Later in the thesis, the requirements and limitations of IWT as shared by the port of Gothenburg and Lake Vänern will be studied in respect to the vessels' characteristics and in order to answer to RQ2.

RQ 2: What are the operational requirements of IWT vessels that are suitable for river Göta and lake Vänern?
In the second research question, the vessels' characteristics such as overall length, maximum beam, draft, air draft, deadweight, engine outputs, type of propeller, rudder characteristics, foldable mast,

speed, and any other quality requirement as well as all the legal requirements applicable to the vessels in the route to Göta Älv - Lake Vänern will be investigated.
In continuation, in the third research question, the outcomes from two previous research questions are used to identify the relevant key learnings for improving the IWT on the Göta Älv - Lake Vänern.

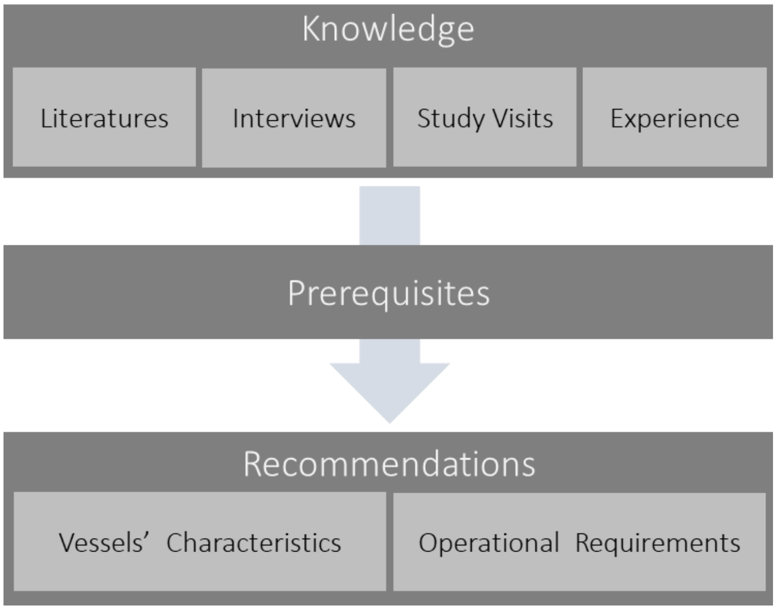
RQ 3: What are the key learnings for IWT on the river Göta Älv and lake Vänern in terms of a well-functioning IWT in Northern Europe, and in terms of vessels and operations?

1.4 Delimitation

This thesis will take into account the inland waterways transportation industry with focusing on the routes' specifications, capacity, limitation and restrictions, ports' facilities and properties, as well as characteristics of the vessels involved in the regions of the study in this project. Since it has been assumed that the main potential as a future interest of IWT on the Göta river to Vänern lake will be container and general cargo transport, this study and research focus on the same type of vessels including the facilities for the container and general cargo transport in this area.
Furthermore, the existing infrastructures are taken into account since this thesis is looking to gather data from the present circumstances in this region and North Europe to use as a guide for piloting IWT in the area of the project. The possibility of scarcity of material in some parts of IWT may cause some parts not to be considered in this work.
Due to the limited time window of this thesis and the limited observations, such as lack of practical observation of the route Göta Älv - Lake Vänern and a single study visit in the Netherlands which has a different climate to the area of project, there is a possibility that some of the facts & features of the IWW vessels and requirements for inland waterway transport be left unseen and unaccounted-for in this thesis.

2- Method

For the purpose of this thesis, the characteristics of typical vessels in Northern Europe are studied through the available technical literature, interviews and study visits of infrastructures related to IWT as well as an IWW vessel operation in the Netherlands.
The scope of work also included, gathering data regarding port facilities, specifications of passages, operational requirements and characteristics of the vessels in Göta Älv – Lake Vänern through existing literature, interviews and study visits.
The gathered knowledge via interviews, study visits, studied literature regarding IWT in the North Europe region and Sweden as well as in conjunction with the knowledge received from experiences of the authors are applied to discuss the prerequisites and thus propose some recommendations for the efficient operation of suitable vessels in the route Göta Älv - Lake Vänern.



Graph 1 – Research approach

Holme and Solvang (1986) pointed out that qualitative research provides a holistic viewpoint regarding the interest area. In this research, a qualitative method is the main type of research method. Qualitative data collection in this research varies in approaches and techniques such as individual interviews, study visits, group discussions and literature reviews.

For data collection, a mixed approach is used to increase the accuracy and quality of data (Yin, 2009). For this purpose, collected data from existing literature and documents within the IWT and data from interviews and study visits are used.

For RQ1, to collect data regarding vessels' characteristics which are trading in IWT of North European countries, the port facilities, the operational features of those vessels, as well as the reasons behind those characteristics, the existing literature is used. Furthermore, one of the IWW vessels which is owned by Vigilia shipping BV (AMICE) was visited on 7th November 2018. A short trip was also made with vessel AMICE in the Dordrecht canal. Additionally, the IWW vessels' traffic control and information centre of Dordrecht was visited on the same date. On 8th of November 2018, barge & truck planning manager of MCS company was interviewed at the IWT terminal in Leeuwarden which is one of the four operating IWT terminals under the supervision of MCS. In the same terminal, its facilities such as storage area, crane, lifting trucks, and equipment for additional services related to containers were visited. On the same day, a short cruise was made on the fairways in Leeuwarden. On 9th of November 2018, the training facilities (simulation systems) for IWW vessels at the Maritime Academy in Harlingen was visited.

In respect to RQ2, the existing literature, case studies and relevant resources such as the Swedish Maritime Administration (SMA) were reviewed. Initial literature study helped us to gain a comprehensive knowledge of the region to uncover the trends and problems. The Study of the existing fundamental and basic data regarding Göta Älv to Väneren lake IWT, infrastructures such as bridges, locks and port facilities provided a map for our further investigation. The critical points guided the authors to identify the topics for interviews.

For RQ3, results and outcomes of the studies regarding RQ1 and RQ2 were discussed internally in the group to propose recommendations.
In the next step, four interviews and four study visits were conducted with the following officials:
Interview one, the interviewee was a strategic planner at the Trafikverket office. He is an expert in the Gothenburg pilotage area, and he has been involved in a mission for increasing coastal and inland

waterway shipping in the year 2016. He has had experience with sailing on the Lake Mälaren. The interview was conducted at the building of Trafikverket on the 19th of October 2018. Later, interview number two was conducted with three individuals in the form of a meeting. The first interviewee was a pilot for the south and north part of the route. He was a nautical academy advisor of the channel and had experience in piloting on the route for almost 7 years. The second interviewee was a master mariner, with the experience of piloting on the same route for four years. He had been an area manager for the pilots of the same area and in the last five years had been working in the Swedish Maritime Administration (SMA), and in the division of maritime infrastructures. He had been involved in the debates regarding the new bridge which is under construction over the Gothenburg river. This bridge is supposed to facilitate maritime traffics. He was also involved in the debate of building new locks on the route. He had a lot of discussions regarding IWT in the Lake Malaren and Värnern. The third interviewee was an area pilot manager. The interview was conducted at Tånguddens hamn, in the building of area pilot manning on 22 of October 2018.

On 24th of October 2018, the port of Kristinehamn was visited. Two members of Vänerhamn AB company were interviewed in a meeting, first interviewee was the port operator of Kristinehamn and the 2nd interviewee was the sales and marketing manager of Vänerhamn AB. He was an advisor for IWT in the area as well.

Method of data collection	Title of interviewee person (or place of study visit)	Date
Interview	1 person: Strategic planner of the Swedish Transport Administration (Göteborg area pilotage expert-involved in a mission to increase IWT 2016	2018-10-19
Interview	3 persons: 1- Pilots area manager 2- Pilot (Nautical academy advisor of Göta Älv - Lake Vänern) 3- Maritime infrastructure advisor of SMA (Former area manager and pilot)	2018-10-22
Study visit and Interview	Port of Kristinehamn 2 persons: 1- Port operator of Kristinehamn 2- Sales and marketing manager of Vänernhamn AB	2018-10-24
Study visit	Dordrecht Vessel “Amice” IWW vessels’ traffic information centre	2018-11-07
Study visit and Interview	Leeuwarden Waterways of Leeuwarden MCS Terminal visited Barge and truck manager of MCS interviewed	2018-11-08
Study visit	Harlingen Maritime Academy of Harlingen	2018-11-09

Table 2, method of data collection

3.Frame of reference

The IWT is an alternative and viable mode in addition to road and rail within European corridors. Its potentials, however, are largely not exploited. Since 1956, the UNECE (United Nations Economic Commission for Europe) by several technical and various policies has tried to promote the efficiency of the IWT mode across the European continent. In the EU, 6% of cargoes carried by the IWT mode and through the countries around the corridors have considerably greater shares in freight transport by inland waterways vessels (Unece, 2018). In addition to the vessels and their characteristics, Inland waterway infrastructures and their related parts also are determinant factors. Canals, terminals, locks, and bridges are the main components of Inland waterway infrastructure (Wiegmans & van Duin, 2017). Therefore, in this section, the main component of the IWT, the waterways, the vessels, the regional matters, the vessels characteristics, the infrastructures and other related issues and parts will be pointed out.

3.1 General on Inland Waterways and definition

There are 600,000 KM of navigable IWWs in the world, and in terms of navigable IWWs more than 50 states are provided with more than one thousand km of navigable inland waterways but, unfortunately , most of these networks are not well developed or are underused (Wilcox, 1931). Inland waterways are categorized by CEMT (European conference of ministers of transport) and according to CEMT, all waterways of **international importance** are Class IV and up, and are considered as important or large waterways. (Res.92/2).

CLASSIFICATION OF EUROPEAN INLAND WATERWAYS

Type of inland waterways		Classes of navigable waterways	Motor vessels and barges – Type of vessel: General characteristics					Pushed convoys – Type of convoy: General characteristics					Minimum height under bridges 2/
			Designation	Maximum length	Maximum beam	Draught 7/	Tonnage		Length	Beam	Draught 7/	Tonnage	
				L(m)	B(m)	d(m)	T(t)		L(m)	B(m)	d(m)	T(t)	H(m)
1		2	3	4	5	6	7	8	9	10	11	12	13
OF REGIONAL IMPORTANCE	To West of Elbe	I	Barge	38.5	5.05	1.80-2.20	250-400						4.0
		II	Kampine-Barge	50-55	6.6	2.50	400-650						4.0-5.0
		III	Gustav Koenigs	67-80	8.2	2.50	650-1,000						4.0-5.0
	To East of Elbe	I	Gross Finow	41	4.7	1.40	180						3.0
		II	BM-500	57	7.5-9.0	1.60	500-630						3.0
		III	6/	67-70	8.2-9.0	1.60-2.00	470-700		118-132	8.2-9.0	1.60-2.00	1,000-1,200	4.0
OF INTERNATIONAL IMPORTANCE		IV	Johann Welker	80-85	9.5	2.50	1,000-1,500		85	9.5 5/	2.50-2.80	1,250-1,450	5.25 or 7.00 4/
		Va	Large Rhine vessels	95-110	11.4	2.50-2.80	1,500-3,000		95-110 1/	11.4	2.50-4.50	1,600-3,000	5.25 or 7.00 or 9.10 4/
		Vb							172-185 1/	11.4	2.50-4.50	3,200-6,000	
		VIa							95-110 1/	22.8	2.50-4.50	3,200-6,000	7.00 or 9.10 4/
		VIb	3/	140	15.0	3.90			185-195 1/	22.8	2.50-4.50	6,400-12,000	7.00 or 9.10 4/
		VIc							270-280 1/ 195-200 1/	22.8 33.0-34.2 1/	2.50-4.50 2.50-4.50	9,600-18,000 9,600-18,000	9.10 4/
		VII						8/	285	33.0-34.2 1/	2.50-4.50	14,500-27,000	9.10 4/

Table 5, the inland waterways classification by CEMT (Res.92/2) (organization, 2015)

One main characteristic of waterways is their total length. According to AGN the total length of all classes in the EU is 27711 km which includes smaller waterways that are classified less than class IV. The below table provides an AGN document and further data which are available on the following:
1-European Agreement on Main Inland Waterways of International Importance (AGN) -1998
2-United Nations Economic Commission for Europe: 'Inventory of most important bottlenecks and missing links in the E waterway network - Resolution N°.49, New York and Geneva, 2003, TRANS/SC.3/159, page 4, Annex

Class	Missing links	Less than IV	IV	Va	Vb	VIa	VIb	Vic	VII	Σ
Length km)	1489	4286	3969	3270	5051	667	5766	1592	1621	27711
Length (%)	5.37	15.47	14.32	11.80	18.23	2.41	20.81	5.74	5.85	100

Table 6, the main European inland waterways as published by the UN-ECE resolution N˚49 (Buck consultants international et al.,2004).

3.2 The comparative views of the Inland Water Mode

IWT in comparison to the road and rail transport is mainly considered as a green inland transport mode with a higher degree of sustainability (Bloemhof et al., 2011). Furthermore, globalization economic and supply chain management are generating greater demand for multimodal transportation infrastructures as well as intermodal services demand (Bloemhof et al., 2011). From that perspective, and from 2000 to 2006, the EU highway transportation, increased by 25 percent and reached 73% (Noreland, 2008). Consequently, EU directives and policies seeking to promote intermodal transportation services including IWT are looking to overcome congestion and environmental issues which have been created by motor carriage (Lewis et al., 2001). The important advantage of an inland waterways' vessel is the capacity of the cargo that the vessel can transport. The capacity of a vessel may be a hundred times more than the capacity of a truck, which is dependent on the size of the waterway and whether the vessel is able to navigate it, as per classified accordingly. For example, Gustav Koenigs, Europaschiff class, Long motor, and Joui class Rhine container type vessels are able to carry cargo equal to 36, 54, 80-120 trucks respectively as well as inland water Ro-Ro vessels can carry 270 cars (Pictures in appendix II) (Rewway, 2018).

3.3 Inland Water Transport in the EU

In many European countries, inland waterways transport is a competitive alternative to rail and road transport. IWT is the most economical inland transport mode because of the crucial characteristics of low external costs and infrastructure cost. However, IWT suffers in some areas such as legal, infrastructural, technical barriers, institutional, etc. Ironically enough, however, IWT is mostly underused in many countries with suitable inland waterways. In 2007, 5.8% of total transported goods among the 27 European Union countries was by means of IWT, and in a sequence, the goods carried by road stood at 76% and by rail at 18% (Un,2018a). In continuation in the same year, the total goods carried by IWT in the Russian Federation alone stood at around 2% which indicates that the IWT importance varies within various countries (Un,2018a). This highlights the economic and geographical effects of IWT as well as the impact of regional and national policies. There is, however, a slight decline in most countries in respect to IWT's share in terms of a modal split since the mid-1990s. That is a sign which shows that the road transport share has increased at the cost of inland navigation (Un,2018a).

In the EU, the Danube river is considered as a backbone of IWT in Europe with its connections through the Rhine (Mihic et al., 2011).The backbone of the future EU multi-modal transport system can indeed be IWT, but the development of inland cargo transport is directly related to the technical characteristics of the inland waterways network, and to the navigational characteristics of inland waterways which have a priority over the building of ships (Backalic and Maslaric, 2012). In addition, Inland water navigation in comparison to other modes is very competitive, and the highest rate of European inland water traffic usage belongs to Belgium, the Netherlands, and Germany, by considering the total load volume to the total navigable length of inland waterways (Radmilović and Maraš, 2011).

3.4 Challenges of Inland Water Transport

IWT faces weather challenges which impact the navigation of vessels and the inland waterways infrastructures also. The weather challenges are such as drought, freezing temperature, floods, etc. Low water period also has an effect on the cargo-carrying capacity and equally, ice on the river may even lead to suspension of navigation, operation or may even damage infrastructures (Schweighofer, 2014). On the other side, for mitigation of climate change challenges and their relevant adverse impacts, the cleanest mode of transportation still seems as being the IWT (Sulaiman, 2010).In spite of that, the rise in IWT navigation could increase ecosystem hazards, namely for freshwater fish (Wolter et al., 2004). In contrast, the development of water resources has mostly been left to the public authority due to “public good”. This has been due to reasons having to do with guarding the the water system output in nature and requirements for preventing externalities and also to the “public good” of using the water system by one party without diminishing the enjoyment by other parties (Howe et al., 2016). And this has made the developmental processes lag behind the incurred damages, as the latter is always easier to experience.

3.5 Inland Waterway Transport Component Concerns

In order to have an efficient investment in IWT, there is a need for national studies as well as other navigational studies on the waterways infrastructure like lock conditions , lock rehabilitation for transport efficiency such as disassembling and reassembling of barges prior to and after entry into the locks and in the movement through the chambers (Martinelli et al., 1993).

For the design of inland water ship, it is noteworthy that the same approach and parameters used for sea-going vessels are not applicable. Certain aspects such as , more effective steerability , low speeds , dimensions of waterways in the region, influence of cross flow , visibility conditions ,fairway width in the bridge openings, canals, rivers , dimensions of locks , dimensions of basins for the turning purpose , type of ship, effective damage control and minimization of damage in case of accidents as well as regional conditions and boundaries are required to be minded (Söhngen and Eloot, 2014). However, the speed of IWW ships in comparison to the rail and road modes is a major drawback. In addition, the restriction of IWWs´ depth and width creates hydraulic impacts from wave generation, flow velocities, and level of water variation on the ships bottom, channel bed and banks (Hüsig et al., 2000). Such wash waves which are produced by IWW vessels have an effect on the safe operation of other vessels, floating objects in the vicinity or even endanger life on the beaches or cause environmental damage (Maraš, 2008). However, technological innovations are continuously developing in all area of water transport vessels, on the power, manoeuvrability, speed ,design ,size and formation of barges in the towage, communication devices, automation of functions, channel and lock design , terminal facilities , and special cargo handling gears (Polak and Koshal, 1980).

Vessels fundamentally for safe operations rely on the ballast water, therefore, ballast tank design, ballast water management and its processes, which are related to legislative and safety issues need to be considered (Eryuzlu and Hausser, 1978).

For instance, in EU coastal waters, the IWWs and adjacent waters, more than 1000 non-indigenous aquatic species have been found. These species are introduced partly through the ballast water transportation and the hull fouling attachment to the area which caused serious ecological and economic issues (Gollasch, 2008). In the Dutch Rhine delta and in a large Western European river, 10% of invasions are from the seaports which are caused by seagoing vessels (van der Velde et al., 2002).In a similar way, the impact of such ballast water exchange on the Göta Älv is clearly visible (Håkansson et al., 2007). Therefore, the introduction of new technologies generates great environmental benefits. For example, low sulphuur fuels despite increasing transport cost saves 50000 lives worldwide per year and prevent many serious health damages (Sieber and Kummer, 2008).

In general, construction of IWW vessels and their propulsion system directly depend on the depth, exit of sluices and their dimensions in the waterways as well as to the ecological conditions of the region of trade (Dymarski and Rolbiecki, 2006). When an inland water vessel is needed for trade in shallow waters, great importance is attached to understanding whether the effect of water depth on the wave-making resistance is favorable, unfavorable or negligible in the area of trade (Hofman and Kozarski, 2000). In case of an inland water container ship, the risk of watering and flooding are increasingly high due to the winding (windage area), and therefore regulations in this regard are suited for a large gauged ship such as ships on the Rhine river while ships on shallow waters such as the Danube are at a greater risk (Bačkalov et al., 2008).

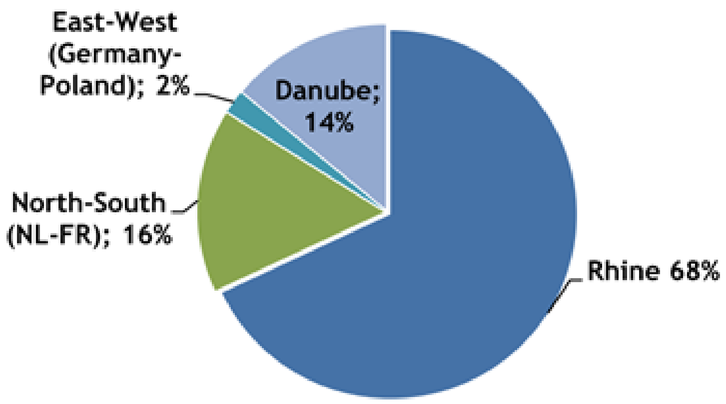
In a similar way, the optimal parameters which have an effect on the utilization of a container ship on inland water transport and success of a container shipping company, depend on the size of the container vessels, on that specific route , the costs and benefits, the ship speed , the number of container shipments on that route (Maraš, 2008). Therefore, the optimization of an integrated transportation network with repositioning of empty containers has a great influence on the inland shipping services and will promote a modal shift towards IWT (An et al., 2015). Although the making of IWW vessels is shifting towards larger sizes, with the expectation of cost reduction, it will also lower the geographical flexibility of the vessels and make the handling times longer. However, the optimal dimension of IWW vessels in many cases and lengthwise is not larger than the maximum allowable. For example, 135 m on the Rhine. However, the beam of future vessels will be wider than the existing ships and the optimal drafts will be close to the normal water levels of the trade route (Hekkenberg, 2013). In the same way, optimal dimensions of IWW ships are related to the characteristics of the route and the logistics chain (Hekkenberg, 2013). In addition, low depth of waterways causes low draft for the vessels in the region which in turn leads to the optimal length and beam of the vessels in the region (Hekkenberg, 2013). Furthermore, it must be noted that Information Technology in the shipping industry is aiming to improve safety and efficiency, for instance the River Information System (RIS) (traffic information and management, law enforcement support ,…etc) can provide benefits for different stakeholders, private and public such as ports, shippers, ships,…etc.(Fastenbauer et al., 2007). Consequently, there are a lot of concerns that need be considered prior to the promotion of IWT in an area.

3.6 Main Dominant Inland Waterways in the EU and their shares for IWT freight

In the year 2013 according to EU statistics 532 million tons of goods were transported by IWT mode which created a freight turnover of above 152 billion tonnes per kilometre (prominent, 2018). The influential inland waterways in the EU, however, are the Rhine Inland Waterway, which includes, the Rhine connections and the canals in the west of Germany, Switzerland, the Netherlands and France, the eastern part and Luxembourg, the Danube Inland waterway (South to East), entire Danube connections and canals, the Main-Danube Canal as well, the east to the west corridor, the northern part of Germany, the Mittelland canal and connections of Elbe, Oder and Wisla. And, the north to the south corridor, the lower part of the Rhine throughout France and connections to Belgian networks. Three of these corridors overlap in Belgium and the Netherlands in the north-west of Europe (Buck consultants international et al.,2004).

Picture 1, The Danube and Rhine inland waterways (Danubecommision, 2016)

In the EU 68% of IWT cargoes are transported on the Rhine corridor, 16% are moved between countries of France, Germany and the Netherlands (North-South corridor), 14% on the Danube corridor and 2 % between Germany and Poland (East-West corridor).



Graph 2, the source NEA, (Delft et al., 2001) Medium and Long-Term perspective of IWT

3.7 Characteristics and Operational features of IWW vessels for purpose of this project

There are many same size vessels working in different regions that have similarity in dimensions such as length, width, draft or other characteristics. Due to regulations in other regions or different nautical statutes or infrastructures their operational features, however, may be different. For instance, the requirement of one bow thruster for ships greater than 90 m is compulsory in the Rhine region according to Rhine authorities. But not in the Danube or stern chains where the length requirements in the Rhine is more than the Danube for the same size of ships. Operational features mostly depend on the operational area of the IWW vessels and compliance with the regional standards and nautical requirements of the regions. Therefore, in this project the operational feature and vessels' characteristics are treated differently. For purposes of this thesis, the length, width (beam), deadweight and draft of the vessels were considered as vessels' characteristics and the rest as an operational features.

4. Rhine Inland Waterways

It is the second-largest river after the Danube in the Central and Western parts of Europe. It is about 1230 Km long and passes through 4 European countries. It starts from Swiss and ends in the Netherlands prior to flowing into the North Sea. The Rhine is an important deep inland navigable waterway in Europe. A lot of cites in Europe are located on the Rhine passage such as Rotherham, Utrecht (Tockner et al., 2009).

4.1- Regional Characteristics of Vessels on the Rhine

Ships with the length of 110 m, a beam of 11.4 m, a draft of 3.5 m and capacity of around 2850 tonnes are the most common types on the Rhine. The other common type of ships are self-propelled vessels which have 80-85 m length, 9.5 m beam, 2.5 m draft and 1300 tons of capacity (Europe-Size). As a result, the vessels within the Rhine and its corridor have a length between 80 to 110 m and width between 9.5 to 11.4 with an allowable draft of up to 2.8 meters.

The locks, rivers and canals in these areas allow a width of 12m and length of 110 meters. The push barges in convoy formation are up to six barges with a total capacity of 16000 tons. These push barges are trading on the lower part of the Rhine with an engine power output of about 4500 kW (Buck consultants international et al.,2004).

However, in the lower part of the Rhine, between the deep-sea ports in the North Sea and Rhine region, the pushed convoys are still trading.

