RE WWay
Research & Education in Inland Waterway Logistics

LOGISTIKUM
CHALLENGE ACCEPTED

viadonau

READER – INTERNATIONAL WATERWAYS

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1 Characteristics of major waterways

Inland waterways are navigable inland transport routes, a distinction is made between natural and artificial inland waterways. Natural inland waterways are rivers and lakes, whereas canals are artificial inland waterways. A canal is an artificial waterway, which connects two rivers. To overcome differences in altitude along a waterway, locks are used, and by filling or emptying the lock chamber, the vessels are either raised or lowered.[1]

The infrastructure of inland waterways is a key factor for the competitiveness of inland navigation. It is therefore crucial to ensure the quality and reliability of waterways in order to promote an increased use of inland waterways as a transport mode. In this context, the fairway can be identified as one of the most important infrastructure elements for an economically efficient transport on inland waterways. Since in most cases transport cannot be carried out by inland waterway only, transhipment to other modes of transport such as trucks is necessary. Consequently, multimodal nodes with appropriate infrastructure are needed to improve the use of different modes of transport within the transport chain. Thus, ports are an important infrastructure element to link inland waterways with other modes of transport. In addition, regular maintenance work is required to ensure the quality and reliability of the waterway infrastructure and the continuous improvement of the infrastructure.[2] The waterway infrastructure is also influenced by external factors such as weather conditions and the geographical location of the respective inland waterway. Weather conditions within Europe can vary considerably, therefore transport conditions on inland waterways vary from country to country. In addition, the topography of a country and the political and economic importance of inland waterway transport influence competitiveness. Even if a country has a wide network of navigable inland waterways, in most countries political promotion of inland navigation is necessary to ensure increased use of inland navigation as an alternative to road transport.[3]

The following chapters describe characteristics or factors that influence large waterways and inland navigation on them.

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1 Cf. Linden W. (1966), p.1743, p 631, p.787.; viadonau, 2013, p.42f., p.200.

2 Cf. viadonau: Good Practice Manual on Inland Waterway Maintenance, Focus: Fairway maintenance of free-flowing rivers (2016), p.6

3 Cf. viadonau: Good Practice Manual on Inland Waterway Maintenance, Focus: Fairway maintenance of free-flowing rivers (2016), p.6

1.1 Ship dimensions

There are basically four dimensions relevant to ships, their length, width, maximum draught and maximum deadweight. These dimensions determine on which waterways an inland waterway vessel can and may sail. In Europe, the AGN, the European Agreement on Main Inland Waterways of International Importance, applies in this respect, in which the inland waterways of Europe are classified in waterway classes. The waterway class of a waterway provides information about the maximum size of vessels that can be used on this waterway. The waterway classes IV and higher are of international importance, the waterway classes I to III are of regional or national importance.[4]