The size of barges also is developed according to the navigation and nautical status of the trading area. The nautical conditions mostly are the main factor which influences the size of barges. For instance, in the Rhine and Danube barges are larger than Elbe or Oder due to draft issue in the Elbe and Oder, which is around 2 meters (buck consultants International et al.,2004). The most common ships and formation of the barges in the area are 110 m x 11.4m m and 85 m x 9.5 m respectively. The most common formations of barges are coupled convoys Class Va with a Europa II barge in a long format and 4 barges in a pushed convoy (B-II) format (Prominent, 2018).

According to Rijkswaterstaat classification in the year 2013 sampling the most common type of vessels and barges in the area of the Rhine and their passage share, are related to the motor vessels with a length of 110 m and width of 11.4 m. The coupled barges Class Va with one Europa II long barge and the push convoys with four Europa barges in a push convoy formation have the greatest share respectively (Appendix III). Source Rijkswaterstaat" Toekomstige ligplaatsbehoefte Overnachtinshaven Lobith 2013" (Prominent, 2018)

4.2 Vessels Characteristics on the Rhine in the Netherlands

Between Rotterdam and Antwerp (and additional waterways in North-South corridor) many different types of IWW vessels are operating. The most representative types are 110 x 11.4 m. This is the most common type of motor vessels on the North-South corridor. The next most common size of vessels in the Netherlands' inland waterways transport is (80.5-85m) x 9.5 m.

In addition, traffic records for vessels in the year 2008 on the Volkerak lock in the Netherlands (according to the RWS 2010 vessel categories), shows the same length of 110 m X width of 11.4 m and has the most trade in the area. Source: Deltares, 2011. Volkeraksluizen - effect zoutdrempel op scheepvaart (Appendix VI)

In this region also, coupled convoys are very common. Coupled convoying enlarges transport capacity by less cost and more usage of the resources. The most common form of coupled convoys in the Netherlands are combination of Class Va vessels with a Europa II barge (push barge (96-110m) in long-formation (BII-2l). The other common push convoys form is wide-formation (BII-2b) which is combination of a Europa Barge II and a barge in the side. In the North-South corridor, 2 barges in long-formation and wide formation are most common combination compared to larger capacity pushed convoys formation (4 and 6 barges).

Extract of traffic records for year 2008 on the Volkerak lock for different barge formation, pushed and coupled convoys in the Netherlands (according to the RWS 2010 vessel categories) show that the greatest share is with Class Va with Europa II barge for coupled convoys and Europa II pushed convoys. (Source: Deltares, 2011. Volkeraksluizen - effect zoutdrempel op scheepvaart) (Appendix VII) (Prominent, 2018).

In the Meuse in the Netherlands, traffics records on the lock of Sambeek show that the most representative type of vessels are 67 m x 8.2 m and 110 m x 11.4 m respectively (according to the RWS 2010 vessels categories, source: Royal Haskoning (2008), 'MER Hoogwatergeul Well-Aijen' based upon the MIT Verkenning Born-Temaaien (Ecorys, 2007) from Prominent project report 2018 (Appendix VIII).

In the year 2018, a section of Meuse (the section between Maastricht and Nijmegen) has been upgraded to a CEMT-class Vb waterway, which allows operation of longer pushed convoy, in the formation of 2 barges, with the maximum dimensions of 190 m x 11.4 m and draft of 3.5 m (Prominent,2018).

4.3 Vessels Characteristics on the Rhine in the Belgium

Statistical data (by NV De Scheepvaart in year 2008) based on a sample of traffics from the Albert canal as the main waterway for IWT traffic in the Belgium shows that the ships larger than 2000 tones are trading in the area with approximately of 110 meters length or longer length (Appendix X) (Prominent ,2018).

4.4 Regional Operational features of Vessels on the Rhine

The nautical characteristics and conditions are different from corridor to corridor in Europe. That is the factor which governs the technical and operational specification of the vessels operating in the region. They are equipped with a single propeller, conventional shaft system, bow thrusters, a multi-blade rudder, an engine with 0.4 kw output power per ton of loading capacity, comfort accommodation for the crew and with elevating wheelhouse arrangement (Buck consultants international et al.,2004)
Almost only fifty percent of the installed ships' power is used for going in the upstream direction and for the manoeuvring where the depth is enough on the free-flowing river (prominent,2018). The required power will be even less where the waterways are smaller or in downstream condition. And, whenever the under-keel clearance is smaller excessive power may lead to an increase in the squat which also increases the chances of grounding (prominent,2018).

In the Rhine corridor fairways are narrow with enough water depth. The river cargo ships with the beam of more than 11.45 are mostly self-propelled by single conventional shaft propeller due to favourable fairways depth (buck consultants International et al.,2004). The Rhine corridor fleet is dominated by self-propelled vessels.
Usually, sailing in the canals (narrow width) required high manoeuvrability with little propulsion power. But, in the Rhine it is different due to market demand that requires higher deadweight tonnage, optimized hull, high propulsion power and appropriate manoeuvrability. With respect to the optimized hull, the fundamental hydrodynamic properties which have an effect on the profitability of vessels' operation are mostly the shape of bow and aft, propulsion system, steering system including transverse thrusters. For instance, the bow or/and the stern thrusters or the bow rudder which has an effect on the manoeuvrability and costs (Institute, 2018).
Type of the vessels on the Rhine vary because the Rhine fleet follows the Rhine standards and regulations. These regulations act as pathfinder or exemplary for other areas. The Rhine authority is maintaining a high safety level which facilitates environmentally friendly transport.
The Rhine fleet mostly is vessels under the flag of Belgium, Germany, France, the Netherlands and Luxembourg. The Rhine Corridor includes Belgium, Germany, parts of France, Netherlands, Switzerland and Luxembourg. The Rhine corridor waterways comply with higher nautical standards than other waterways in the EU due to higher transportation demands and economy. There are around 5500 self-propelled cargo vessels under the Rhine class (Buck consultants international et al.,2004).
The Rhine class vessels and push convoys should fulfil a certain standard. which are announced by the central commission for the navigation on the Rhine (CCNR). For instance, in terms of the manoeuvrability and speed there are the following standards: minimum speed of 13 km/h in relation to the water in the ahead directions is required, stopping distance in still water which is around 305 m for ships with below 110 m LOA, stopping distance of 350m for-ships with 110 m LOA or more. It is noteworthy that the distance increases when navigating in downstream or running water up to 480 m and 550 meters respectively (Buck consultants international et al.,2004). The performance of the German registered vessels at the junction of the two rivers Elbe and Oder are the same as the Rhine certified vessels. They mostly have a Rhine certificate too.

5. Danube Inland Waterways

It is the second largest river after the Volga in Europe, and it passes through 10 countries and 16 important cites in the central and Eastern part of Europe such as Budapest, Belgrade and it is almost 2850 km long. The Danube river starts from Germany and ends in the Ukraine prior to joining the Black Sea. Its branches flow into more 9 countries. It is classified as Corridor VII in the European Union (Linnerooth-Bayer and Murcott, 1996).

5.1 Regional Characteristics of Vessels on the Danube

The main characteristic of the Danube class vessels is that they are mostly in the middle range, with a lower and an economic model size (Buck consultants international et al.,2004). In order to comply with the recommended standards, the pushed barges are different in size and capacity. For instance, the Danube Europe IIb is a class with a capacity between 1350 to 1500 tons and with a different draft between 2.3 to 2.5 meters. In the Danube corridor, because of its nautical conditions, the inland waterways vessels are larger than the Rhine river. Low water period in this region is the main reason that many old towed barge convoys (under certain circumstances) are still in service. On the lower and upper part of the Danube, where the allowable draft is less than 1.7 meters, at some locations, barges can be partially loaded to have a draught less than 1.3 meters (Buck consultants international et al.,2004).
On the Upper part of Danube, the length of single motor vessels is varying between 79-136 meters and the pushers' length is between 22-39 m. The typical draught of Danube ships is between the range of 2.3 to 2.5 meters according to the nautical status of the corridor.
Vessels with a length of 95 m (Steinklasse vessel) are typical Danube. But, vessels with a range of length between 105-110 m are the most common in this area (Prominent, 2018)
Most common vessels in the Danube area as per Fredenau lock records in the year 2014 are motor vessels between 94-136 meters length which amount to a total of 3199 vessels passage within this range far exceed another size (Appendix IV) (Prominent, 2018)
According to another source, the optimum length for a motor vessel to operate on the Danube is 105 m (FatCamel.sk, 2018).
On the Danube river, most dominant vessels in IWT are one pushed convoy with two, four or six barges in contrast to the Rhine where self- propelled ships are the most dominant vessels.
According to the Danube Commission statistics for the year 2010 (Graph 3), the self-propelled vessels, the pushers and the tugs account for 27% of the traffic. Just pushers and tugs alone account for 72% of the traffics. And, around 90% of the traffic is related to the pushers and barges, (a kind of convey) and Finally, 11% is related to the self-propelled vessels (FatCamel.sk, 2018).
To get a better picture, the below table and figures provide some technical information for a common type of motor cargo pusher on the Danube river.

Key data	
Length	95 m
Width	11.4 m
Side height	3.2 m
Draught loaded	2.7 m
Fixed point above base	6.5 m
Maximum tons deadweight	2,000 t
Hatch length	69.5 m
Hatch width	8.8 m
Fuel tank	110 m^3
Ballast tank	380 m^3
Potable water tank	38 m^3

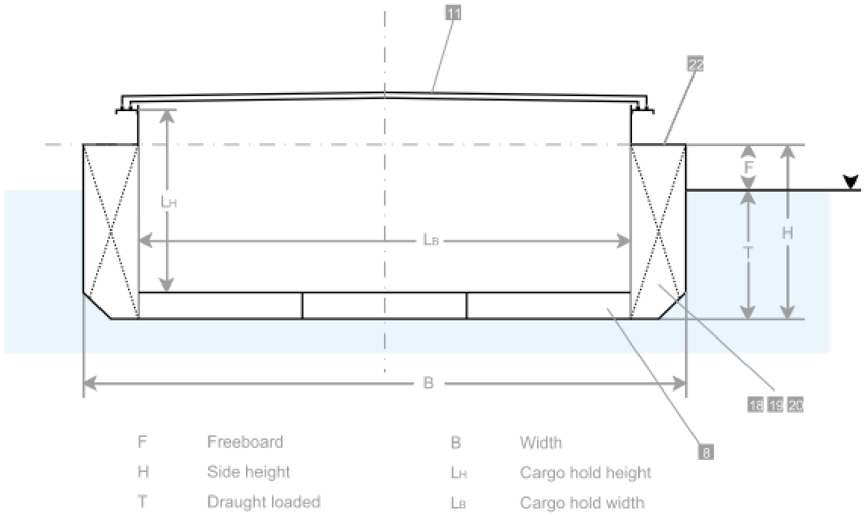


Table 3, the key data and cross section of a "DDSG-Steinklasse" motor cargo pusher
(Rewway, 2018) Source: Helogistics holding GmbH, via danau

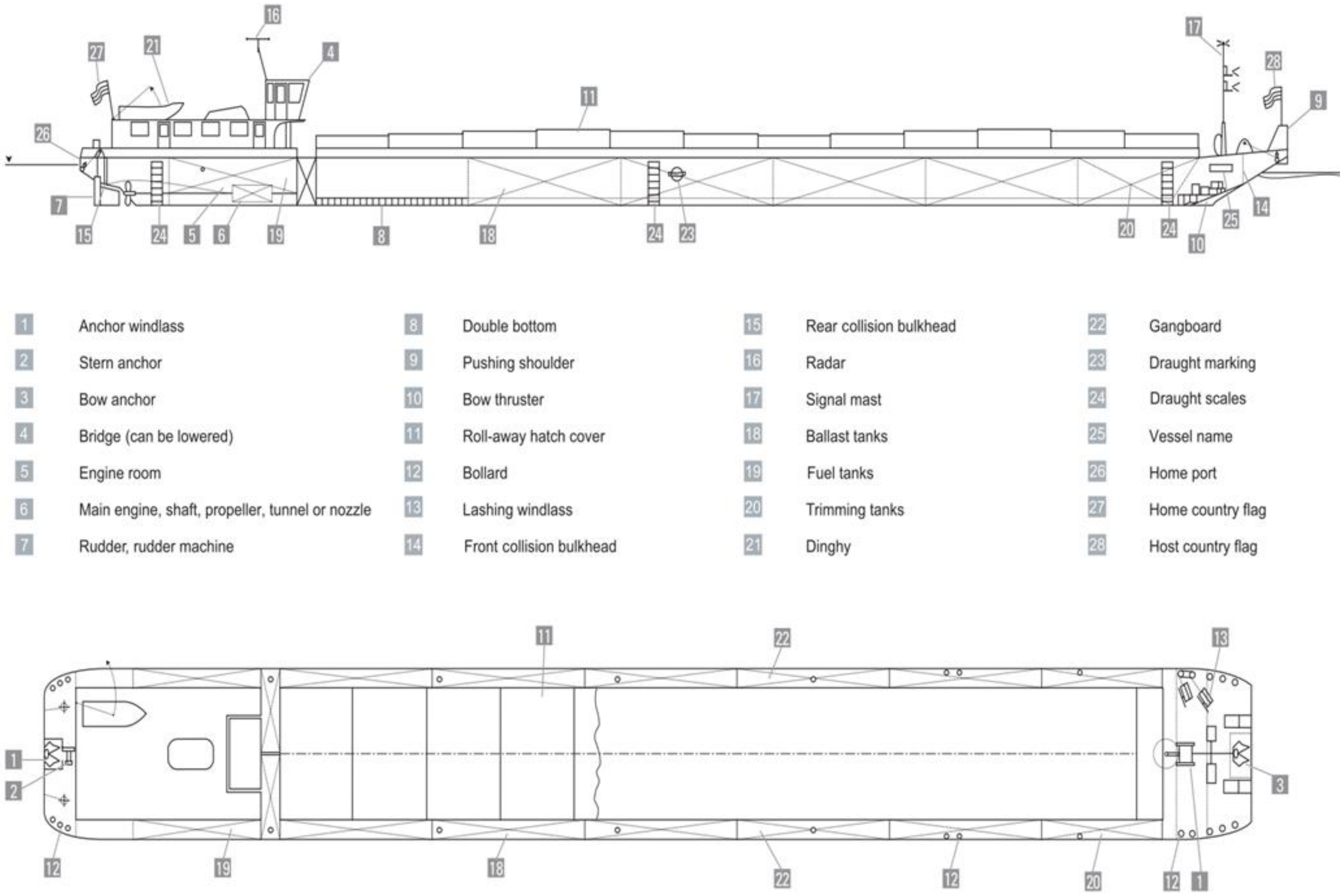
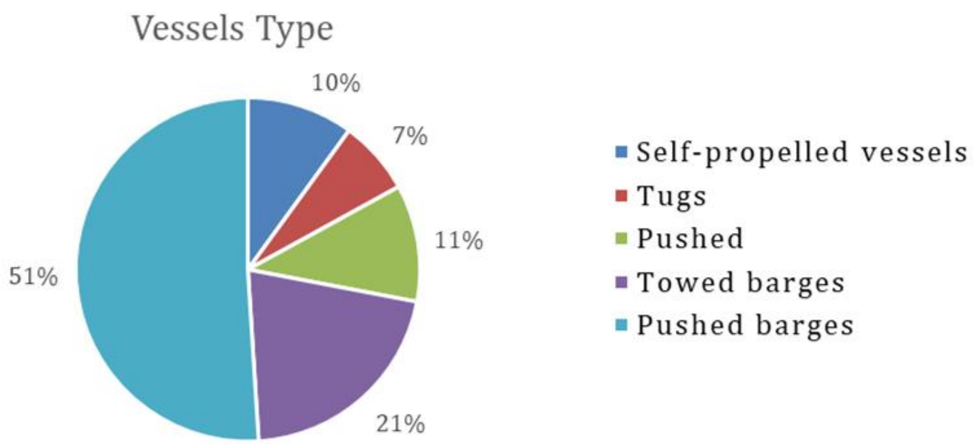


Figure 3, The most important components of an inland waterway vessel based on the example of a "DDSG-Steinklasse" motor cargo pusher (Rewway, 2018),
Source: Helogistics holding GmbH, via danau



Graph 3, the breakdown of the Danube fleet by vessels type for 2010 (FatCamel.sk, 2018).
Source: Danube commission, statistical handbook 2010

5.2 Vessels Characteristics on both Danube and Rhine in the Germany

In central Europe and the network of canals in the west part of Germany, particularly due to the high share of river Rhine freight transport, the Rhine fleet was developed over the time. This fleet consists of vessels exceeding 11.45 m beam and with many of push tow convoys which are not common in the adjacent waterways. The older type of inland waterways vessels was Peniche (Theodor Bayer), Gustav Köings (Dortmund Ems Canal bargea) and Europe Ship, the Johann Weker which some are still in use. Nowadays, as a result of improvement in the technology, new modern ships can work in the restricted canals and waterways in the North West of Germany and Danube which were under use of Johann Weker type, the Europe size ships (Institute, 2018).

A typical vessel trades on the other side of Germany, the Mittelland Canal, the Dortmund/Ems Canal, Elbe river (limited because of draft restriction) are provided by a German company which operates on the West-East corridor. That data reveals that the typical length of vessels, are between 67-80 meters with approximate loading capacity of 1000 tones. While barges are trading in the area with different length and formations. Source, Deutsche Binnenreederel (BDR9, "Gütertransport per Binnenschiff") (Appendix XI) (Prominent ,2018).

5.3 Regional Operational features of Vessels on the Danube

Most of the vessel transportation on the Danube is dominated by a small number of the fleet carrying 75% of the total freight (Prominent,2018). Most shipping companies originate from the former state-owned enterprises and traditionally transport bulk cargoes on long-term open base policies. According to the Danube Commission, the ships and push convoys should reach a speed of 12 km/h in relation to the water and with a stopping distance of 200 meters in upstream conditions and 600 meters in downstream situations. There is also a rough rule that says the ships should stop in relation to the water in three times of their lengths from full speed (Buck consultants international et al.,2004). With respect to engine power, the motor vessels with a length between 94 to 134 meters have an engine power between 600 to 1150 KW (Buck consultants international et al.,2004).
The seasonal shallow water in most parts of the Danube river causes that self-propelled vessels to be provided with a twin-screw system. But, in the Rhine, the same size ships with similar output are normally provided with single propeller because of the different nautical circumstances between the two corridors (Buck consultants international et al.,2004). In a relatively deep-water area, single screw systems are more economical. Consequently, the vessels with a single-screw system engine power between 700 to 1000 kW, 11.4 meters of width, and 2.5 m of the draft are technically feasible as well as economically justifiable. But, if such a vessel cannot use its full capacity due to draft restriction, over a long period of time it makes the vessel operation economically unreasonable. Therefore, to make these vessels economically and operationally viable, using two propellers with a smaller diameter which can be fully submerged at the lower draft, is the main option. That is the main reason why most of Danube self-propelled vessels have a twin-screw system despite having more expenses such as capital, maintenance, repair costs and fuel consumption compared to a single screw propeller on the Rhine (Buck consultants international et al.,2004). The Danube class vessels also operate in the rivers in the northern areas of Germany. The Danube is the second longest river in the EU after the Volga. Because of the geographical location of Germany in central Europe, both Danube and Rhine class vessels operating in Germany they have similar technical properties (Buck consultants international et al.,2004). The below figure shows the formation arrangements of the vessels which are common on the Danube corridors and around it.

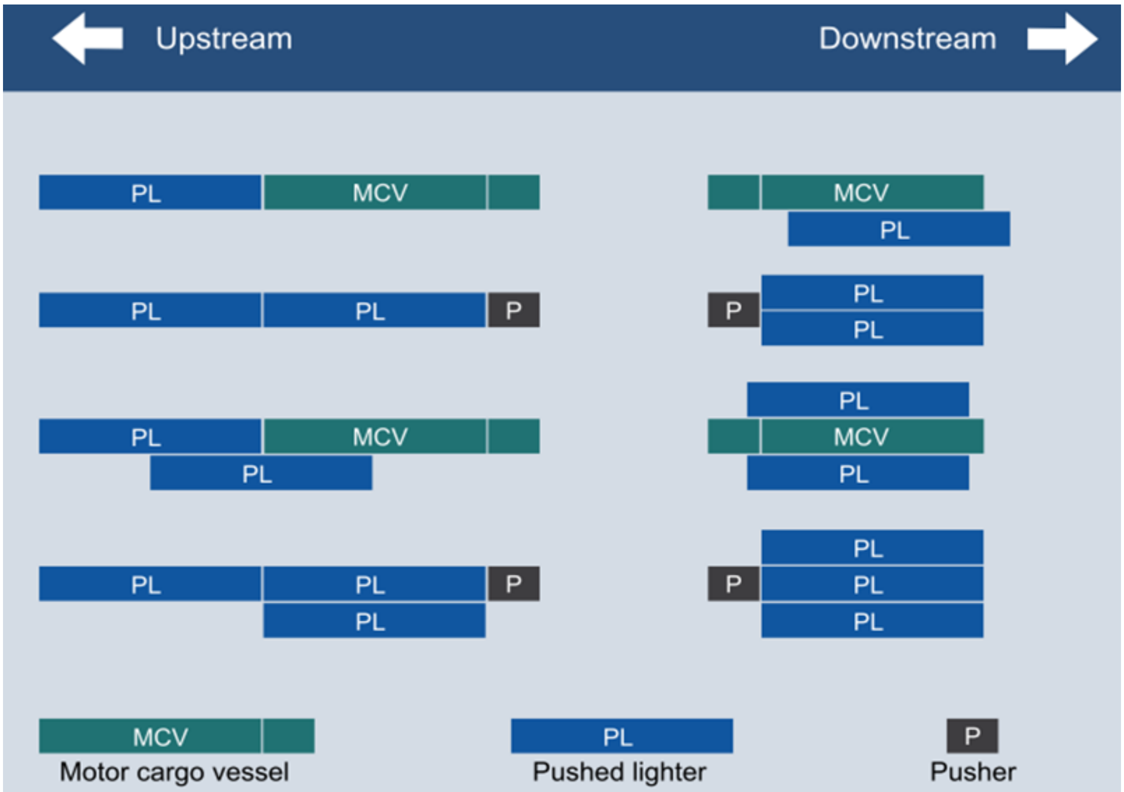


Figure 5, The arrangement of vessel formations on the Danube, Source: via donau (Rewway, 2018)

5.4 Next generation Inland Waterway Ship on the Danube (NEWS)

One of the regional Danube IWW ship designs is NEWS. The News is a novel IWW ship constructed in a project that aimed to build the next generation of European IWWs. The NEWS uses LNG-electric power for the propulsion system and will therefore see an increase in efficiency of 30%. It will also reduce fuel consumption by 10% due to new hull design. The purpose of the project was to reduce greenhouse gas emissions, pollutants and to facilitate a modal shift of goods from road to a more sustainable mode like IWT. NEWS, however, is mainly for the Danube region with the ability to carry 3 tires of the container in four rows and with the capability to trade in 80% of the European IWWs. The NEWS, moreover, is an innovative design with the ability to carry 360 cars in case of a custom design for a car-carrying ship which will increase transport efficiency in the Danube area by 56% and will reduce the operational costs of IWW transport. In terms of external costs, a rough calculation showed that the usage of NEWS highly reduces external and climate change costs (Sihn et al., 2015) .