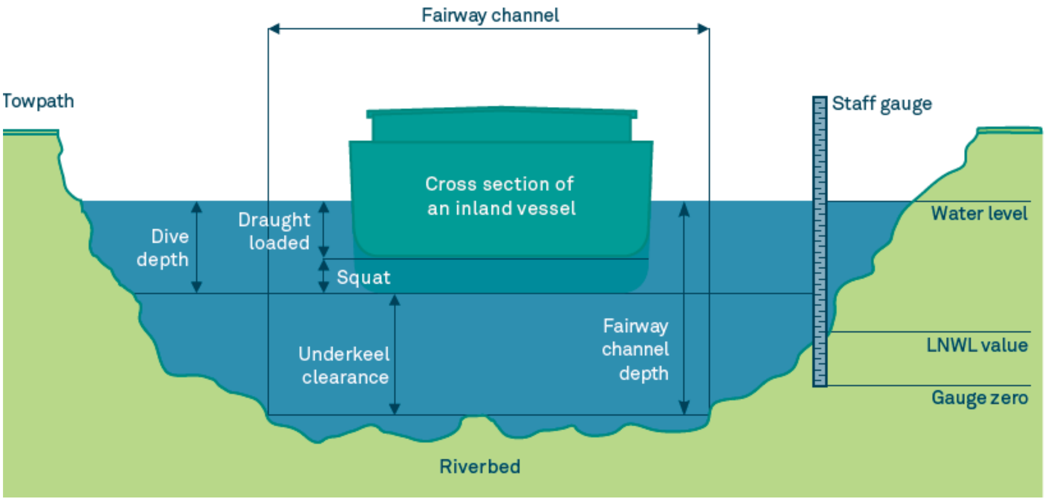
1.2 Fairway

The fairway is the area of an inland waterway in which certain depths and widths of waterways are to be maintained for shipping traffic. Internationally standardized fairway signs, such as buoys or traffic signs on land mark the width and the course of the fairway. The depth of the fairway in the fairway determines how far a cargo ship can be "unloaded"; the more goods a ship has loaded, the greater is its unloading depth, i.e. the draught of the ship at rest corresponding to a certain loading condition. The unloading depths usable by shipping have a decisive influence on the economic efficiency of inland waterway transport.[5] When determining the cross-section of the fairway, i.e. its depth and width, a "minimum" cross-section is assumed on rivers. This is derived from the "shallowest" and "narrowest points" of a particular river section at low water. In order to avoid grounding of cargo vessels during the voyage, the dynamic drawdown and a corresponding safety distance to the bottom of the fairway, the float water, must also be taken into account when determining the possible discharge depth based on the current fairway depth. The total depth of a vessel is equal to the sum of its draught and its drawdown.[6]

[4] Cf. viadonau (2019), p.42ff.

[5] Cf.. viadonau (2019), p 49f.

[6] Cf.. viadonau (2019), p 49f.



Picture 1: Parameters of fairway channel – Source: viadonau

This safety distance is known as float water and is defined as the distance from the hull of a ship in motion to the bottom of the waterway (highest point of the river bed). The float water should not be less than 20 cm for gravel bottom or 30 cm for rocky bottom in order to avoid damage to the propeller and/or the hull. Sinking is the amount by which a ship sinks in relation to its resting position on inland waterways with a limited cross-section (i.e. rivers and canals) while under way. For a loaded ship, the subsidence is approximately between 20 and 40 cm. The authorities responsible for the maintenance of a waterway shall, if possible, maintain the depth of the fairway at a certain minimum level by maintenance measures (dredging). This is referred to as minimum fairway depths in the fairway, which are based on the regulation low water level (RNW) as a statistical reference value for the water level.[7]

1.3 Availability - the example of the Austrian Danube

The availability of the Austrian Danube is 97.7% in a long-term comparison, which corresponds to 357 days per year, meaning that the Danube can be used for navigation on average 357 days per year. Reasons for official closures that reduce availability are extreme situations such as ice formation and floods, as well as traffic accidents, construction work and events. Ice formation and flooding are weather-related closures, with ice formation occurring only in the winter months and, of these, mainly in January and February, whereas floods occur preferentially in the spring and summer months.[8]

7 Cf. viadonau (2019), p 49f.

8 Cf. viadonau (2019), p 24f.

1.4 Bridges

Bridges can span a waterway, a harbour entrance or a river power station and thus a lock system. On free-flowing, i.e. undammed river sections, water levels can fluctuate considerably, which influences the passage possibilities under bridges at high water levels. Depending on the distance between the individual bridge piers, there may be one or more - but in most cases two - passage openings under a bridge. If there are two passage openings under a bridge for shipping traffic, one opening is usually used for uphill and one for downhill traffic. The possibility of passage under a bridge depends primarily on the bridge clearance above the water level and the fixed point height of the ship.[9]

The fixed point height is the vertical distance between the waterline and the highest immovable point of a ship after moving parts such as masts, radar or wheelhouse have been folded or lowered. The fixed point height of a ship can be reduced by ballasting the ship. This can be done by loading ballast water into ballast tanks or by loading fixed ballast. Apart from the height of a bridge passage and the fixed point height of a ship, the bridge profile can also have an influence on the passage possibilities for ships. In the case of arched bridges, a sufficient horizontal safety clearance must be ensured in addition to the vertical clearance. Since the height and width of a bridge passage always refer to the entire width of the fairway, arched bridges have a greater clearance height in the centre of the bridge than at the edges of the fairway. Bridge clearance heights for free-flowing sections of rivers are generally related to the Highest Shipping Water Level (HSW), whereby the specified clearance height corresponds to the distance in metres between the lowest point of the lower edge of the bridge in the entire area of the fairway and the water level at HSW. The width of the fairway under a bridge is related to the regulation low water level (RNW). In sections of rivers regulated by dams, the maximum dammed water level is usually used as a reference point for both the clearance height and the clearance width; on canals, the reference is to the upper operating water level.[10]