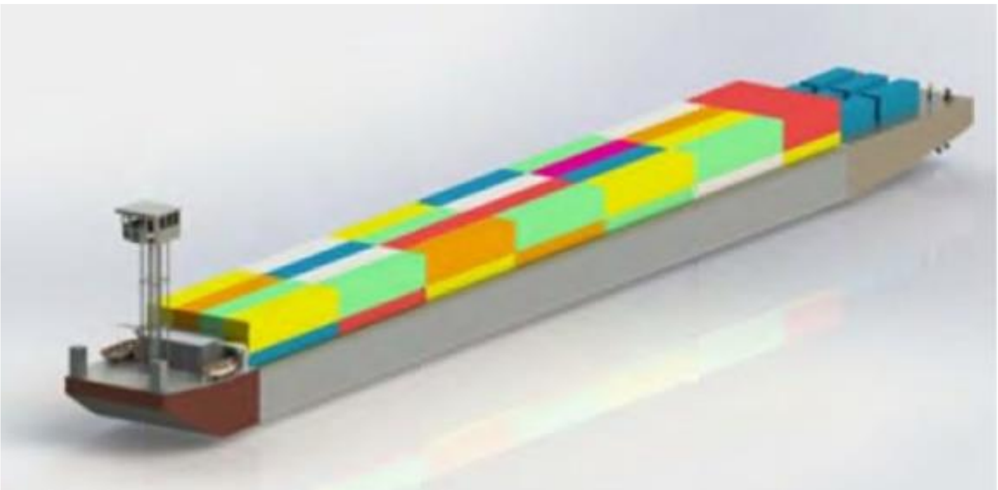


Fig. 4, Self-propelled vessel NEWS (Sihn et al., 2015)

6. Comparison of Rhine and Danube vessels

To do a safe manoeuvre particularly in heavy traffic areas or where the fairways width is restricted on the Rhine, most of the vessels are equipped with an additional steering system, (Buck consultants international et al.,2004).
The Danube vessels are required to go through a set of technical examinations to obtain permissions to sail on the Rhine which causes unnecessary technical burden and administrative work (Vaker, 2001). But recently the Danube specific built ships are genuinely meeting the requirements of the RVBR without any issues (Woehrling ,2002). The differences between the technical regulations are not so significant throughout Europe. These differences will not cause a financial problem for the shipowners from outside of the Rhine region to deal with the Rhine requirements or to satisfy Rhine authorities. The real problem seems to be in the five CCNR countries with respect to safety standards for the inland water operators. Otherwise, the other states will have a voice in the development and establishment of these standards (Hofuizen, 2002).
The Danube vessels are mostly equipped with conventional rudder blades, a usual system due to their better fairways width and spaces to manoeuvre. The push boats commonly are provided with flanking rudders to help them steer. Most of the self-propelled vessels on the Rhine are equipped with bow thrusters. The vessels with a length greater than 90 m, mostly have more efficient bow thrusters to deliver an appropriate side thrust (Buck consultants international et al.,2004).
Regarding barges, some of them are equipped with steering devices on the bows such as rudder blades on the GDP 54 barges which are normally working on the Elbe and around the canals or bow thruster. For instance, on the Europe II barges. Additionally, latest long-range push boats are provided with a more efficient bow thruster. In general, the self-propelled Rhine vessels and push boats have better power than the Danube ships. The reason behind that may be due to the German national inspection regulation on the Rhine vessels (RheinSchUO and CCNR). They are stricter than the Danube and the Elbe (BinSchUO). For example, the length of the stern anchors chain must be at least 60 meters while by the BinSchUO standards, it shall be a minimum of 40 meters. Or, a bow thruster for the vessels with a length greater than 90 is compulsory with minimal specification standards on the side thrust outputs without which there is no permission for that length of vessels to operate on the Rhine area.
The width of push barges in the Danube is 11m in contrast to the Rhine which is 11.4 m. The reason behind that is passing lock chambers allowance standards which are different in two regions. In the West-European countries, allowance is 0.6 meters, therefore, ships with a width of 11.4 m or 11.45 m can pass the locks with the chambers of 12 meters. But, on the Danube, in Iron Gates Lock, the allowance for max width is 34 m and convoy of barges with the breadth of 11 m are allowed to pass (3 barges in sides = 33 m). As a result, the standard barges' breadth is, 11m.
The Danube Push barge, the Europe II size have the same cargo capacity despite a 0.4 meters wider beam at the equal draft. Nowadays, vessels with a length of 135 m are allowed to operate on the Rhine, the requirement of which was previously 110 meters. The self-propelled container vessels with a length of 135 meters, a width of 17 meters and a capacity of 400 TEUs, and in four tiers of containers are regular on the Rhine. But, on the Danube, there are some specialized vessels such as Ro-Ro catamarans which are doing multimodal trailer transports. And, some pushed barges which are oversized in the beam by greater than 12 meters cannot cross some corridors.
On the Danube, due to its nautical status, the large inland container ships are not the same as on the Rhine. In the case of large container vessels, they will meet a lot of difficulties on the Danube and are therefore economically not viable.
The free trade regulation allows and facilitates trade among the various national unions in the EU and as a result, it has paved the path for inland vessels traffic & transportation among them or within the adjacent corridors despite physical barriers such as the route between the Rhine and the North-South corridor. But the vessels' equipment is compatible except for some formalities. When the Rhine ships pass through West Germany to the Elbe river, they face poor nautical conditions and cannot comply with the parameters of the Rhine GMS vessels. For instance, payloads, the lower speeds, the under power makes them economically unfavourable (Buck consultants international et al.,2004). In contrast,

when the ships are coming from the East towards the West on the Rhine corridor, vessels such as Elbe type vessels in Europe Size (2.5 m draught, 1300 DWT) faces difficulties on the nautical, administrative and economic hindrances (Buck consultants international et al.,2004).
There are some similarities in the vessels (or barges) which are trading on the Rhine and Danube corridors that increase the potential for the vessels' economic growth. For example, they have almost the same maximum length, draft, air draft, power, equipment and system. Additionally, there are some distinctive features between the Rhine and Danube vessels. The main feature is single screw ships on the Rhine and the same single engine on the pushed trains on the Danube. There are other differences, however, such as bow thruster requirement for the ships longer than 90 m for the Main-Danube canal etc. (Buck consultants international et al.,2004).
The below table shows the comparison between the two regions in terms of operational features and vessels' characteristics and the reasons behind those differences. In this thesis, the length, beam, draft and dead weight are considered as vessels characteristics and parameters such as navigational depth, speed, bow thruster, engine power, steering and propulsion system which may be different between the regions are considered as operational features, in a comparison between the two regions in the Rhine and Danube.

Parameters	Operational area		Reasons	
	Rhine	Danube	Rhine	Danube
Depth (Navigation depth)	3-5 m	2.3 - 3.5 m	Enough water depth	Lower water depth period due to seasonal shallow
DWT	Higher Tonnage Larger Vessels	Lower tonnage, Middle size vessels	Enough fairways depth Higher transport demands	Lower fairways depth Lower transport demands
Beam	Mostly 11.4 m	Mostly 11 m	lower lock chamber allowance	Higher locks chamber allowance
Length	Up to 135 m	More smaller ships, middle size	Higher transport demands more containerization	Multimodal traffic requirements Lesser containerization Lesser transportation
Draught	Higher draught than the Danube	Lower draught than the Rhine	Enough depth of fairways	Lesser depth of fairways
Speed	Minimum 13 km/h speed standard	12 km/h Is recommended	Stricter standards Denser traffics Economically viable (mostly single engine with a bigger diameter of the propeller)	Lesser standards Lesser traffic density Wider fairways more redundancy available (mostly twin-screw with high manoeuvring capability)
Bow thruster	One is compulsory for the ships longer than 90 m with certain thrust output specifications	Not compulsory	Smaller fairways width Denser traffic (efficient and safe manoeuvring requirements)	Wider fairways Lesser traffics and movements Less redundancy requirement (more space to manoeuvre. mostly two screws so lesser)
Engine Power	A generally higher power than the Danube	Generally lower power than the Rhine	Enough fairway depth Stricter inspections and standards, Economically viable	Lesser fairway depth (smaller propeller diameter requirements, Technically and Economically not viable with single propeller)
Steering	Mostly with additional system	Conventional rudder Push boats with Flanking rudder	Fairways width restrictions Heavy traffics (requires safer manoeuvring)	Wider fairway (more space so restrictions to manoeuvre around but lesser water depth)
Propulsion system	Mostly single screw	Mostly twin screw	Enough water depth (Less fuel consumption lesser maintenance More economical lesser capital and repairs)	Lower water depth period due to seasonal shallow (depth restrictions so higher manoeuvrability requirements)

Table 4, The operational characteristics and reasons behind. This is a compilation of information from (Buck consultants international et al.,2004), (prominent,2018), (Institute,2108) resources as well as personal knowledge and experience.

6.1 Key learnings from Rhine regional Characteristics

The key learnings from the Rhine region with respect to the vessels' characteristics can be their dimensions which are affected by the fairway's width and depth. The vessels have more draft because of adequate fairway depth and width which is a consequence of locks' chamber allowance. In addition, the higher market demands lead to larger vessels dimensions in the area. The common and most common dimensions of vessels and locks can be classified as per the below table and graphs.

	L (m)	W (m)	D (m)
Locks	110	12	1.8 - 3.7
Locks' Chamber Allowance		0.6	
Common Vessels	80 - 110	9.5 - 11.4	2.5 - 3.5
Most Common Vessels	110	11.4	3.5
Barges	110	11.4	2.8 - 4

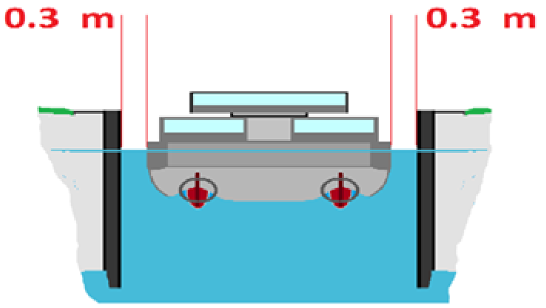


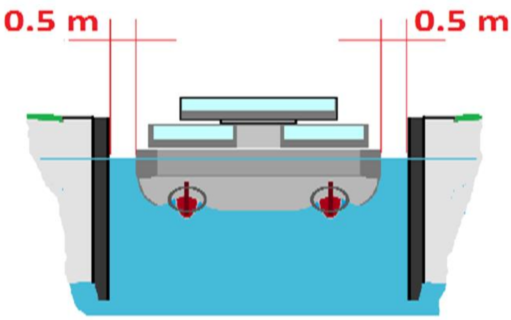
Fig.6, Summary of key learnings from Rhine Region

In terms of operational features, they are affected by the Rhine compulsory standards and requirements for the vessels, as well as to the fairways specifications and traffic density which demands higher safety standards and operational features such as single screw vessels due to having enough depth or one bow thruster requirement for vessels greater than 90 m due to higher safety standard considerations.

6.2 Key learnings from Danube regional Characteristics

With respect to vessels' characteristics, they are affected by the waterway's width and depth as well as to the lock's chambers allowance in the area. Furthermore, the size of the vessels is affected by the size of the market in the area. The common and most common dimensions of vessels and locks can be classified as per the below table and figures.

	L (m)	W (m)	D (m)
Locks	190 - 310	12 - 34	Variable
Locks' Chamber Allowance		1.0	
Common Vessels	67 - 95	8.2 - 11	2.5 - 3.5
Most Common Vessels	95 - 110	11.4	2.7 - 3.5
Barges	85 - 110	9.5 - 11.4	2.8 - 4



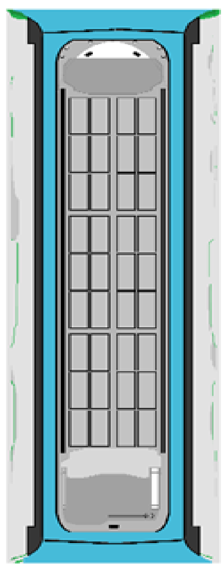


Fig.7, Summery of key learnings from Danube region

In terms of operational features, vessels are affected by the lower degree of market size, the standards which are less strict than the Rhine region. Also, the operational features took effect from fairways specifications such as two screw systems due to less water depth availability.

7. Type of Vessels trading in the EU Inland Waterways

There are different types of ships in inland water transport which may differ by the region of trade. But generally, they are three types of vessels that are trading in the IWWs. They can be classified navigational wise into:

- River-sea vessels
- Inland waterways vessels
- Smaller IWW vessels

7.1 River-sea Vessels

The river-sea vessels have the capability of sailing on both inland waterways and sea. They can operate in two different nautical conditions, in the river, canals, or coastal areas. The river-sea vessels are enabled to do direct transportation of cargo from an inland port, ideally from a factory or port through inland waterways to another seaport or factory port. This option of a vessel saves a lot of time and also eliminates a lot of expenses, risks of damage to cargo, etc. The main component of river-sea service is the navigable waterways, their dimensions (width, depth, bending radius) and infrastructures. For instance, the characteristics of navigable waterways such as dimensions of locks' chambers, the clearances under the bridges, the hydrographical conditions like rate of stream flow, the ice period and its severity, the differences between the level of high and low water tide etc (Buck consultants international et al.,2004). The river-sea vessels require special technical standards to deal with two different nautical conditions. They need to deal with sea and inland waterways conditions. Therefore, they require more additional features such as hull strength, longitudinal strength, stability, powerful engines, large fuel tanks, stern anchor, etc. By the river-sea vessels, destination port can be reached without intermediate seaport calls which save time and money. The isolated destinations such as Scandinavia IWW network will be linked by these types of vessels. They also release load from main seaports and other modes of transportation such as rail and road (Buck consultants international et al.,2004).

The river-sea vessels usually are facing some nautical bottlenecks such as bridge clearance, locks limitations, shallow water and rough sea conditions which restrict them to trade in some areas (Buck consultants international et al.,2004).

The common trade routes of river-sea vessels in Europe are inland waterways and the ports between Belgium, the Netherlands, Germany and rarely, some areas in Scandinavia and the United Kingdom. Other routes are around the Baltic sea, the Baltic countries, Scandinavia and a part of Russia (Buck consultants international et al.,2004).

There are two popular river-sea vessels type in Europe, which can be divided into the "West- European" (Western type) or EU type and the "ex-USSR" or Russian type (Eastern Type). The Eastern type was mostly built in the former Soviet Union and the Western type are mostly built in Germany and the Netherlands. The Eastern types or the Soviet Union types can be divided into the Volga-class, Sormovskiy-class and the ST-type. (Buck consultants international et al.,2004).

The Volga-class are in three versions and of relatively modern design like vessels in Russia and the third version being called" Rossiya".

The Sormovskiy-class faced a lot of modifications. She is the most manufactured series of river-sea vessels ever. Her main specifications, however, have remained constant in the last 25 years. The ST-type are built mostly in the early eighties (Buck consultants international et al.,2004). And the "Eurocoaster" is the modern version designed of "Cargo-Liner". Both have a very low air draft which makes them suitable and ideal for navigation in the numerous small waterways within the European network. The Western types mostly have elevating wheelhouse with the beam of 11.45 m which makes them more flexible for navigating deeper into the smaller waterways, smaller locks chamber and smaller bridges with lower clearance requirement (Buck consultants international et al.,2004).

Type	'Rhein'	'Weser'	'Elbe'	'Cargo-Liner'	'Eurocoaster'
Loa (m)	87.90	88.45	82.50	79.90	81.40
Bmax (m)	12.90	11.35	11.35	9.00	9.50
Draught (m)	5.50	4.94	4.79	2.99	3.10
Air draught (m)	12.60	12.60	9.30	4.60	4.50
DWT (tons)	3750	3000	2590	1360	1500
Output (kW)	1500	1125	1350	n.a.	700
Speed (knots)	11.7	11.5	12.8	n.a.	n.a.
TEU capacity	176	118	118	n.a.	75

Table 7, the main particulars of some typical river-sea ships designed in Germany (Buck consultants international et al.,2004).

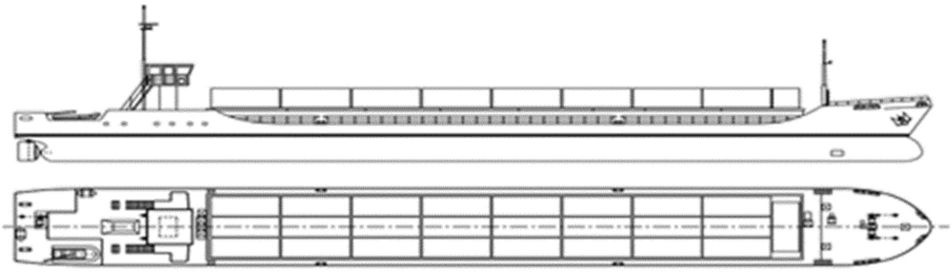


Figure 8, A general side elevation and deck layout of "Eurocoaster" class (Buck consultants international et al.,2004).

The Eastern types river- sea vessels with high and big superstructure with fixed wheelhouse are generally known as the larger and slower vessels in comparison to the Western types' river -sea vessels. They are mostly in five types as shown in table 4 (Buck consultants international et al.,2004).

Type	'Volga 1'	'Volga 2'	'Rossiya'	'Sormovskiy'	'ST'
Loa (m)	139.9	117.5	96.3	119.2	86.9
Bmax (m)	16.6	16.6	13.6	13.4	12.2
d (m)	4.5	4.4	5.2	3.8	2.7
DWT (tons)	5500	4480	3730	3100	1230
Output (kW)	2 x 970	2 x 970	n.a.	2 x 640	2 x 440
Speed (kn)	11.0	n.a.	n.a.	10.5	10.8
N° of TEU	140	104	122	~ 100	54

Table 8, The main particulars of some typical "Eastern" river-sea ships (Buck consultants international et al.,2004).

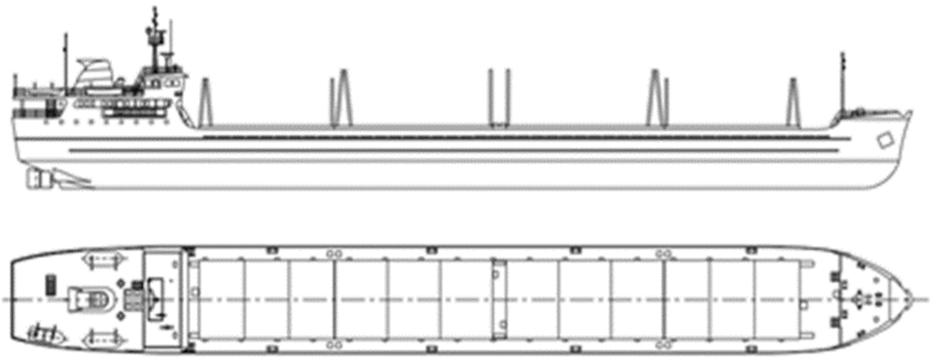


Figure 9, A general side elevation and deck layout of "Sormovskiy" class (Buck consultants international et al.,2004).

7.1.2 Key Learnings from River Sea Vessels

The European class vessels are more compact, and with a single engine which fits the purpose (Extracted from above tables) in addition four of them, dimension wise are suitable for the present locks size of the thesis project (In next chapter) area (Göta-Älv to Lake Vänern). In contrast, and dimensions wise the eastern type, are bulky and close to box shape, so in manoeuvring perspective, it requires two screws to handle the operations (Extracted from above tables) but with more redundancy availability. Furthermore, from the above table only ST type can be accommodated in the present locks' dimensions between Göta Älv to Lake Vänern. Therefore, as noticed totally from Western and Eastern type only, five of them can be fitted in the present lock's dimensions of the thesis area.
Additionally, these types of vessels can face winter climate conditions like ice. From a climate standpoint the project area is very close to the Russian climate conditions in terms of ice.

7.2 Inland Waterways Vessels

These are vessels which are suitable to navigate in the important and international inland waterways and some of them are also authorized to navigate both at sea and coast wise. Since the infrastructure in Western Europe is heterogeneous, there are huge differences in the size and compositions of the vessels. Due to the fairway's depth and width restrictions, the range of the inland water vessels in this region varies between 700 to 1000 DWT while in larger fairway's depth and width, larger vessels with 1200 to 3000 DWT are operational. Besides this, the extra-long vessels (uGMS) with 135 m length and beam of 11.45 m became popular in the last 15 years. Currently, more than 100 self-propelled vessels of "Jowi Class" with 135 m length, 13-17 m width and with 3000 tonnes or above deadweight are trading on the Rhine (Institute, 2018).
Since the container cargo transport has been increased in the EU, the size of IWW vessels on the Rhine and Danube areas are also increased. For instance, the largest vessels on the Rhine, Danube, Dutch and Belgian stretches, have reached135 m in length with 23 m of the beam. In case of push-tow, up to 6 barges convoy with 23 m x 270 m or 34 m x190 m, and average draughts between 3-4 m are trading. While in Europe the depth of the canals is mainly about 2.8 m (Institute, 2018). In order to obtain a greater size for the vessels, limited navigational depths and width of the channels are the bottlenecks (Söhngen and Kayser, 2010).
The push boats of barges in the EU are usually classified according to their total propulsion power. According to the RWS classification system (Rijkswaterstaat), they are classified like, a pusher with a 1 Europa II barge, a pusher with 2 Europa II barges, a pusher with 4 Europa II barges and a pusher with 6 Europa II barges (Panteia, 2013). For instance, A pusher with 2 Europa II barges usually has power between the range of 1000 to 2000 KW, pushers with 4 Europa barges have power above 2000 KW and smaller pushed convoys have a power equal to 500 KW or less than 500 KW (Panteia, 2013).
The pushers with 1 or 2 Europa II barges are more common between Belgium and the Netherlands (North-South corridor), whereas on the larger waterways, pushers with 4 Europa II barges are more common (Institute, 2018).
Furthermore, regional fleet constructions which are estimated in Hannover, Munster, Datteln, Duisburg regions by the year 2030 for self-propped vessel (Single driving or part of push-tow unit) are vessels with deadweight between1001-1500 (T) and for the pushed barges (lighter) (part of push-tow unit) are barges up to 1500 (T) (table in Appendix V) (Institute, 2018)
Therefore, the inland waterways vessels and their characteristics are governed by the navigational and nautical conditions of their operational regions.
An overview of the major role of the inland waterway vessel types and characteristics in different regions reveals that hydraulic phenomena and the size of new canal govern the speed and size of vessels (Verheij et al., 2008).

7.2.1 Regional Characteristics & Operational Features of Most Common Type of IWW Vessels

In this part, the vessels are categorized as per their dimensions, especially length according to the latest information regarding the possibility of a future lock's dimensions (In next chapter page) of the project area which is maximum 110 m and below, above 110 m and a separate common type and formation of barges in the area of Rhine and Danube.

The tables are prepared to illustrate common types of inland waterways vessels' characteristics and their operational features in some European regions such as the Netherlands, Germany, Belgium, around the Danube and Rhine. These tables present the most common types of the vessels which are trading in the above-mentioned regions with their important characteristics such as tonnage, draft, width, length and important operational features such as speed, steering system (rudders and bow-thrusters), propulsion system and engine power which have vital value for gaining speed, in the shallow waters. In addition, navigation depth of the operation areas.

The most common types of IWW vessels with a length 110 m and below

	Area		Vessels' Characteristics				Operational Features				
Parameters Vessels Types	Operation area	Depth - Navigating Depth (m)	DWT (T)	Draught (m)	Beam width (m)	Length LOA (m)	Speed (Km/h)	Bow Thruster	Propulsion system	Rudder	Engine Power (Kw)
PENICHE (TEODOR BAYER)	**Rhine** Germany - Belgium – Netherlands France	3-5	250-365	1.8-2.5	4.8-5.0	37.5-38.5	10-12	-	Single Screw	1 Blade	200
GUSTAV KÖINGS (Dortmund Ems Canal barge) Class III	**Rhine** Germany - Belgium - Netherlands	3-5	749-1300	2.1-2.8	8.2	67-85	14-16	-	Single Screw	1 or 2 Blades	580
JOHANN WEKER (Europe vessels = EV) Class IV	**Rhine - Danube** Germany - Belgium - Netherlands	3-5	1295-2000	2.5-3.0	9.5	80-105	15-18	-	1 or 2 Ducted	1 or 2 Blades	750
Large Motor Vessels (GMS) Class Va	**Rhine - Danube** Germany - Belgium - Netherlands	3-5	1660-2900	2.7-3.2	10.4-11.45	85-110	15-18	1	1 or 2 Ducted	1 or 2 Blades	2000

Table 9, The common types of inland water vessels on the Rhine, Danube, Belgium, the Netherlands and Germany and their characteristics. Table 9 is compilation from information of (Prominent ,2018), (Buck consultants international et al.,2004), and (Institute ,2018) resources. Photos from "Driving Dynamics of Inland Vessels".

The most common types of IWW vessels with a length greater 110 m

Parameters / Vessels Types	Area: Operation area	Area: Depth - Navigating Depth (m)	Vessels' Characteristics: DWT (T)	Draught (m)	Beam width (m)	Length LOA (m)	Operational Features: Speed (Km/h)	Bow Thruster	Propulsion system	Rudder	Engine Power (Kw)
Extra-long Motor vessels (uGMS) Class Vb	**Rhine** - **Danube** Germany - Belgium - Netherlands	3-5	2720-3500	2.8-3.7	11.45	110-135	15-18	2	2 Ducted	2 Blades	2000
Extra-long Motor vessels (uGMS) Wide beam - JOWI Class Class Vb	**Rhine**	3-5	2590-8400	2.8-4	13-17.5	110-135	14-16	2	2 or 3 Ducted	1 or 2 Blade	3000

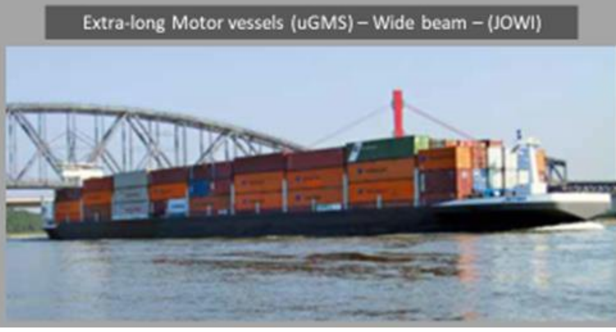


Table 10, The common types of inland water vessels on the Rhine, Danube, Belgium, the Netherlands and Germany and their characteristics Table 10 is compilation from information of (Prominent ,2018), (Buck consultants international et al.,2004), and (Institute ,2018) resources. Photos from “Driving Dynamics of Inland Vessels”.

The most common types and formation of IWW barges

	Parameters / Vessels Types	Area: Operation area	Area: Depth - Navigating Depth (m)	Vessels' Characteristics: DWT (T)	Draught (m)	Beam width (m)	Length LOA (m)	Operational Features: Speed (Km/h)	Bow Thruster	Propulsion system	Rudder	Engine Power (Kw)
Push-tow	Breasted-up/1 barge/Class Vb	**Rhine** - **Danube** Germany - Belgium - Netherlands	3-5	3740-5200	2.8-3.7	11.45	185-190	13-16	2	2 Ducted	2 Blades	2000
Push-tow	Breasted-up/3 barges/Class Vaa	**Rhine**	3-5	7920-10500	2.8-3.7	22.9	185	12-14	2	2 or 3 Ducted	1 or 2 Blades	2800
Push-tow	Breasted-up/4 barges/Class Vab	**Rhine** - **Danube**	3-5	7650-11000	2.8-4	22.9	185-195	12-14	1 or 2	2 Ducted	2 Blades or Flanking	3400
Push-tow	Breasted-up/6 barges/Class Vac	**Rhine** - **Danube**	3-5	11500-17000	2.8-4	22.8	270	11-13	1or 2	2 or 3 Ducted	2 Blades or Flanking	4500

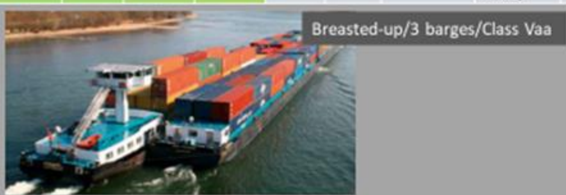


Table 11, The common types of inland water vessels on the Rhine, Danube, Belgium, the Netherlands and Germany and their characteristics. Table 11 is compilation from information of (Prominent ,2018), (Buck consultants international et al.,2004), and (Institute ,2018) resources. Photos from “Driving Dynamics of Inland Vessels”.

7.2.3 Key Learnings from IWW Types vessels

From the most common type of IWW vessels’ tables only four types of them, size wise are in the range of the future lock dimensions of the thesis project area (110 m and below) and in terms of the barge dimensions and formation, they are not suitable for the project area. In terms of the operational area their navigation depth is between 3-5 m, however, operational features are different as per regions of the trade. In addition, the project area in terms of navigation water depth are in similarity with the Rhine area, both areas have sufficient navigable water depth.

7.3 Small Vessels in the EU Inland Waterways

Picture 2, a typical small vessel for transporting containers (Meegen, 2018)

Smaller waterways (SWWs) in terms of volume, dimensions and utilization (in the current and future situation) play an important role in the feasibility of IWT operation on a lower scale and in the SWWs, smaller vessels have value for the regional IWT business. The congestion on the roads, acts as a push factor to bring more attention to using small waterways. Smaller waterways (SWWs) demands smaller vessels. But, in some countries such as Sweden with a well-developed railway network, this advantage is nullified or reduced (Buck consultants international et al.,2004).
According to CEMT, all waterways with classes above IV are considered as an important and international waterway. So, all waterways with classes below that, meaning the categories I, II and III may be considered as Small Waterways. The SWWs including canals, locks (with or without ship elevators) are frequently constructed. Locks with ship elevators create more restrictions on the small waterways and consequently reduce the operation efficiency. However, ships elevator may have recreational value (Buck consultants international et al.,2004).

The countries such as Belgium, the Netherlands, Germany respectively have the longest small waterways in the EU. Additionally, by the size of small vessels, with the maximum being 73 m in overall length and maximum 1000 tonnes in deadweight, the above-mentioned countries (Belgium, the Netherlands and Germany) have the biggest fleet respectively. The below table provides data on the length of SWWs and relevant infrastructures percentage in those countries.

Country	Total Length of Small Waterways	Percentage of Total IWW Infrastructure
Belgium	596	39 %
Netherlands	1802	36 %
Germany	1613	25 %

Table 12, the total length of small waterways in Belgium, the Netherlands, Germany: AVV, 1999 (Buck consultants international et al.,2004).

Country	Total Number of Small Ships	Percentage of Total Fleet
Belgium	1183	26 %
Netherlands	1850	41%
Germany	636	8%

Table 13, The total small fleet, active in 1999, under 1000 tonnes, below 73m Source: IVR, 1999 (Buck consultants international et al.,2004)

The Elbe, Oder and connected waterways links are smaller than the Danube and Rhine corridors. Therefore, smaller units in Elbe and Oder in the West-East corridor are optimized for the operation in extremely shallow water. Their payloads' coefficients are much lower than typical Rhine class. The Elbe and Oder's vessels are characterized by smaller vessels than Danube and Rhine corridors because of unfavourable fairways conditions. The longer period exposes the low waters and water level fluctuation leads to the smaller vessels with less draft. Consequently, the Elbe draft has a variable between 2 to 2.3 meters and in Oder between 1.5 to 1.6 meters. And, hydrodynamic effects of extremely shallow water in navigation influences on the average output of the small vessels. So, their power does not exceed more than 250 KW (Prominent, 2018).

In Belgium, Germany and particularly in the Netherlands there are smaller vessels due to smaller waterways. The small-scale ships from Belgium, Germany, the Northlands, Amsterdam-Rotterdam-Antwerp area (ARA) ports connections, etc. mostly operate on the upper side of Danube. For instance, pushers' characteristics of the NAVROM fleet have a length between 20.72- 34.66 meters, width between 7.78-11.04 meters and draft between

1.5 - 2.04 meters. They have two engines with a power between 2x300-2x1249 KW (Prominent, 2018). Another example is the characteristics of the RUBISHIPS LTD fleet. They have a length between 80.05 - 99.92 meters, width between 9-11.5 meters and draft between 2.5-3.09 meters. Their dead-weights are between 1240-1944 meters and all of them are self-propelled (Prominent, 2018). In Germany, the small vessels are considerably used for the commercial purpose (Buck consultants international et al.,2004). In this regard, in Belgium and the Netherlands, most of their SWWs classes are considerably used for commercial and intensively for the recreational purposes due to connections with the higher classes of waterways except class I which is low or negligible. Recently, in the Netherlands, a few of the modern Neo-Kemp vessels type have been built with limitations to operate in SWWs. The Neo-kemp or River Hopper pallet transport type ships or container ships can operate on some parts of Rhine and North-South corridors in the Netherlands. These ships are working with two crew on the small waterways of the dense network where operation by conventional size vessels is impossible. (FatCamel.sk, 2018). The table below provides more details about the application of small vessels in those four countries.

Country	Commercial	Recreational
Belgium	Considerable, low for class 1 or negligible	Considerable
Netherlands	Considerable, low for class 1 or negligible	Considerable
Germany	Considerable	Not available

Table 14, The small waterways system and their usage, extracted from (Buck consultants international et al.,2004).

In SWWs, using of push barge combinations might be possible but not popular for the passing locks. The combination should split up before locks and put back together after the locks. Therefore, it will become a hard characteristic. The German tugs and pushers on the Elbe have an output of about 350 kW (Buck consultants international et al.,2004).

Another point which is connected to the EU small rivers and canals, is that they are unstable in a large part of the year due to freezing cold temperatures. This cold may decrease the activities, attractiveness and in view of logistics chains, actually reduces reliability. An additional concern is, how the SWWs are integrated with the international network of IWWs. Are they connected directly or by an isolated sea route? (Buck consultants international et al.,2004).

Furthermore, for the professional use of SWWs, the maintenance and management of SWWs are vital. SWWs usage is declining within the last decade. Many countries are economizing maintenance and management costs. In addition, the tradition of a country or region and the authorities' policies plays an important role in the SWWs activity (Prominent,2018). The economic activity is the main driver of transport flows which generates transport demand. Consequently, spatial-economic location and economic activities around the small waterways (SWWs) have a great impact on the usage of SWWs as well as proper useful infrastructures around those economic activities.

The SWWs without ports and transhipment access points cannot play a high role in comparison to road transport. In general, the maximal loading capacity of small vessels cannot be guaranteed because of a lower loading coefficient. Meanwhile, small vessels hardly cope with their operating costs. Small vessels have less revenue and are limited due to the lower transport rate and trades. Logistically, the efficiency of the small ship is limited with their loading capacity, because they are too low to absorb the advantages of the normal IWW market. On another side, they are too large to replace the current truck size. The SWWs utilization is moderate and very low especially for class I. They are mostly for recreational purpose but sometimes for both heavy commercial goods and recreational transport.

7.3.1 The key Learnings from Small IWW vessels

Small vessels are mostly operating where there is regional importance. They have more recreational value than commercial importance. Small vessels mostly operate where there are shallow or extremely shallow waterways. Due to the lower scale their efficiency of operation and revenue is a matter of question. Additionally, the efficiency of small vessels requires appropriate ports, facilities and transhipment access points. Furthermore, they are mostly operating in a limited zone or region and do not cross their zones due to differences in the required standards of various zones.

8. Terminals and Ports

The inland waterways system network and infrastructures such as waterways, bridges, locks and relevant structures should be considered together with the framework components of IWT such as personnel, fleets, laws and regulations, etc.
The proper infrastructure network in the Netherlands, north of Germany and Belgium, provides good links with the hinterlands like the North Sea to the Rhine, the Black Sea to the Danube and, etc.
The nautical and infrastructural bottlenecks and restrictions in the size, draft and air draft, heavily affect the efficiency and competitiveness of IWT in the EU (Buck consultants international et al.,2004).
The water level fluctuations on the free-flowing rivers (such as the Elbe, Oder even Danube areas) and the difficulty of water level predictions have considerable effects on the reliability and utilization of the ships' capacities. Additionally, large variations in seasonal and deviations in nautical conditions such as severe winter and icing, floods, etc. are other issues which become a bottleneck. These variations are limiting the competitiveness of the IWT mode. Some of these bottlenecks have local nature and some have strategic concerns (Buck consultants international et al.,2004).
Most of the ports in these areas are integrated with roads and rails while some of them are involved in river-sea transport too. These ports, as modernized logistics centres are highly adding value to their customers; particularly around the Rhine and Danube corridors (Buck consultants international et al.,2004).
Ports of the Rhine are standing on the higher levels than elsewhere with respect to port facilities and throughput, length of jetties and number of cranes. In the Danube circle, the conventional inland ports have lower average throughputs with a lower rate of crane utilization.
The Danube ports in Germany and Austria partly have high-quality standards except for the container services which hardly exist in the middle and lower parts of the Danube. In these areas, containers can be handled by Reach Stacker with a rate of 45 TEUs in an hour.
Sites between the Elbe and Odra are heavily populated areas but the most annoying things for the operation in that area are harsh winter and ice conditions which cause difficulties for navigation in waterways and cargo handling at ports and consequently cause suspensions and difficulties (Buck consultants international et al.,2004).

8.1 Example for Terminals in the Netherlands, the MCS Terminal

As a part of the study visit, the MCS terminal in the Leeuwarden (Netherlands) was visited. MCS is one of the companies that are operating container terminals in the Netherlands. They focus on IWT as their core business and as a part of their whole transport service chains to the customers. The MCS company is also handling the road transport goods from customer to the terminals and from terminals to the destinations by different modes in addition to operating IWT vessels and IWT terminals, the MCS operates three IWT terminals in the Netherlands at the following places: the Meppel, Groningen and Leeuwarden.
The Meppel and Leeuwarden terminals are in the vicinity of two industrial areas in the Netherlands. The Groningen terminal is located nearby one of the main inland waterway routes. The location of the terminals has been selected carefully with the knowledge and consideration of the cargo flow rates

between the industries and the main ports such as Rotterdam, Amsterdam and Antwerp (ARA ports). The area near the border between the north of the Netherlands and Germany is also one of the markets for the MCS company.
The IWT terminal at Leeuwarden has one Gantry crane which is kept well maintained to avoid any stoppage or delay and with the benefit of high regular maintenance service. The MCS has enough storage capacity at the Kampen and Hengelo locations in addition to the storage capacity of their own terminals. This extra storage capacity acts as a valuable service to the customers, enables them to store their cargo outside their properties to avoid unnecessary costs. The MCS has gained a large share of the transport market by delivering regularly scheduled liner services to its customers (24/7). The MCS also is operating 10 ships under the charter contract which transport around 100,000 containers annually. Each ship has the capacity to carry around 156 TEUs of the containers. The MCS also owns about 100 trucks for the movements of cargoes and containers to / from the terminals.
The Meppel terminal is acting as the control centre for the road transports between the customers and all the MCS terminals. They control the road transport to / from three terminals in the Meppel, Groningen and Leeuwarden. This control centre focuses on the costs and speed in all stages of operation from planning to delivering the service to customers.
The MCS terminals also provide some added value services to the customers such as gas measuring, degassing operation, cleaning and drying, warehousing and AEO certification for the containers in addition to the storage or transport while the containers are in the terminals (from study visit ,2018).

8.2 Key Learnings from Terminal Operations

A good link with hinterland is important, in the Netherlands, Belgium and Germany most ports are integrated with roads, rails and some with sea transport as well. The Ports on the Rhine area have more throughput than the Danube and are equipped with proper facilities, services. Some of terminals monitor and track cargo from origin to destination

9. Inland waterways transport in Göta Älv – Vänern

The IWT in Sweden is in its early stages. Since 2014 the framework and technical requirements for the IWW vessels have been introduced by the authorities. But there has been not much improvement with respect to IWT in the country. There have been a few numbers of studies for a modal shift from road to sea on inland waterways of Lake Mälaren such as the EMMA project which essentially conducted a series of investigations on how to modify the IWW vessels in the EU for navigation in Sweden and at Lake Mälaren during ice period. this was done in the hope of, being able to enable and ensure the IWW trades' commercial viability as a logistic chain in the future (Emma ,2018). The EMMA project is expecting to promote in Sweden and hopes to see initiatives or commercial pilot projects to be launched within this project (Emma, 2018).
Additionally, other studies about IWT have also been done by the Swedish Avatar Logistics AB, Nöks2 project, and Inland Water transport solution (IWTS) by Interreg project.
To enable IWT on this route, knowledge and interested parties should work together. It seems that the IWT in this area, technically and economically is indeed a viable concept. This is because bulk transports already are running in the region. So, the main goal can be to establish and develop a commercial and sustainable logistics model shift for the potential areas such as the Göta Älv route. The IWT in this route has been studied by some shipping companies previously such as Orient line shipping company (Linien, 2018)
But, IWT business has never practically been started here in Sweden.
Furthermore, due to the geographical location of Lake Vänern which is located almost in the centre of Sweden close to more populated areas, it can be connected to the port of Gothenburg which is the largest port in Scandinavia and is connected to open sea via Göta Älv. There is enough fairways navigation depth for the entire route, along Göta Älv which has also been subjected to EU inland water shipping. It also involves a new project in the port of Gothenburg for the expansion of more facilities, and new bridges to facilitate IWW vessels trades (Marieholm bridge). The estimation of increasing container trade and operations in the port of Gothenburg makes this route commercially and technically,

a viable concept for the IWT promotion. The below picture provides a clear view of the geographical location of the project area.

Picture 3, The Göta Älv river, its connection to the Lake Vänern, open sea and port of Gothenburg, picture from SMA website and modified for this project area

9.1 Port of Gothenburg

Port of Gothenburg handles about 30 percent of Swedish foreign trade and is known as the largest strategic port in Scandinavia. This port is located on the west coast of Sweden and offers a broad range of services (Gothenburg, 2018).

Today, IWW vessels between the port of Gothenburg and the ports around (as well as ports in the Lake Vänen) are being used mainly for bulk liquid cargo (Gothenburg, 2018c). A significant change, however, in using IWW vessels in a wider range of cargo in this area, is expected. The intention and a new approach are to shift goods away from congested modes of transport to a lesser congested mode.

The Port of Gothenburg as one of the trade gates of the Scandinavian countries to the world, is geographically located at the end of Göta Älv river.

There are currently some ongoing projects for developing better and new services in the port of Gothenburg in Sweden. An example is the construction of a new terminal which started at Aredal in 2017 and will become fully operational by 2024. The depth of water in this new terminal will be around 10 meters. The area of the new terminal will be about 220000 square meters. The new terminal will be linked to the railway system and will have the ability to handle both ro-ro ships and container vessels with an estimation of handling 200000 ro-ro and containers units annually (Gothenburg, 2018e).

In addition to the infrastructural projects in the port of Gothenburg, in order to promote IWT, the port has introduced a discount of 25% on the port charges for the IWW vessels that are operating between Gothenburg and Vänern area, if they are classified as inland water standard vessels (Gothenburg, 2018d).

Port of Gothenburg predicts that the cargo volume will be increased from 900,000 today to 1,500, 000 TEUs per year in the future. So, they started a project in order to increase maximum depth for accommodating larger container ships. Today, transocean calls with container vessels handle about 3000 TUEs, 1500TUEs for loading, 1500 TUEs for discharging daily which even in this situation, there are some shortcomings (interview 1, 2018). In addition, another hindrance for IWT promotion is that the terminal in the port of Gothenburg, they are using same resources for handling small vessels as they are using for the large container vessels. As a consequence, for the feeder vessels and companies involved in IWT, the labour costs are not in a reasonable range to engage in IWT business.

Geographically, below table indicates the distance between the port of Gothenburg and the ports in Göta älv and Trollhätte Canal. This table reveals that those ports are within a close distance from the mother port (Gothenburg) and there is a possibility to act as a supplementary for the port of Gothenburg port.

Ports in Göta älv and Trollhätte Canal	Distance (Nm) - Between Gothenburg and the ports in Göta älv and Trollhätte Canal
Agnesberg	9
Surte	11
Nol	17
Lödöse	25
Trollhättan	44
Vargön	49
Vänersborg	50

Table 15, Distance between the port of Gothenburg and ports in the lake vänern, information from SMA website

9.2 Ports on the Lake Vänern

There are several ports on the waterways between Göta älv to the entrance of Lake Vänern**.** They are traditional ports and are not adapted to the inland waterway vessels. They don't have that kind of inland water terminals that are common in North Europe (interview 1 ,2018).
The Lake Vänern with 5600 square km is the largest lake in Sweden and the third largest lake in Europe. 22000 islands are located in the Lake Vänern. It has about 7000 km coastlines. Normally, and annually about 1500 commercial vessels and 16000 private boats are sailing in the Lake. It supplies drinking water for 700 000 people. Lake Vänern is situated at a height about 44 meters above the sea level and the controlling depth to Göta canal entrance, is 3 m. Vänersborg is one of the ports which is situated at the south end of Lake Vänern close to the Tröhatta canal. There are some other ports around the Lake which are situated in the north, west and east of the Lake such as kristinehamn and karstad in the northern portion. All ports are almost open throughout the year. There is some limited facility for collecting oily waste, but ship sanitation control is available in most of the ports in the Lake such as Vänersborg (office, 2015).

Ports in lake Vänern	Max Draught (m) (+/- water level)	Distance (Nm) – Between port of Vänersborg and other ports in Vänern	Distance (Nm) – Between port of Gothenburg and ports in Vänern
Gruvön	5.3	74	124
Skoghall	4.6	72	122
Karlstad	5.3	82	132
Karlstad (KMW)	4.2	82	132
Kristinehamn	5.3	82	132
Otterbäcken	4.8	68	118
Hönsäter	3.75	47	97
Lidköping	5.3	54	104

Table 16, Ports in Vänern Lake, distances between Vänersborg and ports in Lake and distances between these ports and port of Gothenburg, information from SMA website (Sjöfartsverket, 2018)

The Vänerhamn AB is one of the largest port operators which is operating several ports in the Lake. The Vänerhamn AB handles about 2.7 million tonnes of cargo annually, including 1.5 million tonnes of cargo which is usually transported by vessels and the rest of available cargos being transported by intermodal transport modes. The municipalities around Lake Vänern are the largest shareholders of the company (Interview 3 ,2018). The Vanerhamn AB company is handling most of the ports in the Lake and most of their activities are in the five ports of Vänersborg, Lidköping, Otterbäcken, Kristinehamn and Karlstad. The biggest port by tonnage capacity in the Lake is Lidköping which is engaged with about 460000 tonnes of cargo annually (interview 3 ,2018). The wood and paper products are the most exported cargoes from the Lake. Agricultural and petroleum products are next in the ranking of cargoes which are handled by the Vänerhamn AB company. In continuation, Kristinehamn port, operated less than 200 container operations by vessels in 2017 (interview 3). The Vänernhamn company owns ice-breakers and towing boats which are available near the ports. In general, and in a short**,** Vänernhamn provides logistics and transport solutions in a cost-effective way in these ports. In the logistics chain network, they provide all stage catering services such as forwarding and clearance, intermodal transport, storage, sorting, processing and packaging.

The Vänerterminalen at Karlstad is the largest centre in the area for storage and freight handling. This port is home of Vänerterminalen which is meant to store, distribute and reload paper products. The Vänerexpressen is a partner company which provides containerized goods transport from and to the manufacturers in central Sweden. The oil terminals are situated at Lidköping and Karlstad, and they store, trans-ship and distribute the oil products mostly for the industries in central Sweden. In brief, the main five ports have the following facilities:

The Vänersborg port: The harbour is close to the major highways, where the Trollhätte canal meets Lake Vänern. This port is specialized in bulk cargo with 4,500 square meters with warehouse and tow railborne cranes with 10 tonnes of lifting capacity as well as forklifts and loading equipment.

The Lidköping port, which is specialized in agricultural products, heating oils, solid fuels, road salt and pig iron. This port provides stevedoring, clearance and forwarding services. This port has 7,000 square meters of harbour warehouse, three railborne and one mobile crane. The Vanerhamn company in this port also arranges carriage of road freight as well as forklifts, loading equipment and bobcats.

The Otterbäcken port is the only natural deep-water port in Lake Vänern and is specialized in bulk cargo. It provides stevedoring, clearance and forwarding services. The port has 7,000 square meters of harbour warehouse with one fixed and two mobile cranes as well as a conveyor belt with the ability to load 500 tonnes per hour. They also have loading equipment, forklifts and bobcats. Karlstad is Vänerhamn's largest port which handles oil, paper products and timber. The port has 64,000 square meters of the warehouse with three rails borne, two fixed and one mobile crane and a heavy-lifting crane with a capacity of 200 tonnes. They have three km of rail sidings which is partly undercover as well as forklifts and loading equipment. The port of Karlstad already has one of the important requirements for being an IWW container terminal and that is having enough storage space. Also, in the port of Karlstad, bioenergy products and sometimes heavy lift shipment for the area are handled. The Port has 105000 square meters of open space storage. The port is connected to the railway and suitable roads for intermodal operation. It has mooring equipment and icebreaker tug (Ab, 2018). Anyhow, according to interview 3 in 2018, the Gantry crane in the port is out of order and old which cannot handle the container operations. However, the Kristinehamn and Karlstad ports are connected to railways, but unfortunately, neither of these ports nor other ports on the Lake have suitable and sufficient facilities for container operations such as Gantry crane or a suitable mobile crane to handle containers to act as container terminal (interview 3, 2018).

The Kristinehamn port is one of the largest ports in terms of, break bulk cargo, general cargo and timber. The operating company provides stevedoring, clearancing and forwarding services. The port has 17,000 square meters of warehouse with four railborne, one fixed and one mobile crane, as well as two km of rail sidings, forklifts, ice breaker and loading equipment (kristinehamn, 2018).

Also, the port has 96000 square meters of open storage area and is connected to the railways and good roads for the intermodal operations (kristinehamn, 2018).

The Location of ports of Kristinehamn and Karlstad are in the northern part of the Lake Vänern which makes them geographically suitable to be considered as a container terminal. Because both ports are connected to suitable roads and railways for intermodal operations and almost located in central and populated part of Sweden. The port of Kristinehamn has a good area for the stacking of the containers but with limited container crane lifting capacity. There is a jetty which is nominated for the container operation. This jetty has an issue of unsuitability for Gantry crane installation due to weaknesses of foundation as well as in the case of mobile lifting cranes, it should park at a certain distance from the jetty edge (interview 3 ,2018). There are spreaders and some other equipment for the container handling in this port but maximum lifting load capacity of available crane in the port is about 22 tonnes.

So, by considering the weight of spreader, it can lift containers with a maximum weight of 18 to 19 tonnes (interview 3 ,2018)

	Karlstad	Kristinehamn
Type of goods	Wood & Paper Products, Sawn Timber, Salt, Lime, Petroleum, Glass, Metals & Metal Ore, Heavy Lifts	Chemicals, Sawn Timber, Wood & Paper Products, Grain, Metal, Salt, Mill Scale, Others
Storage space	64000 m^2 warehouse, 105000 m^2 open space storage	17000 m^2 warehouse, 96000 m^2 open space storage
Container handling	Crane (Slow and limited lifting load) Gantry crane (old and out of order)	Crane (Slow and limited lifting load)
Services	Icebreaker and towing	Icebreaker and towing
Intermodal connection	Connected to the railway and road	Connected to the railway and road

Table 17, characteristics of Karlstad and Kristinehamn ports, compilation of information from the Vänerhamn AB website.

9.3 The Passage

In normal condition, sailing from Gothenburg to Vänersborg will take about 8 hours and from Vänersborg to Kristinehamn also takes about 8 hours. Time from pilot boarding to first lock southbound is about 30 minutes and time of journey to the Gothenburg port is about 8-9 hours.

However, prior to passing under the bridges, the pilot should make a call to the bridges 30 minutes in advance so that they give an approximate time of openings when the ship can actually pass the bridges. In general, there are not more than 10 to 15 minutes of delay. In practice vessels reduce their speed and adjust time for the passage. Seldom, there is a need to wait more than 15 minutes. The bridges are operated remotely from different places in Gothenburg, Trollhattan,etc .(interview 2).

The pilotage is available around the clock and 24 hours (interview 2 ,2018). Pilot rigging arrangements should be in strict compliance with SOLAS and the international Marine Pilot Association (IMPA Pilot Ladder Arrangement Plan) requirements. (Sjöfartsverket, 2018d)

24 hours prior to ETA to the Gothenburg Pilot Station, a preliminary ETA to Trollhättan KC station with the actual draft and air draft is required. After that, 5 hours ETA to KC station with the draft and air draft is required. Cancellation 3 hours in advance and changes less than 5 hours in advance will be charged (Sjöfartsverket, 2018d).