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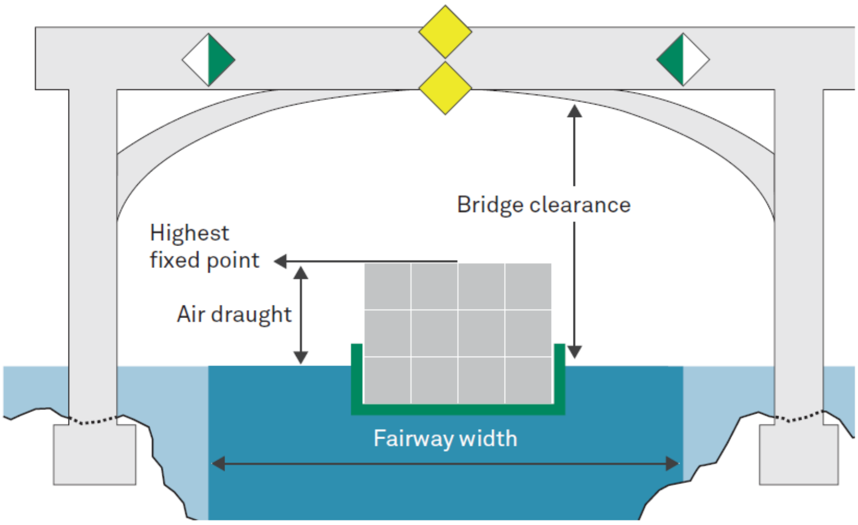
[9] Cf. viadonau (2019), p 55f.

[10] Cf. viadonau (2019), p 55f.



Picture 2: Bridge – Source: viadonau (2019)

From Kelheim to Sulina, a total of 129 bridges span the international Danube waterway. Among the 130 Danube bridges there are 21 lock and weir bridges. With 89 Danube bridges, there is by far the highest density of bridges on the Upper Danube: 41 bridges span the German, 41 the Austrian and 7 the Slovakian stretch of the Danube. On the Middle Danube there are a total of 33 bridges; on the Lower Danube there are only seven.[11]

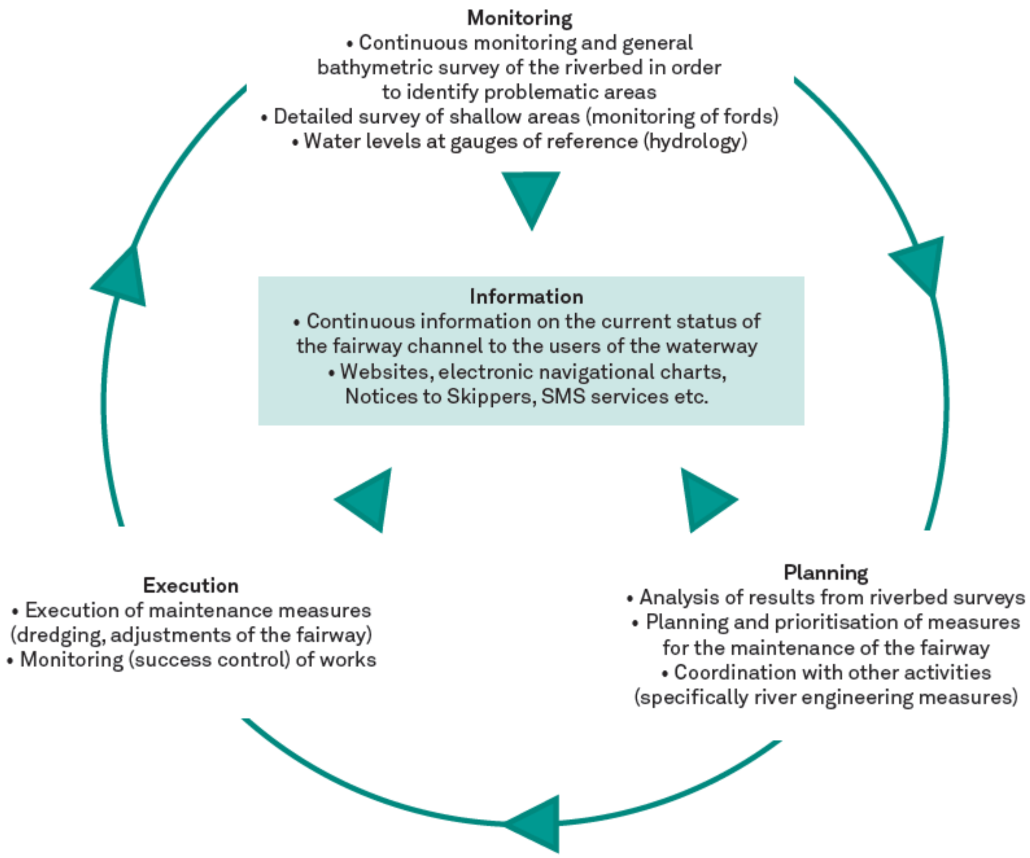
1.6 Maintainance

If the minimum fairway parameters cannot be achieved, the competent national waterway authority must take appropriate measures to restore them. This is normally achieved by dredging at shallow points (fords) within the fairway. Dredging involves the removal of bottom sediments (sand and gravel) and their reintroduction into the river at another point, taking into account ecological aspects. Dredging requires a foresighted planning based on the results of regular bottom surveys and a final review (success control) of the work by the responsible waterway administration body. Since the measures for maintaining the fairway are recurring and interdependent, this can be referred to as a fairway maintenance cycle. The most important measures are:[12]