Pilotage will be arranged through the Swedish vessel reporting system (FRS) and all pilot ordering takes place via Trollhättan and Vänern pilot orders carried out by Trollhättan VTS.

Pilotage is compulsory for all category 1 vessels , the vessels carrying or have uncleaned tanks from last carried (liquefied gas,Liquid chemical as per MARPOL 73,supplement 2 Annex 2 Category A , B , C [vessels without double skin under cargo tanks], category 2 vessels (chemical tankers with unclean tanks and leaden oil tankers), category 3 (all Other vessels of 60 Length overall ,9 m beam or 4m drought over) and vessels carrying more than 5 metric tons of explosives. A checklist as per SMA shall be handed over to the authorities in the locks at Lilla Edet or Brinkebergskulle.

As per admiralty sailing directions, Baltic Pilot Vol 1, NP 18, 17th Edition published in 2015 by United Kingdom Hydrographic, the route between Gothenburg to Vänern Lake is a natural river course of Göta älv, which is canalised in some places. Maximum allowable speed is 10 knots, and while passing another vessel, the speed is reduced, the distance should be around 300 apart. Anchoring in the canal, marinas, and basins particularly near to the bridges, locks, submarine cables, pipelines are prohibited with exception of emergency cases (Office, 2015).

In route from Gothenburg to Lake Värnern, there are no shallow patches. The navigating depth is enough in the whole length of the route and there is no compulsory requirement of tug assistance at any stage of the route (interview 2 ,2018)

9.4 Locks

Annually the average vessels tonnage increases at a rate of 1 to 1.5 per cent, consequently investment in the IWT infrastructures is required to improve the high capacity of waterways and facilitate traffic of large vessels on the major ports.

On the other side, limitations of inland waterways such as locks, or canals require better ships and types of equipment to cope with the restrictions and to ease out the IWT (Institute, 2018).

A typical type of locks in Europe for inland waterways vessels is approximately 12 meters wide and with 110-200 meters long. Therefore, the size of vessels is limited to a maximum beam of 11.4 meters and a length overall of 110 meters. And, barges with a length of around 76 meters, along with consideration of depth limitation. The deadweight for the Europe vessels' (ES) is around 1500 tonnes, for the motor ships it is around 2200 tonnes and for the push barges (SV) it is up to 4000 tonnes (Institute, 2018).

The voyage from Gothenburg to Lake Vänern passes through six locks in three different locations, at Lilla Edet, Trollhättan and Bringeberskulle (Sjöfartsverket, 2018b). The depth at the lowest level is 5.7 meters at the entrance of the first lock. In addition, the vertical distance at the lowest point is 27 meters where passing the locks (Power Cables) (Sjöfartsverket, 2018b).

The vessels with an overall length of 87 meters, berth of 12.6 meters and a draft of 4.7 meters are a maximum size which can be accommodated into the locks under normal conditions. But a special local administration permission allowance can increase the length to 89 meters, a berth to13.4 meters and the draft to 5.4 meters (Sjöfartsverket, 2018b).

Additionally, in case of barge and towage, the maximum length should be 35 meters, the beam 10 meters, draft 3 meters and from the stern of the towing vessel to the end of towage not more than 60 meters (Sjöfartsverket, 2018).

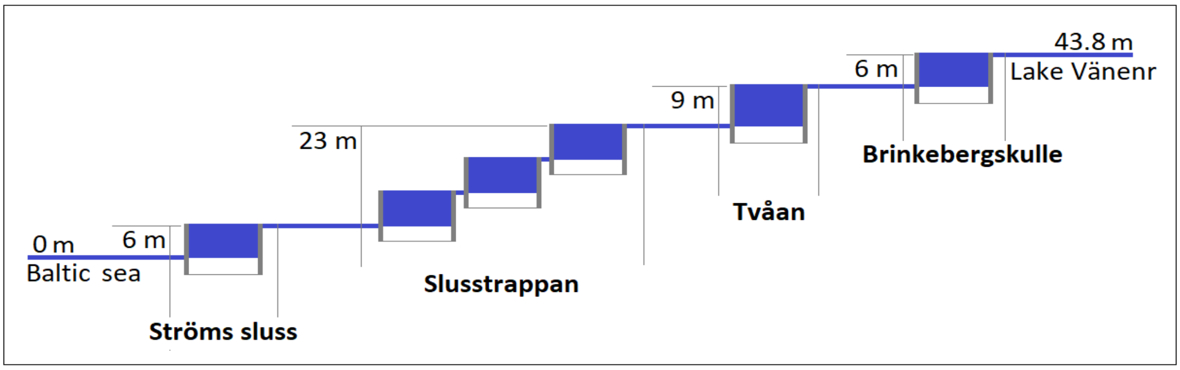
Vessels Passing the locks between Gothenburg – Lake Vänern	Dimensions (m)		
	Length	Berth	Draft
Max vessels in normal condition	87	12.6	4.7
Max vessels with exceptional permission	89	13.4	5.4
Barge	35	10	3
Barge with towage (from the stern of the towing vessel to end of towage)	60	10	3

Table 18, the maximum vessel and barges dimensions allowed to enter locks, information from SMA website.

There is a plan to make the locks between the route from Gothenburg to Lake Vänern larger in dimensions. But they are limited to a maximum draft of Göta älv which is between 5 - 5.4 meters and that cannot be changed. Because it is not possible to dredge the river as there is a problem with land sights and other limitations with the bridge of Marieholm (interview 2 ,2018). Therefore, the width cannot go more than the maximum width of the Marieholm bridge. The beam of new locks cannot be more than 16.5 meters because of the railway bridge at Gothenburg, the Marieholm bridge which is only 22. 5 m wide and the vessels with beams larger than 16.5 m cannot pass the bridge. So, the width of the locks will be around 17.5 meters. The length of the locks will be around 105 meters and the max draft will be 5.4 meters. The locks longer than 110 m will not be practical because of the topography of the ports in the Lake in terms of the jetties length and turning allowance for the vessels in the ports while pilotage or manoeuvring (interview 2 ,2018). Unfortunately, there is not official information regarding the lock's precise dimensions yet. It is a long-term project, and the new locks will be ready by 2030 (interview 1,2018).

Operating heights and locations of the Locks in Göta Älv and Trollhätte Canal		
No	Place	Height (m)
1	Brinkebergskulle	6
2	Tvåan	9
3	Slusstrappan	23
4	Slusstrappan	
5	Slusstrappan	
6	Ströms sluss	6

Table 19, the Locks locations and heights, information from SMA website (Sjöfartsverket, 2018b)



Graph 4, the Locks locations and heights, information from the SMA website.

9.5 Bridges

Distance from Göta älv to Trollhätte canal is about 82 km long with 12 bridges which one of them is not openable (28 meters clearance) (Sjöfartsverket, 2018b). The bridge's clearance from water level varies in height from 45 meters to the lowest point of 2 meters. The table below provides the heights of clearance from bridges.

No.	Bridge Name	Height under the bridge (m)	Closing time (HRS)
1	Älvsborg bridge	45.0	
2	Göta älv bridge	18.3	0600-0900 & 1500-1800
3	Marieholm bridge	5.9	-
4	Angered bridge	47.0	
5	Jordfalls bridge	11	-
6	Lilla Edet bridge	10	-
7	Klaff bridge	3.5	-
8	Railway bridge	2.8	-
9	Stall bridge	28.0	Not openable
10	Grop bridge	4.0	-
11	Railway bridge	2.0	-
12	Dalbo bridge	15.5 - 17.0	-

Table 20, bridge names and their heights clearance between Göta älv and Trollhätte canal, information from SMA website (Sjöfartsverket, 2018b)

There is a new bridge under construction at Gothenburg, the Marieholm bridge which is supposed to facilitate IWW vessels trades with the possibility to open 15 times a day (Interview 2, 2018). For the last past ten years, this has been rather increasing in the number of railway transports. Ten years ago, the Marieholm bridge and railway bridge at Vänersborg, they could be opened all night. They were not many trains passing. But today we have transports which are going 24 hours. So, the times when vessels can pass has been reversed from before, where ships could pass almost at any time. But nowadays it is harder, and trains pass whenever they want. There should be the same level of treatment for all modes of transport in the country (interview 2, 2018)

9.6 Climate

9.6.1 Ice

A local bottleneck such as a climatic condition, is the long-lasting ice in winter times which severely reduces the potential of transport in the Scandinavian waterways; and may have an effect on local business and in a wider range, may affect the path of transport routes, on a part of a given network or even on the entire national or international network (Buck consultants international et al.,2004).
The influence of ice on the IWW vessels is still under research and there is a lack of data in this field. Existing studies in terms of sea ice cannot be applied directly for IWW vessels because IWW ice thickness varies in different waterways. The EMMA project is conducting research on this subject at Lake Mälaren for ships to operate in light ice winter conditions without bringing IWW vessels under ice class design regulations. SMA is also interested to find out the differences between sea ice and IWW ice conditions. Based on the study, if ice thickness in a particular region became predictable that gives

IWW vessels to establish the suitable time window for navigation in that specific region during light winter, and as result, the IWT business will be improved significantly in the icy areas (MengZhang, 2019).

Ice creates challenges for inland water vessels such as ice load on the vessels, and on the structural strength of ships, the influence of resistance increases due to ice in the operations, the sufficiency of the propulsion capacity, etc. Consequently, the load impact of ice in the region on inland water vessels is required to be studied. In order to make sure that structural integrity and safety are maintained, corrective measures should be considered such as increasing the thickness of the plates, increasing the numbers of the frames, etc. In terms of operation, the resistance of the ice on the vessels body depends on the ice thickness in the area. This resistance has a significant effect on vessel performance. Therefore, the potential problems for propulsion which may arise such as speed reductions due to ice resistance and delays should be considered. Therefore, the structural and machinery requirements for dealing with such a situation should be minded prior to make decisions on the design (Emma, 2018).

The Swedish Maritime Administration uses Finnish-Swedish Ice Class Designation requirements. The maximum ship's draft should not be more than freshwater summertime load line draft as per Finnish-Swedish Ice Classes TSFS 2009-11(Administration, 2018).

There are certain requirements as below for a vessel to ask for icebreaker services by SMA.

1- Ship should have ice class II and with the minimum deadweight of 2000 tonnes.

2- Traffic restriction will be tightened up, in severe winters, the requirement is ice class 1A with the minimum deadweight of 4000 tonnes and can be supplemented according to the load and unload cargoes in the ports.

3- The Following table provides the minimum class and minimum deadweight requirements as per class.

Minimum Ice Class	Minimum DWT
II	2000
IC	2000
1B	2000
1A	3000
1A	4000
1A	3000
1B	2000

Table 21, Minimum ice and deadweight class requirements for ice breaker service, information from SMA website (Administration, 2018)

4- To get icebreaker assistance, vessels should be equipped with a powerful searchlight.

5- In a certain condition, may an exemption be granted just for one voyage if the vessel has the capability of ice breaking through an application, but not in the case of a 20-year-old ship or having transit cargo on board (Administration, 2018).

There is a regulation regarding ice class for ships which applies to any vessel whose keel was laid down or was completely built by 1st Jan. 2004 or later, which is mandatory for traffic on the Lake Vänern (TSFS 2009:23).

If the vessels have another ice class notation, according to Swedish Ice class requirements, they must have one of the below ice class notations. (Administration, 2018).

Ice Class Notation	Equivalent Finnish-Swedish ice class
IBV	IC
ICV	II

Table 22, Ice class requirements for Lake Vänern, information from SMA website (Administration, 2018).

In general, vessels can expect to have the assistance of icebreakers if they have minimum requirements and deadweight as per the specific region which is imposed by SMA or equivalent ice class notations. Noticeably, the Executive Board of the Finnish and Swedish Ice-Breaking Services decided that “tugs with barges (barges connected with cables or hawsers) and so-called river vessels are not suitable for winter navigation and cannot count on the state icebreaker assistance, even if they have a relevant ice class granted by their classification society” (Administration, 2018).

The canal normally freezes during the winter for 50 days between December and March, in severe winter like 100 days of presence of close packed ice. The canal, however, and despite this, is open throughout the year with certain limitations on the tonnage during the ice period (Office, 2015).
It is difficult with ice to manoeuvre or navigate from January to March partly because of ice on the Lake Vänern and rivers around. There is ice almost every year, but the intensity is different (interview 1, 2018).
To get an overview of the icebreaker service, all ships calling Sweden should pay fairways dues in which icebreaker service is included. So, these fairway dues are financing the icebreaker services and there are no additional specific fees for the icebreaker services (interview 1). During winter larger vessels have more problem for crossing the locks than smaller vessels. But, on another hand, if we consider the whole passage, the larger vessels have more power and act better. in the event of an unlucky situation, vessels stocked in the southbound route while icebreakers are operating on the north part, should wait until ice breakers come down all the way through the locks. Usually during ice season traffic is down, because only strong vessels with appropriate ice class notations can trade in the area (interview 2, 2018).

9.6.2 Fog

The route is always open to traffic. During summer a lot of leisure boats pass the areas (interview 2, 2018). During summer times, and early in the morning on a typical summer day which is a warm day, the air gets moist and when the temperature goes down in the morning around 02.00 or 03.00 o'clock the fog set in and lasts until 08.00 or 09.00 o'clock, mostly around the E45 (buoy), the way is completely foggy while conditions on the landside is not foggy. Depending on the season, there could easily be a delay of 5 to 6 hours due to thick fog and vessels would therefore as a result then need to stop and wait for the visibility to improve (interview 2 ,2018).

9.6.3 Current

Because of power plants in the passage, the water flow in the canal is affected and the current reaches to a maximum of 2.5 knots in some places (Office, 2015).

9.6.4 Wind

There is no seasonal bad weather in this area or during part of the year. Windy conditions have not been an issue, on this route (interview 2,2018).

9.7 Regulations

9.7.1 IWW National Regulation (IWW Zones)

The EU inland water rule has been introduced in Sweden since Dec. 2014. and in the hopes to improve inland waterways shipping (Gothenburg, 2018g).
There are four zones which are classified according to wave heights. Where zone one has the largest and zone 4 the smallest height of waves "

- Zone 1: The significant wave height is no more than 2.0 meters.
- Zone 2: The significant wave height is no more than 1.2 meters.
- Zone 3: The significant wave height is no more than 0.6 meters.
- Zone 4: Wind waves do not occur" (Transportstyrelsen, 2018).

This decision is made by the member states in terms of territories, zone and water areas. The zones and the relevant wave heights are classified as per below:
"Zone 1

- Lake Vänern, to the south bounded by latitudinal parallels through Bastugrund's hake.
- Göta River and Rivafjord, to the eastbound by Älvsborgsbron, to the west of the longitudinal parallel through the lighthouse of Gäveskär, and to the south of the latitudinal parallel through the lighthouse of Smörbådan.

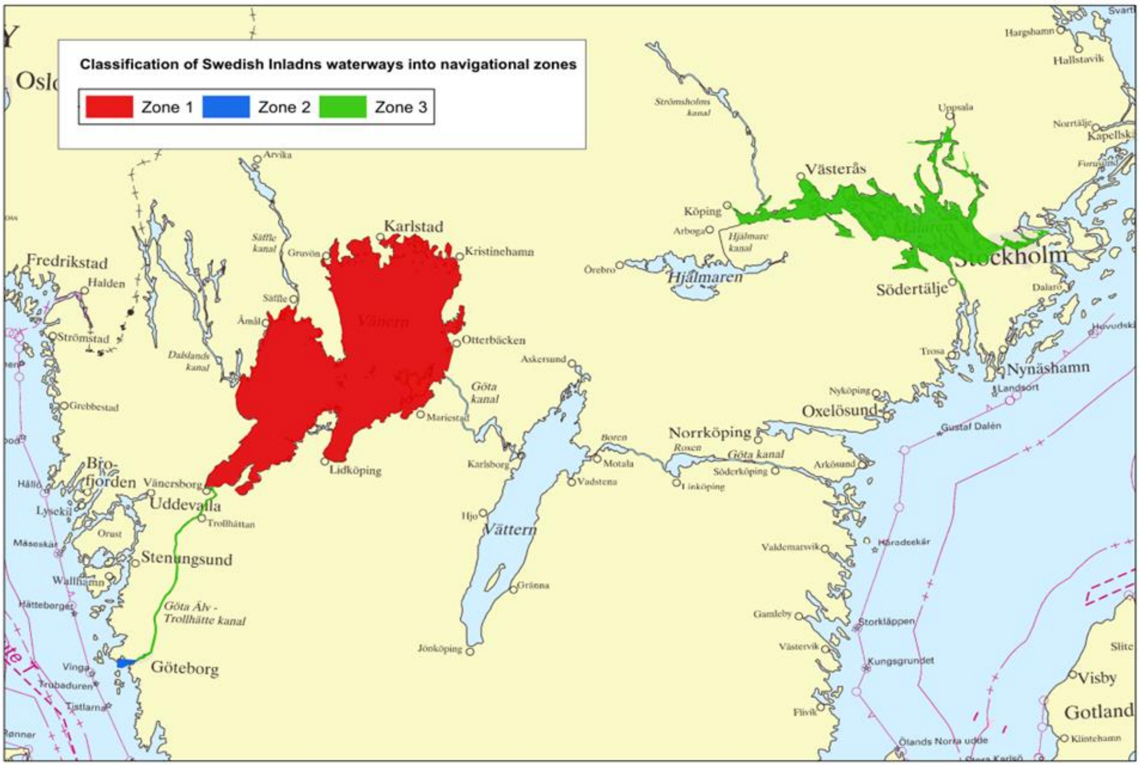
Zone 2

- Göta River, Eastbound by Götaälvbron, and westbound by Älvsborgsbron.

Zone 3

- Trollhättet canal and Göta älv, from latitude parallel through Bastugrund hake to Götaälvbron.
- Lake Mälaren.
- Stockholms port, in the northwest, bounded by Lidingöbron, in the northeast of a line through the lighthouse Elfviksgrund, carrying 135-315 degrees, and in the south of Skurubron.
- Södertälje canal and Södertälje ports, to the north bounded by Södertälje sluss, and to the south of latitude parallel N 59 09.00.

This rule applies to Lake Värnern, Lake Mälaren and the Göta Älv river in the form of those zones and according to wave height and technical requirements for ships trading in those zones."
"It is thus only in these water areas that it is possible to carry out traffic with ships certified for inland waterways. See map of the zones in Sweden" (Transportstyrelsen, 2018).



Picture 4, Zone 1, 2, 3 areas for IWW vessels trade in Sweden, (Transportstyrelsen, 2018)

Some coastal areas are under analysis which may result in additional water areas to be classified as inland waterways (Transportstyrelsen, 2018).
However, some issue like the level of crewing and pilot obligation remains. The crewing is not related to the number of the crew but mainly to the knowledge of the ship's master (Port,2018a).
In addition regarding inland water vessels trading in the area, the Swedish transport agency is responsible for the regulations and right now they are investigating how to make the inland water areas larger to include or connect Gothenburg with port of Few Borden (large oil terminal) or Lake Mälaren with the new container terminal, and the Novick on the east coast as well as to Malmo (interview 1 ,2018).

9.7.2 Local requirements for Maximum size Vessels to pass the Locks

Local requirements and recommendations about manoeuvrability and visibility of max size vessels for passing the locks such as rudder, engine power, navigation bridge and bridge equipment, have been established by the Swedish Maritime Administration (SMA), where an application form must be filled and handed to the authorities by all Max size vessels prior to passing the locks (Appendix XII) (Sjöfartsverket, 2018c).

9.8 Cargo flows

Assessing the type, amount and flow of goods for transport at the present situation is crucial to foresee the market demands for IWT within the route Göta Älv – Lake Vänern. Obviously, any route is not limited to transport of goods between start and end of the route, meaning that there is some percentage of the goods that are transported via a certain route as a part of their journey. Therefore, finding accurate figures regarding type, amount, flow, location and destination of goods that may be transported by IWT within the route Göta Älv – Lake Vänern is not easy. Additionally, there are always some hidden customers with a demand for transport that will be seen when the business is promoted.
For purpose of this research that is not focusing on the availability and flow of the cargo, only some figures regarding cargo flows were gathered through interviews and by referring to the presented official figures on the website of Vänerhamn company.
Vanerhamn AB company is handling over 2,7 million Metric tons cargo annually including heavy lifts, raw materials, refined products in the form of liquid cargo, bulk cargo, general cargo and containers. IWT seems to be the most suitable way for the transport of heavy lifts such as machine parts, tanks, parts for wind turbines. Port of Karlstad is equipped with a heavy lift crane in the Lake.

9.9 Echo Bonus

For the EU countries there are some guidelines for inland water navigation, the noncompliance of which will cause problems with the European Commission. At the moment, the government is trying to establish an Eco bonus system for paying a bonus to cargo owners who shift parts of their cargo transport or the whole it from road to sea according to a certain standard within the EU guidelines and requirements. This system cannot last for longer than three years, for which the Swedish government has approved 50 million SEK per year for a three-year period. Such a system has now existed in Norway for almost two years and in the UK and Italy as well. The authorities are still waiting for the Eco bonus to be approved by the EU Commission (interview 1 ,2018).

9.10 Key Learnings from Route Göta Alv to Lake Vänern

To grasp a clear view of the key learnings over the project area, the findings of the project area are classified in the form of a SOWT chart analysis. Therefore, it is obvious that the priority is to deal with threats and weakness for the promotion of IWT in the area.

Strengths - Location of Vänern - Connected to Port of Gothenburg and open sea via Göta Älv - 7000 km coast-lines - Number of ports in close distance - 1500 commercial vessels and 16000 sailing boats annually - Industries around - 2.7 million tonnes cargo operation annually by Vänerhamn company (1.5 m by vessels) - Enough navigation depth	**Weaknesses** - 44 m above the sea - Size of locks - Lack of suitable cranes for the container operation in ports - Lack of facilities in ports at Lake Vänern - Lack of facilities for IWW container vessels at Port of Gothenburg - Bridges (operation, air draught) - Weak IWW vessels operation (numbers) - No ship to ship transshipment - Bulk liquid transported by river-sea instead of IWW vessels - Lack of skill
Opportunities - Subjected to EU Inland water shipping - Eco bonus - Congestion of road & rail - New projects in the port of Gothenburg - Hidden cargo flow possibility - Port of Gothenburg: largest port in Scandinavia, 30 % Swedish foreign trade - Increase in container trades is expected	**Threats** - Regulations (pilot compulsory) - Fairway and pilotage dues - Uncertainty about cargo flow (lack of interest) - Lack of interest in investment - Climate condition (especially ice & fog) - Supply of 700.000 people fresh water - Accidents in the passage

Table 23, the SWOT analysis of the project area

10. Recommendation

The opportunities, market potential and demands for IWT in this area (Göta Älv – Vänern) have been discussed previously in this thesis by referring to other reports and interviews. Enough depth and width of the passage and enough depth in the ports around Lake Vänern, and position of the Lake in Sweden makes project area a viable potential for transporting cargo between the ports in Lake Vänern and the port of Gothenburg by IWW vessels as well as via direct transport between ports in Lake Vänern and North European ports by a wide range of river-sea vessel. Obviously, there are some barriers and operational requirements that must be eliminated to achieve the expected share of goods transportation by IWT in this area.

In this chapter, the gathered knowledge from interviews, study visits, studied literature regarding IWT in the North European region and Sweden as well as the knowledge from the authors' own experience has been applied to discuss the prerequisites and propose some recommendations for an efficient operation of suitable vessels in the route Göta Älv - Lake Vänern.