- regular measurement of the riverbed to identify problem areas in the fairway (reduced depths and widths)
- Planning or prioritisation of the necessary measures (dredging, changing the course of the fairway, traffic regulation) based on the analysis of current river bed surveys
- Execution of maintenance measures (especially dredging including success control)

[11] Cf. viadonau (2019), p 56.
[12] Cf. viadonau (2019), p 58f.

- Continuous and target group oriented information about the current condition of the fairway to the users of the waterway.



Picture 3: Maintainance circle – Source: viadonau (2019)

1.7 Ports

Ports link the modes of transport road, rail and waterway with each other and are important service providers in the field of handling, storage and logistics. In addition to the basic functions of a port such as transshipment and storage, a whole range of logistical value-added services are often offered to customers, such as packaging, stuffing and stripping of containers, sanitary inspection and quality control. This turns ports into logistics platforms and drivers for the establishment of companies and economic development. As multimodal logistics nodes, they assume the hub function between the various modes of transport. An important indicator of a port's performance is the volume of cargo handled between the different modes of transport. In a port, transhipment takes place not only between waterway, road and rail, but also between non-waterborne modes of transport such as rail-rail or road-rail.[13]

[13] Cf. viadonau (2019), p 86f.

The basic structure of a port can be divided into three parts: the waterside, the port area and the hinterland. The hinterland is the catchment area of a port, i.e. the region immediately adjacent to a port and connected to the various modes of transport. The size of the hinterland depends on the economic distance. The landside inbound and outbound traffic of seaports is referred to as hinterland traffic.[14]

The range of services offered by a port must be attractive to shippers and logistics service providers. In addition to universal ports, there are also specialised ports that gear their business to a specific type of goods. The specialisation of a port in sub-sectors can lead to competitive advantages. A port specialises in certain types of goods on the basis of an increased demand for a certain type of goods or an increasing volume of goods in the hinterland. This means that a port can also have several specialised terminals. One form of specialisation is, for example, in the High & Heavy sector. Heavy goods ports that specialise in the handling of oversized goods require special technical equipment and special logistical solutions. Tried and tested lifting techniques and equipment with high load capacities are requirements for a heavy-duty port. Special handling equipment is also required for handling liquid goods such as liquefied natural gas (LNG) or crude oil. Special suction or pumping devices are required in the port. Since the majority of the liquid goods handled are hazardous goods, special safety precautions must also be taken in a port.[15]

Green ports, i.e. sustainable port management, is a trend that has increasingly established itself in the field of port development over the last few years. Green ports should represent a balance between environmental impacts and economic interests. A core area of the European Commission's "Europe 2020" strategy is sustainable growth (European Commission 2010a). National and regional political guidelines should also lead to more sustainability in the field of port development. Green Ports as a concept includes not only the development of ports but also the complete redesign of logistics chains.[16]

1.8 Weather

Floods can be caused by high rainfall over a long period of time or by snowmelt after winter. A high water level mainly affects the water level of the waterway and thus the inland waterway traffic and infrastructure of the inland waterways. A high water level can lead to disruption of navigation, delays, damage to infrastructure such as ships, ports and locks due to driftwood. Possible consequences include flooding of the surrounding inland waterways, changes in the inland waterways themselves and bank morphology. Floods thus have a major impact on inland waterway

14 Cf.. viadonau (2019), p 87f.
15 Cf. viadonau (2019), p 101.
16 Cf. viadonau (2019), p 102.

traffic, as they have a negative impact on waterway infrastructure, which is crucial for efficient transport by inland waterway vessels.[17]

Drought can be caused by low precipitation and high temperatures. Consequently, inland waterways are confronted with low water levels during periods of drought. The effects on inland navigation are therefore different from those of floods. On the one hand, the freight capacity of inland vessels decreases due to low water. On the other hand, transport duration increases, which also leads to higher fuel consumption by inland vessels. Depending on the geographical location, droughts or floods can last longer and therefore also have a considerable impact on the economic efficiency of inland navigation. Floods and low water can thus be identified as weather phenomena with a high impact on inland navigation.[18]

In winter, ice can affect inland navigation. If the ice layer is very thick, inland navigation vessels may not be able to continue their journey. Nevertheless, traffic on inland waterways is only affected by ice on small parts of the route. For example, there has been no ice blockage on the Rhine for the last 40 years. Waterways with low flow velocities and canalised sections are mainly affected by ice. Damage can occur, for example to locks, which affects the safety of shipping. Due to damaged locks, vessels may not be able to continue their journey and delays or interruptions may occur.[19]

As most inland vessels are of stable construction, even strong winds do not have a major impact on inland navigation. Nevertheless, local high wind speeds may affect inland navigation. The effects vary depending on the type of vessel and the cargo transported. For example, pushed convoys without cargo or container ships with open holds can be strongly influenced by the wind. This can affect the manoeuvrability of the inland vessel, which can lead to collisions with the waterway infrastructure or other vessels. In addition, more time is needed for the manoeuvring process, which causes delays. Furthermore, the transport can also be interrupted if a safe continuation is endangered. If visibility is reduced by fog, rain, haze, snowfall or other reasons, inland vessels must be navigated by radar. Depending on the actual situation, the captain of a vessel must take certain measures to ensure safety. Due to the limited visibility, inland vessels must navigate at a safe speed to avoid collisions with other inland vessels or the waterway infrastructure. This may cause delays due to an interruption of transport or speed reductions.[20]

1.9 Geographical location and political importance

Due to different geographical conditions, the number of navigable waterways varies from country to country. At global level, China and Russia have the most navigable waterways available. In Europe,

[17] Cf. Schweighofer J. (2014), p 25ff.; Strobl et al (2006), p 383ff.

[18] Cf. Schweighofer J. (2014), p 25ff.

[19] Cf. Schweighofer J. (2014), p 25ff.; Maniak U. (2016); Wirtschaftskommission für Europa (2013), p 47.

[20] Cf. Schweighofer J. (2014), p 25ff.

France, Finland and Germany have the most available waterways. In comparison, Greece, Liechtenstein and Luxembourg have only a small share of navigable waterways in Europe.[21]

Another factor that influences the use of inland navigation as a means of transport is its political importance. In Europe, inland waterways are important for the transport of goods. The European Commission aims to strengthen inland navigation through various measures such as promotion programmes and cost advantages. In China, water transport can also be considered a very important part of freight transport. In contrast, the importance of inland waterways in Brazil is very low. In addition, waterway management of inland waterways is inefficient in Brazil.[22]

The political importance of inland navigation also has an influence on transport policy and thus on investment. Infrastructure measures are expensive and therefore need political support. China is the world's largest infrastructure investor. In the period between 1992-2011 China spent 8.5% of its gross domestic product (GDP) on infrastructure investments. Most of this sum was spent on investments in road, electricity, rail and water infrastructure. By comparison, Europe spent 2.6% of GDP on infrastructure investments. To implement transport projects, the EU budget for the period 2014 - 2020 was set at 26 billion euros. In contrast, investments in waterways is a low priority in Brazil. In general, Latin America has invested only 1.8% of its GDP in infrastructure investments.[23]

2 Inland waterways in Europe

In 2018, a total of 544 million tonnes of goods were transported by inland waterways in Europe (total performance: 135 billion tonne-kilometres).[24] As can be seen from the figure, goods transported by inland waterways are mainly metal ores, coke and refined petroleum products and agricultural products. The Netherlands has the largest share of inland waterways transport in Europe. The main waterway axis on the European mainland is the Rhine-Main-Danube corridor. The Rhine and Danube basins, which are connected by the Main-Danube Canal, are the backbone of this axis. This waterway axis connects 15 European countries via inland waterways.[25]

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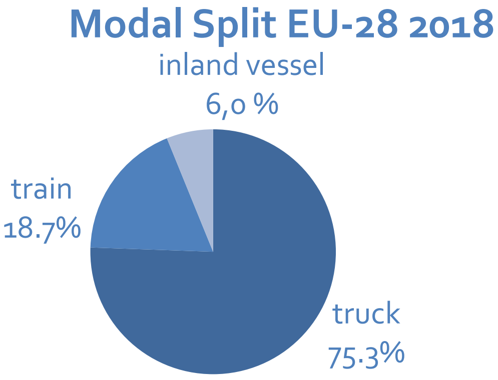
21 Cf. Indexmundi, URL: http://www.indexmundi.com/map/?t=10&v=116&r=xx&l=en [24.04.2020].

22 Cf. Chen Y., Matzinger S., Woetzel J.: Chinese infrastructure: The big picture, URL: http://www.mckinsey.com/global-themes/winning-in-emerging-markets/chinese-infrastructure-the-big-picture [24.04.2020]Vgl. DeWoskin K.: China, URL: http://www.britannica.com/place/China/Waterways [24.04.2020].