Despite relevance between some of the required features for the vessels and operational requirement for IWT, in this thesis, it has been preferred to divide the requirements into two different categories:

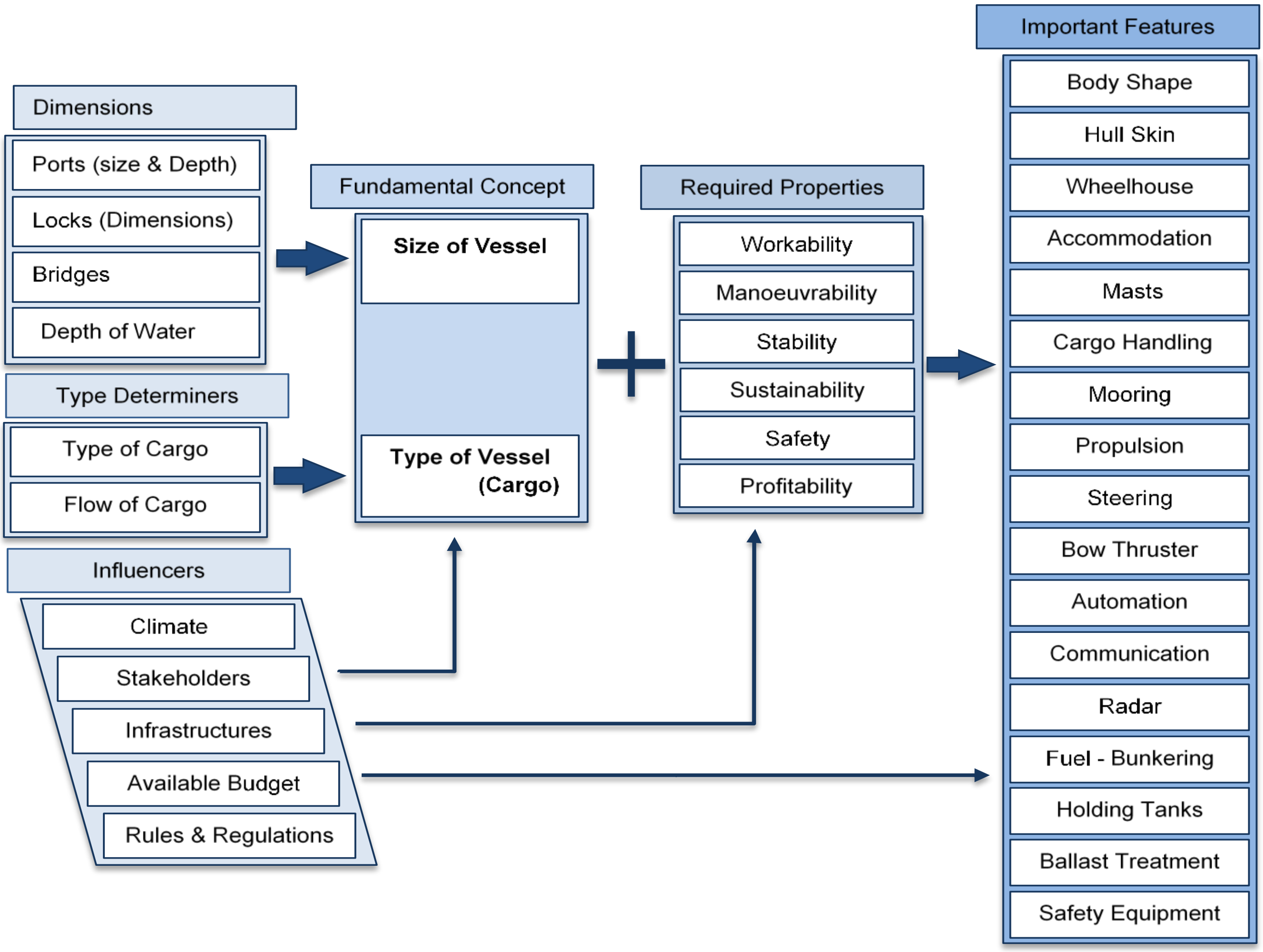
- Required features for vessels in Göta Älv – Lake Vänern. (River-sea vessels and IWW vessels)
- Operational requirements for efficient IWT in Göta Älv – Lake Vänern.

10.1 Required Features for Vessels in Göta Älv – Lake Vänern (RSV & IWW Vessels)

A ship can be considered as an accumulation of some equipment and components in the form of a buoyant and movable object to serve several or at least one purpose. The purpose of the vessel will lead designers to decide on the size and shape of the vessel prior to thinking about the details of the vessel. Then the operational needs for fulfilling the desired purposes will be applied to the basic concept, in order to decide what equipment and specifications are required for the vessel. For instance, for a naval vessel, higher speed, faster response, and higher manoeuvrability may be considered as the most important required properties. In order to determine the requirements for efficient operation of IWW vessels in Göta Älv and Lake Vänern, the approach begins by looking through the basic factors that may significantly affect the main characteristics of the vessels and their operations in the area. For instance, the type and size of the vessel may be determined by the availability of cargo (adequacy of cargo flow) and based on the size of the locks and height of the bridges in the route. In the next step, the general and specific operational requirements (which are specifically related to this area) will be discussed. In this step, key learnings from literature and collected information from the interviews, study visits and observations will be applied in the recommendations, in terms of vessels components and operational requirements.

We assumed that the size and type of the vessels may be determined by some fixed factors such as dimensions of ports, locks, bridges and waterways between the port of Gothenburg and Vänern (Graph 5-Dimension determiners), as well as availability and cargo flow at the present time (Graph 5-Dimension and type determiners). Obviously, availability and flow of cargo will be considered as variable factors due to the possibility of changes in demand, interest, competition position, etc. Later on, the variable and fixed factors (Table 25) will be explained in the next pages.

Required properties for efficient operation in this route can be divided into six main categories. (Graph 5- required properties). When the basic concept of the vessel (Dimension and type of the vessel) is determined based on the main determinant factors (Graph 5-Dimension Determiners and Type Determiners), in order to tailor the vessel for the desired purpose in this route, the required properties must be discussed and applied on the basic concept. (Graph 5-required properties). For instance, when the size and type of vessels are determined by considering the dimensions of the locks, navigation depth in the passage and ports, type and flow of the cargo and,…etc, in order to decide on the required engine power, manoeuvrability of the vessel as one of the required properties for efficient operation in the route will be considered by crossing the influencers. (Graph 5-required properties and influencers). In this example, the higher engine power is providing higher manoeuvrability, but higher engine power is proportionally related to the size of the engine and its fuel consumption, the influencers such as available budget, rules and regulations, stakeholders' interests will also be considered. At this stage, the required properties and their interaction effect on each other will be investigated.



Graph 5, Parameters that are affecting the design of IWW vessels for a region

Table 24 shows the most important factors that influenced the properties and basic design. Later, all the important components of an IWW vessel will be discussed by considering the required properties. The dimension determiners, type determiners and influencers that have been mentioned in Graph 5 are divided and presented as sub-factors in Table 24. The status of these sub-factors at the present situation will be considered for deciding on the vessels characteristics as a starting point, however the status of some factors will be changed in the future. Obviously, the future status of those factors need to be forecasted and accounted for. Therefore, those factors have been assumed as variable factors. For instance, the parameters belonging to the flow of cargo and the competition position will certainly change over time.

Main Factors	Sub Factors		Type		Impacts of factors on Vessels' Features	Impacts on vessels' properties					
			Fixed factors ▲	Variable Factors ▼		Workability	Manoeuvrability	Stability	Sustainability	Safety	Profitability
Ports	The depth of water in ports		▲		Draught of vessel	√	√	√	√		√
	Crane for container		▲	▼	Crane on board	√		√	√	√	√
	Waste receipt facilities		▲		Holding tank	√		√	√		√
	Fuel supply facilities		▲	▼	The capacity of fuel tanks	√		√	√	√	√
	Container Storage Space		▲		The dimension of the vessel	√			√		√
Passage	Lock	Length	▲		Length of vessel	√	√	√	√	√	√
		Width	▲		Width of vessel	√	√	√	√	√	√
		Draught	▲		Draught of vessel	√	√	√	√	√	√
	Bridge	Height	▲		Air draught	√	√	√	√	√	√
		Width	▲		Width	√	√	√	√	√	√
	Depth of water		▲		Draught of vessel	√	√	√	√		√
	Width of passage		▲		Width of the vessel	√	√	√	√	√	√
Climate	Current		▲		Power - Shape	√	√		√	√	√
	Wind		▲		The shape of the windage area	√	√	√	√		√
	Fog		▲		Additional Radar, Camera	√				√	√
	Ice		▲		The shape of the body, Ice class	√	√	√	√	√	√
Regulations	IWW (Zone 3) - (Freeboard) National regulation		▲	▼	Freeboard	√	√	√	√	√	√
	local regulation for Passing the locks		▲	▼	Steering & Propulsion	√	√		√	√	√
	Pilotage - (local rules)		▲	▼	Length of vessel ≤ 60 m < Length of vessel	√	√	√	√	√	√
Market	Flow of cargo			▼	Dimensions - Utilization	√	√	√	√	√	√
	Competition position			▼	Capacity – Speed – Additional features	√	√	√	√	√	√

Table 24, Comprehensive table of the main, sub, dynamic and static factors impacts on design properties.

Below table shows some of the requirements that allow vessels to be operated in the route Göta Älv - Vänern which are defined by SMA as local regulation for sailing in this route and are determined through some factors such as dimensions of the locks, bridges and passage conditions.

Parameters	Göta Älv to Lake Vänern passage	Göta Älv to Lake Vänern passage, future
Depth (Navigation depth)	Enough depth in fairways (Interview 2, 2018)	Enough depth in fairways (Interview 2,2018)
DWT	About 4200 (Trafikverket, 2018)	5000-6000 (300-360 TEUs) (Trafikverket, 2018)
Beam	12.6 m-by permission 13.4 m (SMA Website)	15.2 m (SMA Website)
Length	87m- by permission 89 m (SMA Website)	100-110 m (SMA Website)
Draught	5.4 m (SMA Website)	5-5.4 m (SMA Website)
Speed	10 knots (SMA Website)	10 knots (SMA Website)
Bow thruster	At least one for max size vessel (87 m) (SMA Website)	At least one for the max vessel (SMA Website)
Engine Power	Not defined Depends on the dimensions, shape and DWT	Not defined Depends on the dimensions, shape and DWT
Steering	Robust and Effective (Becker or Schilling is advised by (SMA Website)	Robust and Effective (Becker or Schilling is advised by (SMA Website)

Table 25, requirements for vessels to operate in the passage between Göta Älv to Lake Vänern for now and the future. Table information: compilation from data of SMA and trafikverket websites and interviews.

10.1.1- River-sea Vessels

River-sea vessels usually are made to trade between at least two different regions. It means that customizing a vessel based on the specification of a region would not be reasonable. Obviously, the owners of the vessels prefer to own vessels that can sail in different routes as many as possible. Therefore, moving from the characteristics of existing river-sea vessels to a series of specific characteristics for a region seems to be limited to adding some special features only. Due to specifications of Göta Älv, the Lake Vänern, and the passage in between, including the size of the locks and dimension of the bridges, most of the existing vessels which can be fitted in the locks, seem suitable for use on this route. Furthermore, the following features seem to be helpful to overcome the operational requirements and needs if the budget allows.

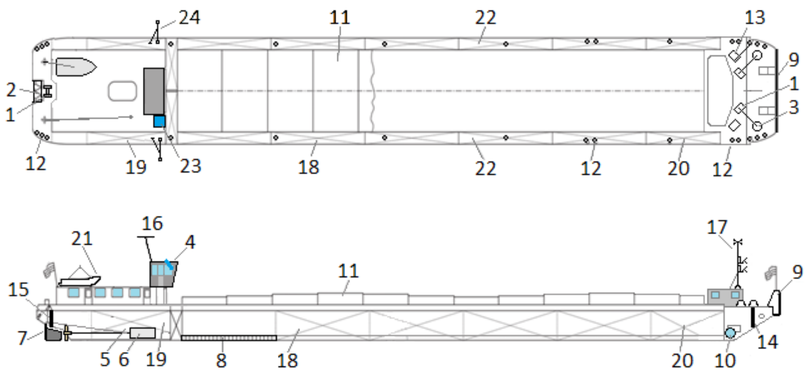
- **Workability**
  - **Control the vessel from wings**
    During navigation in a traffic area and during passing the bridges, or manoeuvring especially near the locks and jetties, pilots need to look outside of the vessels from the wings. These wings are mostly projected objects which are constructed in both sides of the wheelhouse and extended to the outer body of the hull. The control stands for the speed and manoeuvring from the wings will be quite helpful while approaching the locks and berths' sides. Some of the existing vessels are already equipped with the control desks on both wings including joysticks and knobs for controlling the speed and direction of the vessel.
  - **Standardized controlling instruments**
    Practically, monitoring and controlling instruments in the wheelhouse and the layout of controls knobs and joysticks on the control stands are various in different vessels. The above-mentioned issue may cause-hindrances for the one who is piloting a vessel and is not familiar with a given bridges' instruments. Therefore, an investigation regarding the layout of instruments in the bridge and wings prior to the design of vessels for This region, seems to be a logical suggestion. A unique arrangement for the layout of the instruments in the wheelhouses will reduce the load and stress from ships' officers and pilots during operation, minimize the human errors and accidents, and may consequently reduce the total costs.
  - **Crane on the vessel**
    Currently, most of the ports in the lake are not equipped with suitable cranes for handling the containers (interview 3, 2018). Vessels with cranes will be able to handle containers in all ports in this area will be a good option when there is no container lifting facility.

- **River radar**
  Very poor visibility condition due to fog in some places of the route, especially in the summer has been reported by pilots. In addition to poor visibility due to fog, some places on the route are usually congested by leisure boats in summer time (interview 2, 2018). Therefore, in order to proceed in such condition, vessels that are trading in IWW need to be equipped with at least one river radar. The number of radars on board is defined by flag administration.

- **Sustainability**
  - **Ballast water treatment system, dirty water holding tanks**
    The Lake Vänern is providing drinking water for more than 700 000 people. Cleanliness of the water in the lake and the sustainability of the Lake ecosystem is crucial. Therefore, the ballast water treatment system and dirty water holding tanks are needed for the river-sea vessels that may trade to or from the Lake Vänern and in that area.
  - **Twin skin hull**
    Due to a shallow and narrow passage and due to traffic in the IWWs, the vessels that are trading into IWWs and lakes, are at the higher probability of risk of collision comparing to trading in the open sea. With attention to the sensitivity of the cleanliness of water in this area, to avoid pollution and environmental disaster in case rupture of the body, twin skin hulls may prevent oil spill or water contamination by the fuel or cargo. Due to the sensitivity of the ecosystem in this area and public interests, it seems that it becomes compulsory in the future (Interview 2, 2018)
  - **Stern anchor**
    In addition to two forward anchors, one stern anchor could facilitate position keeping in case of failure in the propulsion system, steering system or any other emergency cases.
    it will reduce numbers of accidents and even may prevent disasters (Interview 2, 2018). Generally, a huge advantage may be gained by a low additional cost for installing a stern anchor, especially by considering the occurred disasters in the last few years (reported in interview 2). According to interviewees, using a stern anchor could prevent such accidents in this area if the vessel was equipped with (interview 2, 2108).

10.2 Inland Waterways Vessels

According to literature, interviews and visits, it is concluded that the following features will facilitate and make the vessel more suitable and fit for operating in this area. Due to differences between climate conditions of this area and studied regions (Netherlands, Germany and Belgium) and similarity to the climate of some parts in Russia, Finland and Norway, separate research on IWW vessels with a focus on the same climate conditions as project area seems to be needed.
the below figure shows the structure and important components of most common IWW vessels for the project area. These components will be discussed in the next pages.



1 Anchor windlass
2 Stern anchor
3 Bow anchor
4 Bridge
5 Engine room
6 Main engine, shaft, propeller, tunnel or nozzle
7 Rudder
8 Double bottom
9 Pushing shoulder
10 Bow thruster
11 Roll-away hatch cover
12 Bollard
13 Lashing windlass
14 Front collision bulkhead
15 Rear collision bulkhead
16 Radar
17 Signal mast
18 Ballast tanks
19 Fuel tanks
20 Trimming tank
21 Dinghy
22 Gangboard
23 Blue sign
24 wings

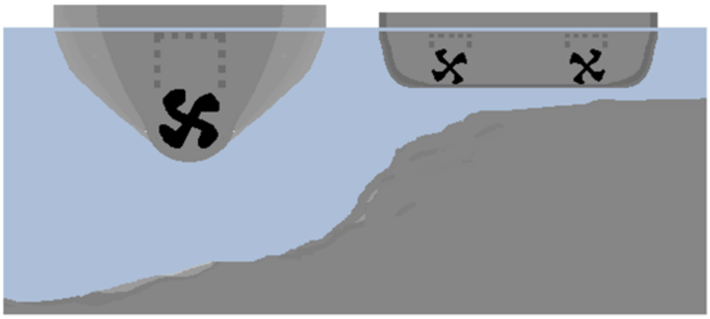
Figure 10, structure and important components of an IWW vessel for project area – original picture from source: (Rewway, 2018), the picture is modified

- **Vessel's Capacity and Dimensions:**
  With larger IWW vessels, there always is a tendency for transporting cargo in shorter time slots. When the demand is frequent service delivery and flexibility of cargo transport, smaller and faster vessels with customized features will be more suitable. To decline the high fixed costs, the inland waterways vessels should be adapted to the market's niches in various locations where the conditions and volume allow. For this purpose, maximizing the capacity in the most efficient way such as increasing the quality of cargo stowage is required. Currently, the vessels with 88m length,13.2m width, 5.4m draft, and 4000 to 5000 cubic meters volumetric capacity (Vänernmax) are allowed to trade from/to the Lake Vänern. However, the most common capacity is between 2300-3600 cubic meters. Almost all the vessels have the chance to load some cargo in returning voyage from the Lake. Therefore, with referring to the locks' size and present condition of the market, it seems that container vessels with less capacity such as 100 -150 TEUs have more chance to trade frequently with higher utilization. But multipurpose vessels with smaller batches and the possibility to transport container and dry cargo at the same time may be more reasonable for beginning and entering into the market.
- **Type of vessel**
  Obviously, the type of available cargo (a reasonable amount, for an acceptable time period) will make an attraction for ship owners to invest in a specific type of vessel to operate for such a purpose. It seems that using a specific type of vessel which is well tailored to a type of cargo may cause higher efficiency. However, ship owners and operating companies prefer to invest in multipurpose vessels, enable them to shift to new markets in case of any major change in the market demands. In another word, market competition and risk of possible changes in the market demand, lead the owners to avoid investing in the special vessels unless they have been secured financially by a reasonable chartering contract. To support the above statement, it is mentionable that currently, most of the IWW dry-cargo vessels have been designed to transport containers, general cargo and packed or bulk dry cargo.
- **The Shape of the body, box shape and pushing shoulder**
  Most of the IWW cargo vessels are in box-shape with a slight curve in front and aft of the body. The box-shape vessels have more cargo stowage capacity in a certain length and width compared to the traditional shape of seagoing vessels. However, in a certain condition, in comparison to traditional-shaped vessels, the box-shape vessels usually consume more fuel and reduce manoeuvrability of

the vessels. The main deck of most of the barges is almost in a shape like a rectangular. This shape will make the mooring and coupling operation easier (pushing shoulder). Also, this shape in forwarding will act as a bumper and guider in entering the locks.

- **Manoeuvrability**
  - **Propulsion (Engine) power**

    Required propulsion power for any vessel shall be calculated accurately. Engines with higher power may increase the manoeuvrability of the vessel and consequently increase the safety of the vessels. But engines with higher power consume more fuel. Adequate, reliable and affordable power usually will be calculated by considering the weight of the vessel, the shape of body and resistance of water and air on the body. Hydrodynamic behaviour of the body in the water and aerodynamic resistance of the body above the waterline will be derived and considered. Hydrodynamic resistance of the body is directly related to the draft and the shape of the body. Due to enough depth in the route, a wide range of the vessels with low and high draft can be used in this route. The larger draft allows designers to select a larger diameter for propeller if needed. Therefore, in this route, vessels with a single engine and single propeller can be used. In some regions, shallow water dictates designers to select smaller propellers. In that case in order to provide the required power, two smaller engines will be used instead of one large engine. Using two (or in some cases three) smaller engines instead of one large will increase the redundancy of propulsion and steering systems. For this arrangement, the vessel's shape at the stern needs to be like a rectangular box to accumulate two engines in the sides. Laying two engines in the sides of the box shape body of IWW vessels may increase the stability of the vessels to some extent.



Graph 6, the effect of water depth on ship construction and propulsion system

    Two engines may increase the initial cost and maintenance cost. However, the strength of vessels' structure with traditional shape is higher than box shape bodies. Hydrodynamic resistance in traditional shape is less than box shape bodies with the same draft. Therefore, vessels with the traditional shape of the body are more suitable for seagoing vessels. As mentioned previously, in the Rhine, the depth of water allows using larger propellers and more powerful engines. Therefore, most of the vessels in the Rhine are equipped with one engine. Since the depth of water in this route is higher than the Rhine, one large engine with adequate power can be recommended.

  - **Rudder**

    Larger angle and prompt action of the movement of the rudder are crucial factors as well as the efficiency of the steering system which is coming from size, shape and position of rudders. Navigating in IWW requires using an effective steering system. Turning and manoeuvring in a passage which may be crossed (or be congested in some places) by leisure boats, requires fast response steering system. Also, while vessels are passing the locks, where the water stream on the propellers and rudders are less, the effectiveness of the steering system is very important. According to interviewees, during the entering to the locks in the passing of Göta Älv - Lake Vänern, where the current is higher (around the power plants), effectiveness of the rudder is very important and critical (Interview 2, 2018) to that extent which SMA has established rules and defined some certain characteristics for max size vessels to meet prior to passing the locks.

Therefore, the initial cost and maintenance costs of the steering system may not be a priority while selecting a steering system.

- **Bow thruster**

  For numbers of bow thrusters and their size, the draft, the length and the shape of the vessel are determining factors. Two smaller bow thrusters instead of a large bow thruster may increase the manoeuvrability of the vessel, especially in convoy barge coupling. In addition to the rudder in the aft of the body, the bow thruster (or bow thrusters) in the forward of the body may be used for fast turning in the passage. On the other side, the required capital, maintenance costs of two bow thrusters may act as a deterrent. Bow thrusters may compensate for the costs related to tug assistance services. Another point of view is numbers of the crew on board of IWW vessels which are limited. Two bow thrusters may facilitate mooring operations with fewer numbers of involved crew. Furthermore, two bow thrusters may reduce the risk of collision in arrival and departure to or from ports and locks by increasing the manoeuvrability of the vessel, especially in case of operation without expert pilots if the new regulation allows IWW vessels trade without pilots.

  Finally, according to the SMA regulation, at least one bow thruster is a requirement for the max size vessels for passing the locks.

- **Propeller with cord nozzle (Ducted Propeller)**

  Ducted propellers (propellers with cord nozzles) are usually more efficient than non-ducted propellers. Especially bodies of vessels with lower draft required ducted propellers in order to increase the propulsion efficiency and steering efficiency. Cord nozzles will also act as a safeguard against damages by ice packs or in case of minor grounding as well as giving more efficiency while the vessels are in the locks where availability of the stream water is limited.

- **Gear Transmission**

  A reliable transmission gearbox will provide variable RPM on the propellers while the engine RPM is constant. It will increase the controllability of the propulsion and consequently increase the performance of the propulsion system without changing the engine speed. Engine speed fluctuation increases the operation costs by consuming more fuel and reducing the life cycle of engine parts. But gearboxes require higher capital (initial investment) and increase the maintenance cost. There is a tendency to operate IWW vessels by lower costs until the vessel is fulfilling the minimum requirements. In contrast, the experienced pilots in this route prefer a gearbox system due to more reliability of accessing power in time (interview 2, 2018).

- **Stability**
  - **Draft**

    The depth of the water in this route is enough to operate vessels with a higher draft compared to other IWWs in the EU. The higher draft makes freedom for having a longer distance between the center of gravity and centre of buoyancy. Stability of a ship is highly related to the distance between the centre of gravity and centre of buoyancy. Higher stability will facilitate the possibility of installing crane on the vessel. On the other hand, a higher draft needs more engine power and consequently causes more fuel consumption. However, a higher draft will provide a wider range of options to ship designers for increasing the effect of the propeller by leading a higher percentage of the water stream to the propellers.

- **Workability**

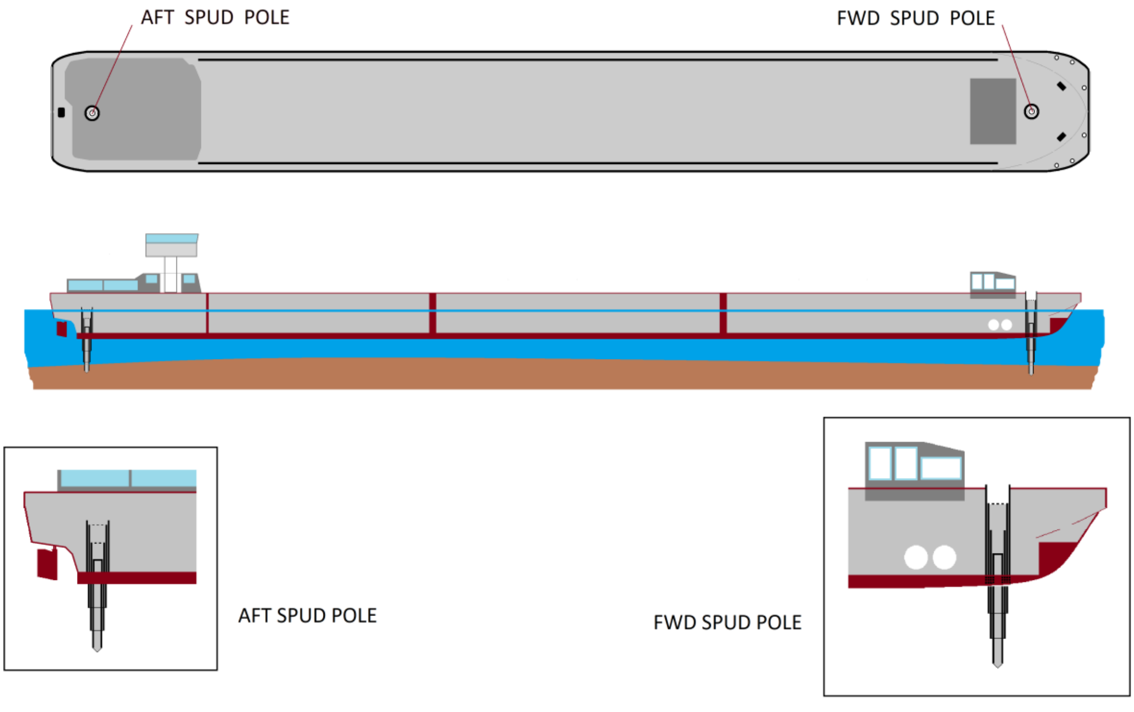
  The higher level of vessels' workability ensures that vessel can be operated effectively by the crew and other engaged parties such as pilots, tug operators, bridge operators, stevedores, etc. In addition to below mentioned points, the simplicity of the operation, possibility to inspect the hull and machinery, maintainability of the machinery and components, possibility to change and to upgrade the equipment are common elements of workability of vessels.