23 Cf.. Brazilian Ministry of Transport (2013), S.30.

24 Cf. Eurostat, “Freight transport statistics – modal split”, (2018), URL: http://ec.europa.eu/eurostat/statistics-explained/index.php/Freight_transport_statistics_-_modal_split [24.04.2020].

25 Cf.. Eurostat, “Inland waterway transport statistics”, URL: http://ec.europa.eu/eurostat/statistics-explained/index.php/Inland_waterway_transport_statistics [24.04.2020].



Picture 4: Modal Split of EU-28 – Source: Eurostat

In order to create the most uniform conditions possible for the development, maintenance and economic use of inland waterways, the Inland Transport Committee of the United Nations Economic Commission for Europe (UNECE) adopted in 1996 the European Agreement on Main Inland Waterways of International Importance (AGN) (United Nations Economic Commission for Europe 2010). The Convention entered into force in 1999 and provides an international legal framework for planning, based on technical and operational parameters, the development and maintenance of the European inland waterway network and ports of international importance. By ratifying the Convention, the Contracting Parties declare their intention to implement the coordinated plan for the development and extension of the so-called E-waterway network. The E-waterway network consists of European inland and coastal waterways, including the ports located along these waterways, which are important for the international transport of goods. E-waterways are each designated by the letter "E" followed by a combination of digits, whereby main inland waterways are identified by two digits and branches by four or six digits (for further branches). For example, the international waterway Danube has the identification E 80, its navigable tributary Sava has the identification E 80-12.[26]

Waterway classes are designated with Roman numerals from I to VII. Waterways of class IV and higher are of economic importance for international freight transport. Classes I to III designate waterways of regional or national importance. The class of an inland waterway is determined by the maximum size of the vessels that can be used on this waterway. The width and length of inland waterway vessels and convoys of vessels are decisive here, as they represent fixed reference values. Limits on the minimum draught of vessels (2.50 m) and the minimum clear headroom under bridges

[26] Cf. viadonau (2019), p 42.

(5.25 m in relation to the maximum navigation water level), which are fixed for an international waterway, are only possible in exceptional cases and for existing waterways.[27]

Motor cargo vessels						
Type of vessel: general characteristics						
Water-way class	Designation	Max. length L (m)	Max. width B (m)	Draught d (m)	Deadweight T (t)	Min. height under bridges H (m)
IV	Johann Welker	80-85	9.5	2.5	1,000-1,500	5.25 / 7.00
Va	Large Rhine vessel	95-110	11.4	2.5-2.8	1,500-3,000	5.25 / 7.00 / 9.10
Vb	Large Rhine vessel	95-110	11.4	2.5-2.8	1,500-3,000	5.25 / 7.00 / 9.10
VIa	Large Rhine vessel	95-110	11.4	2.5-2.8	1,500-3,000	7.00 / 9.10
VIb	Large Rhine vessel	140	15.0	3.9	1,500-3,000	7.00 / 9.10
VIc	Large Rhine vessel	140	15.0	3.9	1,500-3,000	9.10
VII	Large Rhine vessel	140	15.0	3.9	1,500-3,000	9.10

Picture 5: Waterway classes according to the AGN –Source: United Nations Economic Commission for Europe, 2010

TEN is a high-level EU transport network and is an instrument for the standardisation of transport systems. Strengthening multimodal transport, i.e. strengthening the interconnection and combination of transport modes, is one of the objectives of TENs. TEN-T is a part of TEN and deals with the area of transport infrastructure. TEN-T is based on a three-level priority system consisting of the basic network, the core network and the corridors. The EU provides EUR 225 billion for priority projects up to 2030, 80% of these funds are used for railways and inland waterways.[28]

Europe has 40,000 km of waterways, half of which are navigable for vessels with a capacity of 1,000 tonnes. Currently (with Croatia's accession to the EU) 19 out of 28 EU Member States have access to navigable waterways. Within Europe, France has the most available waterways (including rivers, canals and other navigable waters), followed by Finland. Germany is in third place. In contrast, Austria has only 358 km of navigable waterways and ranks 26th.[29]

Although many inland waterways are available, inland navigation is generally the least used mode of transport in Europe. Nevertheless, there are different values at national level: In the Netherlands, inland navigation has the highest share in the modal split of inland freight transport with 43.2% in

27 Cf. viadonau (2019), p 42f.

28 Cf. Europäische Kommission (2018) Infrastructure – TEN-T – Connecting Europe. Online: https://ec.europa.eu/transport/themes/infrastructure/ten-t-guidelines/maps_en [24.04.2020].