- **River radar**
  Today, IWW vessels in the EU are equipped with at least one river radar on the foremast and one radar somewhere on the aft. It has been observed that some of the vessels have two river radar. Also, river radar on the forward foldable mast will tilt up automatically and will remain operational when the mast is folded (interview 2, 2018). River radars enable navigation in poor visibility due to thick fog in this area.
- **Searchlight**
  According to mentioned regulation regarding ice, ice breaker service will be provided when the vessel is fitted with a strong and powerful searchlight. Also, a powerful search light is useful during towing operation, icebreaker service, restricted visibility and in case of emergency.
- **Ice-class**
  As mentioned previously, there is a restriction for delivering icebreaker service to the barges and inland water vessels during winter in this area. Therefore, one option could be using more customized river-sea vessels instead of using IWW vessels in the winter time. Ice class River-sea vessels have enough power and enough structural strength.
- **Camera**
  IWW vessels are operating mostly with the minimum crew on board. Close circuit cameras will enable pilot or wheelman to see the vessel from a different angle on the display screens in the wheelhouse while the vessel is in the passage or in the locks, during berthing and unberthing operations. Cameras also save costs by reducing required manpower for lookout and reducing delays due to poor visibility. Especially in the summer time that thick fog has been faced repeatedly on this route, cameras which provide a view from a different angle will be helpful for pilot or wheelman to get a better image of the situation (Interview 2,2018). It saves time by reducing delays, especially in the case of regular container services, so that the scheduled time table will be kept duly maintained.
- **Foldable masts**
  Both masts (forward and aft) must be foldable to increase the air gap (between the higher point of the vessel and lower point under the bridge) while the vessel is passing under the bridges. By considering the length of the vessels, fewer numbers of the crew on board as well as weather conditions, remotely folding masts in forward and aft will be more convenient and thereby increases workability (Study visit,2018). In addition, it is also recommended by SMA for max vessels trading in the area. This may facilitate the passing process in some bridges without the need for opening the bridges. It saves passage of time by reducing the number of movements or delays, as well as reducing fuel consumptions, risks and depreciations of the engine parts and propulsion systems by reducing the numbers of movements.
- **Elevating Wheelhouse**
  In normal visibility conditions, wheelhouses with higher height provide a better view of foreward and sides of the vessel. Especially when cargo on deck has obstructed the line of sight, moving wheelhouse to a higher height will be helpful. However, this can reduce the level of the vessel’s stability. To increase air draft (clearance under the bridges) during the passage, the wheelhouse needs to be lowered down. Also, according to SOLAS chapter V, rule 22 visibility should not be impaired (Study visit ,2018).
- **Foldable Wings**
  During the study visit it was observed that an IWW vessel was equipped with two foldable arms on the outreach of the upper deck at the port and starboard sides. The wings were stretched out when needed. Remote-control cameras were installed on the outer reach of the arms at each side as well as some lights to transmit a better view from sides of the vessel to the screens in the wheelhouse. Since these arms are attached on the deck near the wheelhouse, folding them can be done easily by one person where the manpower is a matter of issue (Study visit, 2018).

- **Blue sign (blue board) and Flashing white light**
  Inland waterways vessels in European IWWs are using a rectangular blue sign which is located on the starboard side of the wheelhouse and flashing white light when passing on the opposite side of navigation standard side or when performing special manoeuvring. Blue sign is the 1m x 1m board for large vessels and 0.6m x 0.6 m for small vessels in light blue colour. Flashing white light is flashing 40-60 times per minute. The status of the blue sign shall be logged in Inland-AIS position reports and it will be transmitted to other vessels automatically every 10 seconds by Inland-AIS transponder (Unece, 2018).
- **Accommodation (Habitability, Cleanliness)**
  In the Netherlands, Belgium and Germany, most of the IWW vessels are operated by family members of private-owned companies. Usually, at least half of the crew are family members or even all of them. Accommodations of such vessels shall be suitable for the living of the staff who are living and working on board the vessels. Most of the vessels have two separate accommodations, which is built on a single floor and are located on the aft and forward. Usually, forward accommodation is for the sailors that need to be available in the forehead of the vessel to do operations like mooring. They are in communication with wheelhouse by the wireless device. Aft accommodation is usually larger with more rooms for the family members. Normally, all the compartments are well equipped with the required furniture to be comfortable like home (Study visit, 2018).
- **Ergonomic wheelhouse**
  Pilot (captain) of the vessel must be able to see all the instruments, indicators and screens and to operate all the instruments from consoles in the wheelhouse. Today, most of the controlling joysticks are located on the sides of the master chair which is in the centre line of the wheelhouse. Engine control and control of the bow thrusters are on the right side and steering control in the left side of the chair. Starting and stopping the engines can be done from the switch board on the panel in front of the chair. Alarm monitoring display and gauges also are located on the front console. Screens of CCTVs are located in the front, on top of the chair, just under the ceiling. Also, a display unit at the wheelhouse shows the shear and bending forces while loading or discharging the cargoes. An inclinometer is located at the center line of the wheelhouse for observing the vessel's list. It is one of the SMA standard requirements for max vessels' pilotage. The wheelhouse has all-round (360 degrees) visibility according to SOLAS chapter V, rule 22 requirement when lookout availability is limited mainly because of less crew on board. (Study visit,2018)
- **Internal Communication**
  There are several means of communication such as Man Call Buzzers, Talkback units and walky-talky to facilitate internal communication between crew members enable them to continue their tasks or take rest instead of being stand-by in certain positions. In addition to that, due to less crew on board using a tracking system to monitor the location of the crew during working hours in the wheelhouse, the excessive communication may be reduced in some cases thus reducing the time for making decisions in case of an emergency.
- **Automation**
  Today, using new technologies and a higher level of automation enable owners to operate the vessels with fewer crew members. High expenses of hiring a crew for vessels have made an intention for using automation to reduce labour costs. Using autonomous or semi-autonomous vessels may be reasonable for some regions where the labour cost is high like Sweden. It also may reduce risks and accidents.
- **Mooring (anchoring, towing, docking and undocking)**
  Mooring Winch
  Remote control tensioning and auto tensioning winches for IWW vessels which are operating in cold climate with a few numbers of the crew may be helpful. In practice, in the case of convoy forming, the cables may need to be checked for tension regularly and if needed tightened

manually. This operation can be shifted from a manned-operation to remote control or an auto-control operation. In contrast, some owners are not interested in auto-tension winches because of maintenance cost and the possibility of failure or oil leakage. Mooring which is one of the SMA standard requirements for a max vessel to cross the locks.

- **Spud poles**
  One or two spud poles (one in the forward and one in the aft) may facilitate easier and faster holding of the vessel in position rather than fastening mooring ropes while berthing. Spud poles can be operated from wheelhouse remotely. Using spud poles in some locations with a lack of mooring bollard on the jetty can be the best option for holding the vessel in the position. It reduces manpower need and facilitates a safer mooring operation while approaching and leaving the berths particularly by considering that the IWW vessels are mostly run without pilot engagement. It will reduce the risks as well as the costs in terms of no requirement for the mooring boat engagement. Using spud poles requires awareness of the clearance under the keel and seabed type.



Graph 7, Shape and locations of spud poles on board a vessel.

- **Cargo handling (Lifting Gears)**
  Since most of the IWW transhipment centres in the EU are equipped with cranes, the IWW vessels in the EU mostly don't need to be equipped with cargo handling devices. Installation of cranes on the vessels will increase the initial cost as well as maintenance related costs. The other reason for that is related to the stability and hydrostatic behaviour of the vessels with the very low draft. But due to a depth of water, vessels with higher draft can be used in this route and in the ports. Deeper water in this area provides the possibility of using more ballast waters to reserve adequate stability. Currently, most of the ports in the lake are not equipped with suitable cranes for container operations. Therefore, a vessel with a crane can serve in most of the ports in the lake Vänern. Feasibility and workability of this idea require more study and research. There are few IWW vessels (barges) in Europe which are equipped with a suitable crane for handling containers (and general cargo). Below picture shows a typical IWW vessel with lifting gear which is fit to work in this area by dimensions. The MCKS Mercurius (Length 86 m, beam 11.55, depth 3.5 m, tonnage 2150 T / 1930 cubic metric) is a container ship with two engines (800 Hp each). She has two holds in a box shape with a crane between. This vessel has been built in 2005 (Mercurius, 2016).

Picture 5, Sample IWW vessel with crane suitable for container operation in all ports in the Lake.

- **Sustainability**
  - **Ballast treatment system**
    Because of the sensitivity of the Lake Vänern in terms of providing drinking water for the cities around, cleanliness of water in the Lake and sustainability of the Lakes' ecosystem are crucial, so to prevent invasive species' entrance in the region via ballast water exchange, the ballast water treatment system and dirty water holding tanks are essential.
  - **LNG vessel**
    That is a bright idea if the vessel uses LNG fuel because the required facility is already available in the port of Gothenburg. It may be economically viable, environmentally friendly and may satisfy the public interest in using fewer emission fuels. However, feasibility, environmentally friendly and energy efficiency of LNG fuel are not guaranteed for all type and size of the vessels.
  - **Electrification**
    Due to the sensitivity of the area with respect to environmental issues, public interest and energy efficiency, it seems a logical idea that due to availability of electricity in the port of Gothenburg, the port does agree to absorb the expenses of required facilities for providing electricity to the vessels in all berths of new terminal to minimize emissions.
- **Safety**
  - **Hull**
    Due to environmental interest in this region and high public awareness since the Lake Vänern is providing drinking water for people around it, it seems that double hull skin vessels will provide higher insurance for preventing or minimizing pollution or contamination of the waters and natural resources in case of accidents. Double skinning will increase the stability and strength of the structure against bending and shearing forces. Higher draft required a higher strength of the vessel's structure. The stronger structure will add the possibility of loading heavy cargo on board. Stronger structure with the higher draft and higher stability will facilitate the installation of cranes on board. However, a double hull skin will reduce the ratio of cargo capacity on the vessel dimensions and extra burden on ship crew and may increase the costs for ships owners.
  - **Stern Anchor**
    One stern anchor in addition to the two forward anchors, would facilitate keeping vessel's in position to avoid a collision or minimizing the damage in emergency cases. It could be also helpful during manoeuvring in the river and in case of a strong current to keep the vessel in a place where there is enough depth of water to avoid grounding which may lead to hull rapture and disaster (Interview 2 ,2018). Stern anchors are usually operable remotely from wheelhouse to compensate manpower issue on board of IWW vessels. But another perspective is that, such a strict regulation may act as a deterrent for the business of area and reduces trades of vessels in the region. Most vessels that are trading in the area are not equipped with a stern anchor (interview 2 ,2018).
  - **A rescue boat and lifeboat**
    Most of the IWW vessels in the north EU is equipped with a single rubber Gemini boat that serves as rescue boat and lifeboat. These boats are very small, light and easy to handle and launch. For this region with Ice condition, it seems that boats with stronger body rubber than Gemini boats are required and adequate measures for ice period are required.

- **Security**
  Vessels with less crew, large length and boarding deck which are in the level of jetties may be an easy target for criminals. Therefore, some compartments such as the engine room, accommodation and wheelhouse require effective security measures. However, the crew needs to have easy access to the different compartments.

Summary of the most important recommendations for characteristics of the vessels in Göta Älv - Lake Vänern:

Symbol	Remarks
RSV	River-Sea Vessels
IWWV	IWW vessels
⬜	Highly Recommended
🟩	Recommended
🟥	Advantageously required

Characteristics & Most Important Recommendations	Remarks RSV	 IWWV	Reasons
Control the vessel from wings	🟩	🟩	Control stands for the speed and manoeuvring from the wings will be quite helpful while approaching the locks and berths' sides.
Standardized controlling instruments & Ergonomic wheelhouse	🟩	🟩	It minimizes human errors and accidents. Consequently, it may reduce total costs.
Crane on the Vessel	⬜	⬜	Currently, most of the ports in the lake Vänern and in the route are not equipped with suitable cranes for handling the containers
River Radar	🟥	🟥	Due to long hours of thick fog in the area which may cause a delay Mostly IWW vessels are provided with two river radars
Ballast Water Treatment System	🟩	🟩	Cleanliness of the water in the Lake and sustainability of the lake ecosystem is crucial
Twin Skin Hull	🟥	🟥	Prevents oil pollution in case of accident and rapture of the hull The sensitivity of the ecosystem and fresh water supply for the cities around
Stern Anchor	🟥	🟥	Keeping in the position and direction in case of engine failure and to minimize accidents
draft (Increasing Stability)	🟥	⬜	The higher draft gives the possibility to increase stability and provides a vessel to have a crane on board
draft (Increasing Capacity)	🟩	🟩	Higher draft increase capacity but in box shape of IWW vessels it increases hydrodynamic resistance and reduces manoeuvrability
Shape of body V-shape	🟥		Consume less fuel (less hydrodynamical resistance) suitable for rough sea (Hull strength is high)
Shape of body Box shape		🟥	More cargo stowage capacity in a certain length and width compared to the traditional shape of seagoing vessels.
Body strength			Due to ice required more body strength
Pushing Shoulder		🟥	Facilitates mooring operation
Effective Rudder	🟥	🟥	The effectiveness of the steering system is very important in canals and locks
Bow Thruster	🟥	🟥	Required by SMA
Power Transmission	🟩	🟩	Gear box, pilots experience of the area
Duckted Propeller	🟩	🟥	Shape of body Ice condition
Strong Searchlight	🟥	🟥	Required for ice breaker operation and good for poor visibility or in case of emergency
Foldable masts	🟥	🟥	Advised by SMA, less delay time
Camera	🟩	🟥	Due to poor visibility
Elevating Wheelhouse	🟥	🟥	Advised by SMA, less delay time
Foldable Wings		🟩	In IWW vessels, less crew on board, increase visibility and safety
Blue sign (blue board) and Flashing white light	🟩	🟥	Required by regulation
Accommodation (Habitability, Cleanliness)	🟩	🟥	IWW vessel usually run family members and required comfort living space
Internal Communication	🟩	🟥	IWW vessels require more effective communication due to less crew on board
Automation	🟩	🟥	IWW vessels require more effective communication due to less crew on board

Inclinometer	■	■	Required by SMA
Mooring Winch and Auto tensioning	■	■	IWW vessels require remote control winches due to less crew on board. Normal winches are required by SMA for max size vessel.
Spud Poles		■	Holding the vessel in position rather than fastening mooring ropes while berthing (less crew on board, faster operation)
A rescue boat and lifeboat	■	■	Boats with a stronger body rather than rubber boats are required Rubber boats are not suitable for ice and winter season

Table 26, Most important recommendations for characteristics of the vessels in Göta Älv - Lake Väner

10.3 Operational requirements for efficient IWT in Göta Älv – Lake Vänern

Ports and logistics (port facilities)

The potentials are closely related to the density of ports and availability of the cargo in those ports as well as possibilities to use such network tendency and transshipment sites. The IWWs, the ports and transshipment sites in most of the EU countries are not in the vicinity except in the Netherlands, northern part of Germany and Belgium. The IWT economy will rely relatively upon, cheap and reliable transport services, adaptation to new technical developments, embracement of modern management methods as well as a better communication means, the establishment of regional transshipment centres, the possibility of more frequent and smaller batches or volumes to reduce stock via building regional bulk freights transshipment centres (Buck consultants international et al.,2004).

Using the latest communication technologies will help to monitor the location of goods and will improve transport times.

The containerization is continuously increasing and integrating into the transportation of various products. For instance, flexible tanker containers increasingly are used for petroleum and chemicals in the liquid form due to expenses of transport by tanker wagons, drums or trailers.

Even by dividing flexible tanker container into the several compartments and reducing the batch size, it may become more popular along with versatility in the container's usage and variety in design (Buck consultants international et al.,2004).

The Netherlands and Belgium international traffic exceeded the domestic container traffic. In the last decade the growth has been impressive, mainly because of the fixed liner services along with the inland waterways container terminals network which made IWT as a secure link in the logistics chain system.

The profitability of the IWT in case of multimodal chains and logistics integration depends on the long-term contracts, the time and costs minimization and the organizational functionality of the terminals (Buck consultants international et al.,2004).

Another option could be guaranteeing the carriages on a specific route through high frequency of circulation of ships in connection with pre and end haulage organization by forwarders.

Moreover, mixed cargo in the size of truckloads, carloads or railway in mass quantities and homogenized form will come economical and will be accessible via using containers in the method of roll-on and roll-off technology. As a result, IWT should look up into this type of logistics system with larger quantities of the containers. But short transport distance can be efficient by avoiding transhipment or in case of transhipment, the time-consumption and cost-intensive are less, such as using Ro-Ro ships (Buck consultants international et al.,2004).

Additionally, extending the navigation by IWW vessels from nominated IWW zones by local regulations to the coastal area where the geographical conditions allow, may improve the IWT in the country (interview 2 ,2018). It may require that IWW vessels be strengthened to trade along Swedish coasts until to the Malmo and to Denmark respectively. It may create a great opportunity to connect with the Danish market in an easier way.

- **IWT facility in the port of Gothenburg**

It seems the facilities that have been used for operation on large vessels at the port of Gothenburg, the same is in operation on the IWW vessels. Operating those facilities for IWW vessels does not cost wise reasonable. In this case, the operating cost for IWW vessels in port will be high even by considering the discounts for IWW vessels (Interview 1, 2018). For instance, the height of the Gantry

cranes for IWW vessels can be less to reduce the required time for each move. Also, the labour cost and the maintenance cost for larger gantry may be highly different from the costs related to the samller one. Due to high labour cost in this region, using automation and digitalization for container handling (lifting and storage), planning the flow of the containers and storage place, tracking the containers from/to terminal and planning the IWW vessels berthing may be cost effective.
For efficient operation of a container terminal and obtaining the optimum capacity utilization, the storage capacity and cargo lifting capacity of the terminal will be considered to be matched with probable container flow rate.

- **Bunkering**
  Bunkering facilities in the Lake will increase the efficiency of the vessels' operation by reducing the bunker weights and required space for fuel tanks on board and adding the cargo capacity. In addition, bunkering during sailing seems to be crucial for container vessels which need to keep scheduled voyage within the time window. Currently all vessels have a chance to fill the fuel tanks only in the port of Gothenburg. Based on discussions in the interviews, the port of Karlstad has the potential to provide bunkering services in the Lake.
- **Ice-breaking Services**
  present regulation restricts delivering ice-breaking service to the IWW vessels in this route. Considering the shape of the IWW vessels which are mostly box-shape that may require more cleared path than other river-sea vessels, it seems that the existing barges which are operating in the Netherlands and Germany are not suitable to be used in the ice season of this route unless a proper ice-breaking service to be provided for IWW vessels whenever needed.
- **Ice class and deadweight**
  In order to meet the requirement for ice class in the Lake, the standards say that the vessel should meet certain class and deadweight as a minimum requirement. But meeting that deadweight for the IWW vessels which are mostly below the required tonnage is a hindrance. Revision of the regulations may encourage companies to consider the route for trade by certain ships with additional construction and frame strength.
- **Communication centre (External communication)**
  To monitor the availability and manage the flow of cargo to / from the ports in this route, a trans-shipment centre will communicate and cooperate with all involved parties in IWT to harmonize the operations in a most efficient way.
- **Conflict of Interests**
  Currently, none of the ports in the Lake are equipped with suitable cranes for handling containers. Lack of Gantry cranes or even suitable cranes in the ports at Lake almost has held the containers flow by IWT. The public authorities as the owner of the ports are not interested to invest in ports unless they see the cargo flow. On the other side, the operating company is not convinced yet to invest in the ports which are not owned by them (interview, 2018). Some informative presentations based on evidential and reliable research that shows the possible flow of cargo and highlights the positive impact of efficient IWT on productivity and development of the industries around the Lake as well as the profitability of such investment may convince the parties to invest in the ports and other required infrastructures.
- **Locks**
  Construction of new locks for this route has been decided, however the dimensions of the locks are not confirmed yet. In case of a change in the regulations regarding IWW zones in the future to allow the IWW vessels sail and trade between the Lake and ports in coastal zones such as Malmö and ports in Denmark, then higher cargo flow will dictate larger dimensions for vessels. In that case, dimensions of the locks may be a bottleneck of the passage if new locks are not enough large. However, in contrast, the dimension of berths in the Lake and topography of the ports might be seems an issue, that can be handled by good seamanship like using tugs for manoeuvring. Making the locks with 110 m length, like the locks on the Rhine, will provide the possibility of using the

existing Rhine class vessels with a length of 110 m (interview 1 ,2018). To recall only four of the most common types are within this range.

Parameters	Göta Älv to Lake Vänern passage	
	Present	Future
Depth (Navigation depth)	Enough depth in fairways (Interview 2, 2018)	Enough depth in fairways (Interview 2,2018)
DWT	About 4200 (Trafikverket, 2018)	**5000-6000 (300-360 TEUs)** (Trafikverket, 2018)
Beam	12.6 m - by permission 13.4 m (SMA Website)	**15.2 m** (SMA Website)
Length	87m - by permission 89 m (SMA Website)	**100-110 m** (SMA Website)
Draught	5.4 m (SMA Website)	**5-5.4 m** (SMA Website)
Speed	10 knots (SMA Website)	10 knots (SMA Website)
Bow thruster	At least one for max size vessel (87 m) (SMA Website)	At least one for max size vessel (SMA Website)
Engine Power	Not defined Depends on the dimensions, shape and DWT	Not defined Depends on the dimensions, shape and DWT
Steering	Robust and Effective (Becker or Schilling is advised by SMA) (SMA Website)	Robust and Effective (Becker or Schilling is advised by SMA) (SMA Website)

Table 27, The present and future locks dimensions in the project area.

-The recommendation for the future lock's dimensions

By present locks' dimension, the lowest depth is 5.7 m which by considering river-sea vessels from tables, the highest draft is 5.5 m and with 0.3 m allowances, the new locks are required to have a depth of around 5.8 m to be able to fit in all types of river-sea vessels depth wise.

Type	'Rhein'	'Weser'	'Elbe'	'Cargo-Liner'	'Eurocoaster'
Loa (m)	87.90	88.45	82.50	79.90	81.40
Bmax (m)	12.90	11.35	11.35	9.00	9.50
Draught (m)	5.50	4.94	4.79	2.99	3.10
Air draught (m)	12.60	12.60	9.30	4.60	4.50
DWT (tons)	3750	3000	2590	1360	1500
Output (kW)	1500	1125	1350	n.a.	700
Speed (knots)	11.7	11.5	12.8	n.a.	n.a.
TEU capacity	176	118	118	n.a.	75

Type	'Volga 1'	'Volga 2'	'Rossiya'	'Sormovskiy'	'ST'
Loa (m)	139.9	117.5	96.3	119.2	86.9
Bmax (m)	16.6	16.6	13.6	13.4	12.2
d (m)	4.5	4.4	5.2	3.8	2.7
DWT (tons)	5500	4480	3730	3100	1230
Output (kW)	2 x 970	2 x 970	n.a.	2 x 640	2 x 440
Speed (kn)	11.0	n.a.	n.a.	10.5	10.8
N° of TEU	140	104	122	~ 100	54

Table 28, Western and Eastern type of river-sea sea tables

In regard to Eastern type river-sea vessels only ST type with length of 86.9 m can be accommodated in the present locks dimension. From the above tables only 50 % of the river-sea type vessels (5 categories) can be fitted in the present locks dimension. But, due to ice it seems that main trading vessels in the present and future will be sea-river vessels which can stand the ice climate conditions. In continuation, the longest length of river-sea vessels in tables is 139.9 m so by considering one-meter allowance the ideal length will be something around 140-141 m. To continue, with respect to the width of the locks, the common widest river- sea vessels in tables is 16.6 m by considering the Rhine locks chambers allowances 0.6 m, the width will be 17.2 m or by minding the Danube allowances which are one meter, the breadth will be 17.6 metres. Therefore, the dimension suggested for the new locks will be L=140-141 m, W= 17.2-17.6m and depth of 5.8 m. This suggested dimension for the locks makes them suitable even for the future IWW vessels of 135 m long.