29 Cf. Van Deleur, Caroline: Platina F&F General (2012, URL: http://de.slideshare.net/carolinevandeleur/platina-ff-general-14427068 [24.04.2020]; Indexmundi, URL: http://www.indexmundi.com/map/?t=10&v=116&r=eu&l=en [24.04.2020].

2018 (% of total tonne-kilometres) and Romania and Bulgaria also have a relatively high share compared to other countries in Europe. In contrast, in other countries (e.g. Austria, Latvia or Lithuania), inland waterways transport has a very low or no share in the modal split. These differences can be explained by different limiting factors such as accessibility, transport distance and transport volume. Accessibility of inland waterways through ports is crucial to encourage the increased use of inland waterways. Moreover, inland waterways are more likely to be used when the transport distance is relatively long and the transport volume relatively high. This is only possible if a suitable waterway infrastructure is available.[30]

2.1 Main traffic routes

The largest volume transported on inland waterways flows from the North Sea ports of Rotterdam, Antwerp and Amsterdam to Germany and Switzerland. Thus, around 68% of the volume transported by inland waterways in Europe is carried on the Rhine route. In 2013, 193.5 million tonnes were transported on the "traditional Rhine", which runs between Switzerland and the German-Dutch border. A total of 330 million tonnes were transported on the Rhine route in 2010.[31] The north-south link from the Netherlands to northern France via Belgium, with a share of approximately 15%, is also an important inland waterway route in Europe. This route is important for transport between France, Belgium and the Netherlands, although the volume of transport is relatively low.[32]

Another important inland waterway in Europe is the Danube, with a 14% share of traffic. In contrast, the east-west route accounts for only 2% of the volume transported on inland waterways in Europe. Transport is mainly within Germany, between the Ruhr area and the area between Berlin and the Elbe. With the exception of the east-west route, all the inland waterways mentioned are important for international transport.[33]

30 Vgl.Eurostat: Freight transport statistics – modal split (2016), URL: http://ec.europa.eu/eurostat/statistics-explained/index.php/Freight_transport_statistics_-_modal_split [24.04.2020].

31 Cf. Zentralkommission für die Rheinschifffahrt: Information on the waterway Rhine, URL: http://www.ccr-zkr.org/12030100-en.html [27.04.2020]

32 Cf.. Zentralkommission für die Rheinschifffahrt: Market observation for inland navigation in Europe (2008), URL: http://www.ccr-zkr.org/files/documents/om/om07I_en.pdf [27.04.2020].

33 Cf. Quispel, Martin: Medium and long term perspectives of Inland Waterway Transport in the European Union, URL: http://ec.europa.eu/transport/modes/inland/events/doc/2011-07-05-naiades-stakeholder/2011-07-05-presentation-perspectives.pdf [27.04.2020]

Picture 5: The Rhine – Source: www.pixabay.com

2.1.1 The Rhine-Route

The route of the Rhine runs from Rotterdam (Netherlands) to Basel (Switzerland) and has a length of 1,320 km. In 2010, 330 million tonnes were transported on the 885 km long navigable section of the Rhine, with an average transport distance of 200 km. Two thirds of all goods transported on inland waterways in Europe pass through the Rhine. This underlines the importance of this inland waterway for the European economy and the transport sector.[34] In 2014, the goods mainly transported were solid mineral fuels, petroleum products and ores. Most goods are handled in the Port of Duisburg (inland port) and the Port of Rotterdam (seaport). The most important goods for transport on the Rhine are containers, weight-intensive goods and chemicals.[35]

2.1.2 Danube-Route

The total length of the Danube is 2845 kilometres, of which 2,415 km are navigable. The transport volume in 2017 was 39 million tons. The average transport distance was 600 kilometres. The most important market for freight transport on the Danube is the transport of iron and iron ore. Therefore, the product category (ores and metal waste) can be identified as the most frequently transported on the Danube in 2017, followed by oil and agricultural products.[36]

[34] Cf. Observatory of European Inland Navigation: Rhine, URL: http://www.inland-navigation.org/river/rhine/[24.04.2020].

[35] Cf. World Wide Inland Navigation Network: The Rhine, URL: http://www.wwinn.org/the-rhine [24.04.2020].

[36] Cf. viadonau, 2019, p 20f.

2.1.3 Rhine-Main-Danube-Corridor

The Rhine-Main-Danube corridor has a total length of 3,504 km and connects the port of Rotterdam (Netherlands) with the port of Constanta (Romania) and thus also 15 European countries directly by water. Comparing the Danube waterway with the Rhine, it is 2.7 times longer than the Rhine.