- **Bridges and river traffic information centre**
  There are many bridges in the route between the port of Gothenburg and Lake Vänern which need to be monitored and operated frequently in an efficient way if the traffic of IWW vessels were to increase in the future. In that case, synchronizing between rail, road and IWW traffics requires to be handled by centralized traffic information (based on observation from study visit of Netherlands, 2018).
- **Training and Training Centres**
  Currently, the IWWs in this area is mostly used by river-sea vessels. lack of professionals for the operation of IWW vessels (barges) in this area caused a lack of required skills in all sectors of IWT operations.
  Training by simulating different types of vessels in a different situation may be the fastest way to train the required crew for operating IWW vessels in this route.
  Training can be planned from an early stage of age to culturize IWW related activities in Sweden. As noticed from study visits, training of IWW vessels takes place from an early age to familiarize youths with the knowledge and related cultures. It seems that Sweden has a long way to go until it culturizes the IWW vessels' operation by family members. It needs a long planning.
- **Pilotage and Fairway Dues**
  The IWW vessels are mandated to have a pilot on board in this route. In addition to that, fairway and pilotage dues are very high in this region. But most of the IWW vessels in most of the northern European countries such as the Netherlands are operating without a pilot and with a negligible due (Study visit, 2018), that makes IWT economically viable when there is equal treatment with other modes.
- **Ice-class Regulation for IWW Vessels**
  As noticed, icebreaker service is not available for inland water vessels and barges in the region. Therefore, to make IWW vessels trade practicable during winter, some modification either in the IWW ice class notations or in regulation are required to motivate investment in this domain.
- **Cargo Flow**
  At least two paper mill factories are located around the Lake with enough productions and cargo flow. Currently, these factories are transporting their products by containers via rail and road. There are other products and material that may be transported by IWT if efficient and reliable services are available for the customers in the future. The reliability, flexibility and cost effectiveness are the most important characteristics of an efficient transport service. But as mentioned previously, there are some potential players such as paper mill factories which can provide enough cargo to make the IWT business model in this area commercially viable.

11. Conclusion

The IWT has become the center of attention nowadays due to the benefits of large capacity and higher capability in carrying all bulk goods at lower transportation costs per km than other available transport modes. However, Nowadays, due to environmental issues and climate change the IWT option, is gaining in attention, especially from those countries which already have a suitable natural waterway. Sweden is one such country, which has been blessed by inland waterways despite them being chiefly underused. In order to promote IWT in the project area, this thesis comes to the following conclusion with respect to research questions (RQ). In so doing our findings show that the two main inland waterways in the North Europe, the Danube and Rhine are the drivers of the IWW vessel's characteristics and operational features. In response to the RQ1(a), from common and most common types of vessels, the characteristics of vessels (Length, beam, draft, DWT) in the Danube region, the sizes vary between 67- 110 m in the length, 8.2 -11.4 m in the beam, 2.5-3.5 m in the draft and DWTs' are between 1295-3500 (T). In terms of barges for the same area, the sizes vary between 85-110 m in the length, 9.5-11.4 m in the beam, 2.8-4 m in the draft and DWTs' (in different formations) are between 3740-8400 (T). And, in the same manner, for the Rhine region, their size varies between 80-110 m in length, 9.5-11.4 m in the beam, 2.5-3.5 m in the draft and DWTs' are between 250-8400 (T). And, for the barges in the Rhine, their length is 110 m, beam is11.4m, the draft is between 2.8-4 m and DWT in different formations differ in the same aforementioned range as the Danube tonnage.
In response to RQ1(b), it can be said that in terms of operational features of the vessels and barges (speed, bow thruster, rudder, engine power) for the common and most common vessels and barges in the Danube area, the speeds vary between 15- 18 Km/h and for the barges they stand between 13-16 km/h in different formations. In terms of a bow thruster, in both regions, most vessels from length above 110 m and for barges above 185 m (in different formations) are equipped with one or two bow thrusters. In view of the propulsion system, in the Danube and Rhine when lengths are above 80 m, vessels and barges are equipped with one or two ducted propeller systems and in some cases with three ducted systems. But, in the Rhine, vessels below 80 m length are mostly single screw type. The number of rudder blades in both regions for the vessels and barges vary between one or two and are sometimes provided with an additional flanking rudder. But, small vessels below 38.5m length in the Rhine are mostly equipped with one blade rudder. The last operational feature, being the engine power is also different between regions. In the Danube it is between 750-2000 KW, in the Rhine is between 200-3000 kW but for the barges in both regions it is somewhere between 2000-4500 kW.
In answer to RQ1(c), the reasons behind vessels and the barges characteristics (length, beam, draft, DWT), in both Danube and Rhine areas, are derived from the locks' size, the chambers dimensions and clearance allowances, fairways dimensions, depth of waterways, transport demands and finally the economics of the area. In terms of operational features (speed, bow thruster, rudder, engine power), the characteristics are guided by the severity of the standards and regulations enforcement within the region, requirements of the region, traffic density of the area, redundancy and safety considerations of the area, the economic viability for the region, fairways dimensions and no doubt the seasonal shallow period of the area . The matter of differences for the vessels' operational features in the two regions such as the power of the engines, type of steering system and other equipment are mostly related to the nautical conditions.Some of the environmental & external reasons, however, are the same in both areas such as flow and type of cargo, geographical and climate conditions. However, there are some intrinsic similarities also in the features of the vessels in both these regions. For example, most of the vessels are self-propelled.
Although most of the goods are suitable to be carried by IWW vessels, the IWT share in Sweden is, however, not promising. The most vital issue in the IWT business for the area is its un-competitiveness in relation to the other transport modes. The government, seemingly enough, is favoring rail more than IWT. Some local bottlenecks or interests might have a major impact on the several chains of the network with strategic nature as well as on the efficiency of the entire chains with a negative effect on IWT. It seems analysis and national policies for the promotion of IWT within the country, the whole approach, needs to be wide enough to cover all aspects relevant to IWT business.
With respect to answer RQ2, on IWT requirements for the project area, our findings through the SWOT analysis reveal that promotion of IWT in the area requires specific attention to weaknesses and threats. Therefore, in response to those shortcomings and requirements, findings of RQ2 (threats and weakness) are presented in the form of recommendations (RQ3) for the vessel's characteristics, operational features, and infrastructural needs. This also means that recommendations are mostly in the area of what is lacking and what is required (RQ2) which were observed in advance and prior to the

suggestions. Therefore, the answer to RQ2 and RQ3 are merged and have shaped our recommendations. For example, suitable lifting gear for container operation on vessels or ports, directly appear in the recommendations.

For IWT promotion in the project area, pilot requirement regulation, fairway and pilotage dues, ice-class standards and ice breaker regulations for servicing to IWW vessels are needed to be modified in favor of increasing the IWWs' vessel trade. Furthermore, lack of interest in investment and uncertainty about the cargo availability in the region needs to be addressed. In terms of the climate condition of the project area such as ice, visibility and safety requirements to reduce accidents such as astern anchor, double hull skins due to fresh water supply of nearby cities, the local regulatory requirements for the IWW max size vessels are needed to be minded in the prior stages of vessels construction or modification. In regard to infrastructures, rehabilitation of locks dimensions, or new locks or bridges, the construction parameters need be thoroughly investigated in advance to ensure right dimensions. In a similar way, suitable lifting gears for the container operation and suitable facilities in the ports around Lake Vänern such as bunkering, facilities for container operations and unified traffic information center for rail, road, ocean and river vessels where they cross each path are also needed to be properly established.

In the same way, lack of a direct trans-shipment operation between Mega container vessels and IWW vessels in the port of Gothenburg, the proper equipment for handling IWW vessels and more automation as well as having adequate skilled crew for the IWW vessels' operation for reducing operational costs are certainly required and need be effectively dealt with for the improvement of IWT in the area. Additionally, harmonization of all transport modes through a wider policy and a unified body where they cross each other's paths are needed for boosting IWT in the country. In brief, the vessels characteristics such as length, beam, draft, and DWT are affected by the locks and area of the trade waterways' dimensions and available depths. Furthermore, operational features as recommended for the consideration of building a new vessel or in the case of modification of existing vessels are as follows: controlling stands for the vessels to enable manoeuvring near the bridge wings , latest controlling instruments in the wheelhouse, suitable lifting gear for the container operation on vessels, river radar, ballast water treatment system, double skin hull, stern anchor, one bow thruster, box shape vessel with pushing shoulder for the IWW vessel, V-shape body for the RSV , an increase in body strength due to ice, effective rudder equipment, gearbox power transmission system, ducked propeller system, strong searchlight, foldable mast, elevating wheelhouse, camera for poor visibility, blue board and white flashing light, comfort accommodation, effective internal communication system, inclinometer, effective mooring winch, spud pole for the IWW vessel , effective rescue boat and high automation for the IWW vessel.

At the end it must be said, under present conditions, to overcome lack of lifting gears for container operation and to deal with the uncertainty of cargo flow in the area, a multi-purpose vessel within the present locks dimension range that is equipped with a proper lifting gear for container and a suitable draft limit which enables her to call most of the ports in the Lake, is recommended for the initiation of a container line in the project area.

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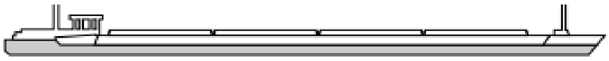
Appendix I

Description about SSPA Company

The SSPA plays a historic major role in the promotion of sustainable development by providing research via coordinating the expertise, technology and tools in the maritime industry. SSPA company offers maritime solutions to shipowners, shipyards, manufacturers, ports and maritime authorities worldwide. The master thesis will be part of an ongoing INTERRG project within the North Sea region “IWTS – Inland Waterway Transport Solutions”, which runs from 2017-2020, and involve partners in Sweden, Netherlands, Belgium, Germany and Great Britain. The overarching aim of the IWTS project is to “*mobilize potentials and capacity to move freight to smaller waterways that are applicable in all North Sea region*”.

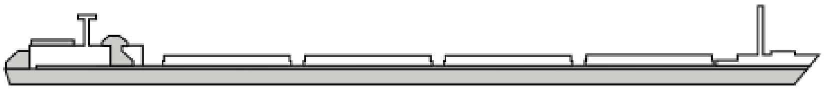
Appendix II

The main type of Inland waterways dry cargo vessels in the EU and their capacity equality to the numbers of truck



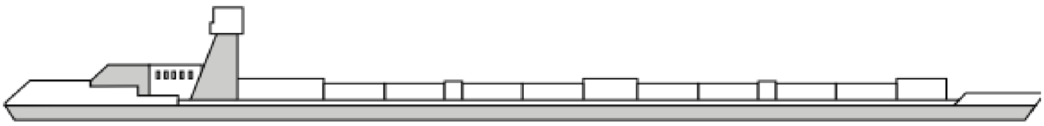
Gustav Koenigs	
Length:	67 m
Width:	8.2 m
Max. draught:	2.5 m
Deadweight (dwt):	900 t

Gustav Koenigs (Rewway, 2018)



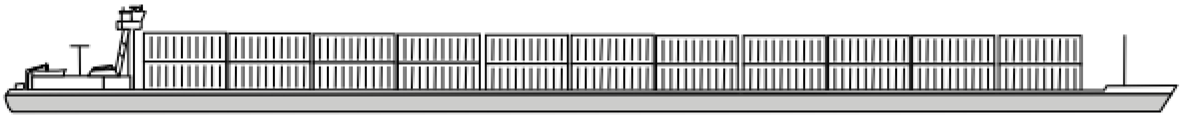
Europaschiff	
Length:	85 m
Width:	9.5 m
Max. draught:	2.5 m
Deadweight (dwt):	1,350 t

Europaschiff (Rewway, 2018)



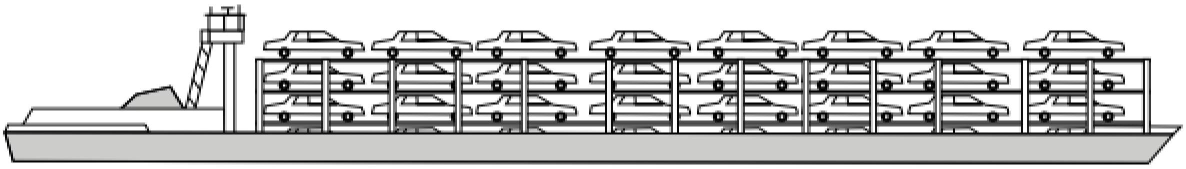
Large motor vessel	
Length:	95 m / 110 m
Width:	11.4 m / 11.4 m
Max. draught:	2.7 m / 3.5 m
Deadweight (dwt):	2,000 t / 3,000 t

Large motor vessel (Rewway, 2018)



Container vessel	
Length:	135 m
Width:	17.0 m
Max. draught:	3.7 m
Deadweight (dwt):	470 TEU

JOWI class Rhine container vessel (Rewway, 2018)



Ro-Ro vessel	
Length:	105 m
Width:	9.5 m
Max. draught:	1.4 m

270 x 

Ro-Ro vessel (Rewway, 2018

Appendix III

The most common type of vessels and barges in the area of Rhine and passage share

Vessel type	Share in the number of passages
Motor vessels (reference dimensions)	
M1 (38.5*5.05m)	0,5%
M2 (50*6.6m)	3,7%
M3 (55*7.2m)	3,7%
M4 (67*8.2m)	4,5%
M5 (80*8.2m)	7,5%
M6 (85*9.5m)	15,9%
M7 (105*9.5m)	5,5%
M8 (110*11.4m)	31,9%
M9 (135*11.4m)	6,9%
M10 (110*13.5m)	1,0%
M11 (135*14.2m)	3,0%
M12 (135*17.0m)	2,2%
Coupled convoys	
C2l (Class IV+Europa I barge long)	0,4%
C3b (Class Va+Europa II barge wide)	0,3%
C3l (Class Va+Europa II barge long)	4,4%
C4 (Class Va+3 Europa II barges)	0,6%
Pushed convoys	
BII-1 (Europe II pushed convoy)	0,2%
BII-2b (2 Europe II barges in a wide pushed convoy)	0,2%
BII-4 (4 Europe II barges in a pushed convoy)	3,2%
BII-2L (2 Europe II barges in a long pushed convoy)	0,1%
BII-6b (6 Europe II barges in a wide pushed convoy)	0,9%
BII-6l (6 Europe II barges in a long pushed convoy)	1,0%

(Prominent, 2018

Appendix IV

Record of amount of motor cargo vessels trade on the lock Freudenau in the year 2014 in the Danube area
L= Length of the vessel
MCV= Motor Cargo Vessel (dry Cargo)
MTV=Motor Tanker Vessel
PUSH=Pusher or tug
0B= Vessel without Barge
1B= Vessel with one barge

Vessel type	Nr. of passages	Nr. of passages [%]	Total
L 94-136 MCV 0B	1323	16,92%	3199
L 94-136 MCV 1B	585	7,48%	
L 94-136 MCV 2B	13	0,17%	
L 94-136 MCV 3B	20	0,26%	
L 94-136 MCV 4B	1	0,01%	
L 94-136 MTV 0B	1179	15,07%	
L 94-136 MTV 1B	78	1,00%	
L 79-86 MCV 0B	1079	13,80%	1600
L 79-86 MCV 1B	173	2,21%	
L 79-86 MCV 2B	5	0,06%	
L 79-86 MCV 3B	1	0,01%	
L 79-86 MTV 0B	341	4,36%	
L 79-86 MTV 1B	1	0,01%	
L 66-68 MCV 0B	43	0,55%	44
L 66-68 MCV 1B	1	0,01%	
L 56-58 MCV 0B	6	0,08%	336
L 56-58 MTV 0B	2	0,03%	
L 56-58 PUSH 0B	19	0,24%	
L 56-58 PUSH 1B	18	0,23%	
L 56-58 PUSH 2B	262	3,35%	
L 56-58 PUSH 3B	28	0,36%	
L 56-58 PUSH 4B	1	0,01%	
L 31-39 PUSH 0B	84	1,07%	1079
L 31-39 PUSH 1B	58	0,74%	
L 31-39 PUSH 2B	691	8,84%	
L 31-39 PUSH 3B	53	0,68%	
L 31-39 PUSH 4B	192	2,45%	
L 31-39 PUSH 5B	1	0,01%	
L 22-24 PUSH 0B	239	3,06%	1563
L 22-24 PUSH 1B	275	3,52%	
L 22-24 PUSH 2B	1016	12,99%	
L 22-24 PUSH 3B	26	0,33%	
L 22-24 PUSH 4B	7	0,09%	
	Σ	100,00%	7821

(Prominent, 2018)

Appendix V

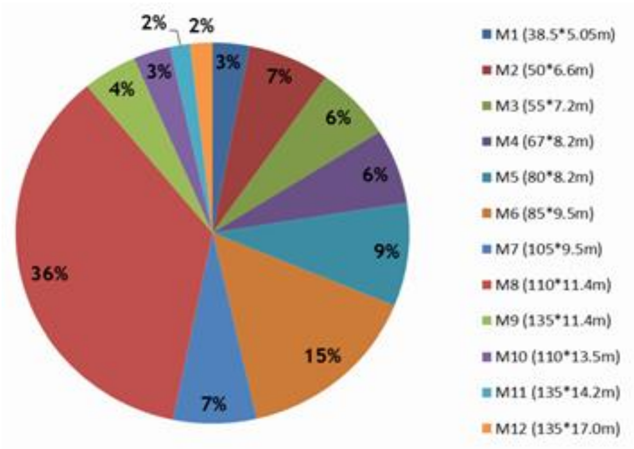
Fleet constructions estimation by 2030 in some European regions

Vessel size class [DWT]	MLK (Hannover)	DEK (Münster)	WDK (Datteln/Friedrichsfeld)	Rhein-Herne-Kanal, Duisburg
E 0 - 400	1.2	0.5	0.3	0.3
E 401 - 650	3.5	4.2	3.3	0.7
E 651 - 900	14.9	12.7	10.3	6.4
E 901 - 1,000	9.5	6.1	3.4	2.5
E 1,001 - 1,500	32.2	45.4	37.7	38.5
E 1,501 - 2,000	10.0	11.0	19.9	29.5
E 2,001 - 2,500	9.2	6.4	8.6	8.4
E 2,501 - 3,000	9.5	7.1	7.5	7.2
E > 3,000	2.7	2.0	6.0	2.4
SL 0 - 1,500	5.8	3.7	2.1	4.1
SL 1,501 - 2,000	0.2	0.1	0.2	0.0
SL > 2,000	1.3	0.8	0.7	0.0
Ø DWT E	1,467.0	1,399.0	1,604.0	1,595.0
Ø DWT E + SL	1,424.0	1,374.0	1,588.0	1,547.0

E: Self-propelled vessel (Single driving or part of push-tow unit)
SL: Pushed barge (lighter) (part of push-tow unit)
DWT: Deadweight Tonnes
(Institute, 2018)

Appendix VI

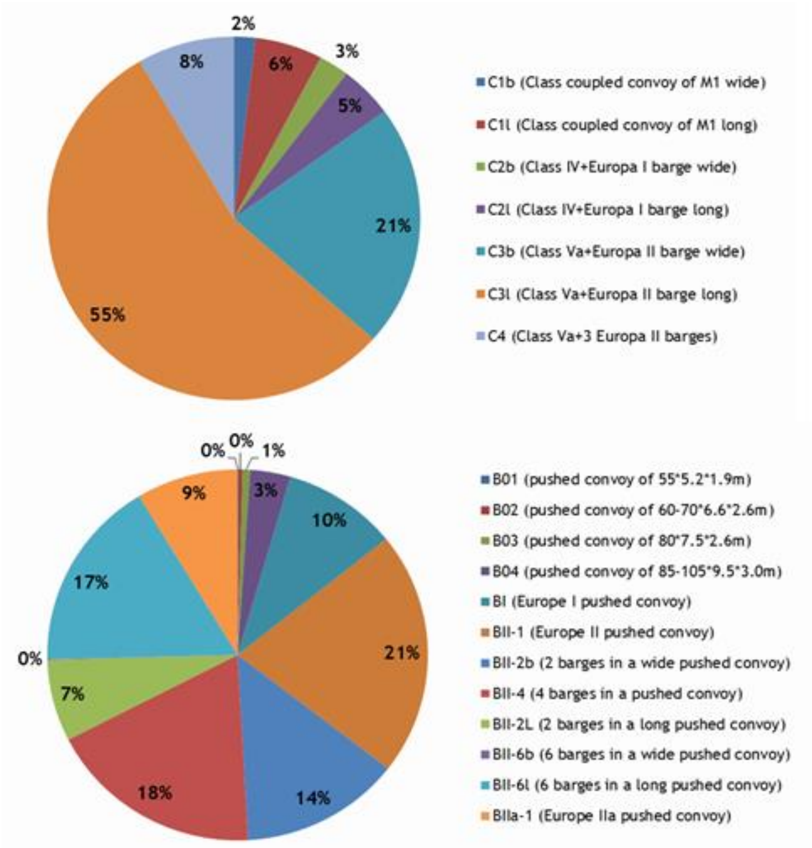
Percentage of vessels traffic on the Lock Volkerak in the Netherland for year 2008 according to size



(Prominent)

Appendix VII

Traffic percentage on the Volkerak lock for different barges formation trade in year 2008 in the Netherland



(Prominent, 2018

Appendix VIII

Vessel traffic records on the Sambeek lock in the Netherlands

Vessel type	Share in the number of passages
Motor vessels (reference dimensions)	
M1 (38.5*5.05m)	1.56%
M2 (50*6.6m)	15.08%
M3 (55*7.2m)	13.30%
M4 (67*8.2m)	20.73%
M5 (80*8.2m)	14.06%
M6 (85*9.5m)	14.75%
M7 (105*9.5m)	5.52%
M8 (110*11.4m)	15.00%
Pushed convoys	
BII-2L (2 Europe II barges in a long pushed convoy)	0.00%

(Prominent, 2018).

Appendix IX

Tonnage and Length records on Alberta Canal in Belgium

Vessel type		Share in the number of passages
Loading capacity [tonnes]	Estimated vessel length [m]	
=< 300	< 38.5	0.6%
301 - 650	38.5 - 55	19.1%
651 - 800	55 - 70	6.8%
800 - 1350	70 - 80/86	21.8%
1350 - 2000	80 - 105	16.5%
>= 2000	>= 110	35.2%

(Prominent, 2018)

Appendix X

Typical vessels traffic records on German canals and Elbe

Schubleichter /Typ (Länge / Breite / Tiefgang; Meter)	Anzahl	Tragfähigkeit t (von – bis)
Containerschubleichter TC 1000 (71 m / 10,45 m / 2,5 m)	15	1.450 54 TEU
Containerschubleichter SL 65–9,50 (65 m / 9,5 m / 2,4 m)	26	1.190 54 TEU
Trockenschubleichter SL 65 (65 m / 8,2 m / 2,33 m)	44	975
Containerschubleichter SL 36/37–9,50 (32,5 m / 9,5 m / 2,17 m)	13	530 24 TEU
RoRo-Schubleichter GSP 65 (65 m / 9,5 m / 2,27 m)	3	1066
RoRo-Schubleichter GSP 54 (54 m / 11 m / 2,06 m)	3	960
Trockenschubleichter SL 36/37 (32,5 m / 8,2 m / 2,1 m)	214	bis 470
Wannenschubleichter (32,5 m / 8,2 m / 2,1 m)	61	430
Mörtelschubleichter (32,5 m / 8,2 m / 2,1 m)	2	430
Trockenschubleichter Finow (31,3 m / 5,04 m / 1,7 m)	6	210
Tank- und Produktentankschubleichter (32,5 – 65 m / 8,2 m / 2,15 m)	5	500–1.023 m³
Schubleichter gesamt	392	

Schubschiffe / Typ	Anzahl	kW (von – bis)
Schubschiff 26 flachgehend	5	448–894
Schubschiff 27	6	574–890
Schubschiff 25 / 26	16	352–1.102
Schubschiff 24	28	220–588
Schubschiff 22 / 23	17	69–366
Schubschiffe gesamt	72	

Motorschiffe / Typ (Länge / Breite / Tiefgang; Meter)	Anzahl	Tragfähigkeit t (von – bis)
Trockenmotorschiffe (67 – 80 m / 8,2 m / 2,35 m)	30	922–1.146
Tankmotorschiffe (80 m / 8,2 m / 2,35 m)	2	1.000–1.100
Motorschiffe gesamt	32	

(Prominent, 2018)

Appendix XI

Local requirements for maximum size Vessels to pass the locks in Route Göta älv to Lake Vänern

1- Robust steering, and propellers to provide a transverse load for the safe manoeuvring
2- In case of Becker and Schilling model rudders or any high effective rudder are good but if not, the vessel rudder must not be less than 0.02 area conditions when actual draft corresponds to the lateral surface.
3- From 35-degree starboard to the 35-degree port or vice versa shall not exceed more than 15 seconds
4- Reserve steering with similar regular steering equipment should immediately be possible
5-The rudder should be manoeuvrable from the centreline or near and on the bridge wings
6- In all steering locations rudder angle indicators should be provided and easily readable
7-By fixed propeller, the possibility to reduce engine speed by 25 per cent of full stop without engine stop and speed should not exceed 5 knots in the ballast condition
8- Change of engine speed from slow ahead to the slow astern or vice versa should not take more than 8 seconds
9- In the case of pitch propeller, in reverse condition, it should have the same characteristics as a fixed propeller
10- Engine or propeller control should be provided on the bridge wings
11- Navigation bridge shall have good view and visibility from the wheelhouse or steering point in the ballast or loaded conditions according to SOLAS chapter V, rule 22
12- To avoid delay in the voyage or to reduce voyage time or waiting for the bridge openings, foldable masts are recommended to lower the masts prior to crossing the bridges
13-Vessels more than 85 meters long are recommended with mooring winches to facilitate the mooring operation
14- Wheelhouse should be provided with an inclinometer
15- Vessels should be provided with two radars and one with suitability for the canal navigation
16- It is recommended that the vessels have turn indicator in the bridge
There is an application form for all vessels prior to passing through canals and locks which need ~~to~~ be handed to the authorities before crossing the canal (Sjöfartsverket, 2018).