Nevertheless, in 2017 4.8 times more goods were transported on the Rhine than on the Danube. The transport performance on the Rhine in 2017 was thus 1.6 times higher than on the Danube. The limited branching of the Danube waterway allows only a spatially concentrated use, furthermore a longer pre- and post-carriage by road or rail is necessary. As a consequence, inland navigation in the Danube Region generally has a smaller share in the national modal split. However, Danube transport is characterised by longer distances compared to transport performance. Accordingly, the average transport distance on the Danube is about 600 km, while that of the Rhine is only about 300 km. A total of 129 bridges span the Danube from Kelheim to Sulina. Since the bridges allow a maximum of 2-3 layers of container traffic on the Danube, which would be less economical, there is practically no container traffic on the Danube. Container transport is mainly operated in the Rhine area. In addition, the Rhine has four main tributaries, which strengthen the role of the Rhine as the most important waterway in Europe. The economic activity and high population density along the Rhine also support an increased use of this inland waterway as a mode of transport.[37]

Picture 6: Rhine-Main-Danube-Corridor – Source: viadonau

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[37] Cf. viadonau 2019, p 20.

2.1.4 Seine

The Seine basin is the most important river basin in France in terms of freight transport. Between 2005 and 2018, more than 20 million tonnes of goods were transported annually on the Seine. In 2018, 4 billion tkm were transported on the Seine. Important markets for the Seine are container transport, the transport of building materials and agricultural products.[38]

An important project linking the Seine basin to the Rhine basin is the "Seine-North Europe Canal". The new canal is part of TEN-T and, with a length of 106 km, will in future replace the existing "Canal du Nord", part of the "Canal latéral à l'Oise" and a small section of the river Oise. The existing waterways allow a maximum capacity of 250-650 tons for inland vessels, in future up to 4,400 tons will be possible.[39]

2.1.5 Tisza

The catchment area of the Tisza River covers about 157220 km2 with a river length of 966 km. The catchment area extends through the territories of five countries: Romania (47%), Hungary (29%), Slovakia (10%), Ukraine (8%) and Serbia (6%). The river Tisza originates in the Marmarosch Mountains (Ukrainian Carpathians) and flows into the Danube at the city of Titel (Serbia). Before its regulation the Tisza often changed its course and caused often flooding along their banks. The eight tributaries of the Tisza are as follows: Bodrog, Sajó, Bódva, Hernád, Szamos, Kraszna, Körös and Maros rivers.[40]

2.1.6 Sava

The source of the Sava is in the Slovenian mountains, its mouth in the Danube near Belgrade. Along its course (944 kilometres) the Sava connects four countries and has a catchment area of almost 100,000 square kilometers. Even today, large sections of the Sava still flow freely, such as that extensive flood plains and floodplain forests have been preserved until today. For the Sava is hardly used for the transport of goods (only 400,000 tons per year are transported transported).[41]

2.1.7 Volga

With an area of 17,098,200 km2 Russia is the largest nation on earth. The territory extends from the Baltic Sea to the Pacific Ocean (about 9,000 km) and from the Arctic Ocean to the Black Sea (about 4000 km). Russia has a total coastline length of 37,653 Miles. About 75% of the population lives in

[38] Cf. Zentralkommission für die Rheinschifffahrt (2019)

[39] Cf. French Waterways: Information about the 106km long Seine-Nord Europe Canal (Project), URL https://www.french-waterways.com/waterways/north/seine-nord-europe/ [24.04.2020]

[40] Cf. Lescesen, Urosev, Doinaj et. al , 2016; Donaukommission, 2013.

[41] Cf. Riverwatch, EuroNatur: Die Save. Europas natürlicher Hochwasserschutz. URL: https://balkanrivers.net/de/schwerpunktgebiete/die-save [24.04.2020]

the European part of Russia, where the capital is Moscow. The urbanization rate is very high. About 73% of the total population are located in urban areas. Due to their strategically advantageous location between Europe and Asia, a large population and a hinterland market with a total of 280 million inhabitants in the CIS states, Russia has the potential to become a central to establish a logistics hub between Asia and Europe. The Volga is 3,700 km long and thus the longest river in Europe. It flows only through Russia. The transport volume is approx. 20 million tons per year, the most important markets are the transport of grain, petroleum products, building materials and wood.[42]

2.1.8 Port of Rotterdam

The port of Rotterdam is the largest seaport in Europe with an annual turnover of 465 Millions of tons. In 2019, 14.8 million TEU containers (twenty-foot equivalent unit) the port of Rotterdam. The port area covers an area of 40 km and comprises 12,500 ha including land and water, and a commercial area of 6,000 ha. 30,000 seagoing vessels and 110,000 inland vessels pass through the port of Rotterdam every year. This indicates that the proximity of ports to urban areas is important to increase the use of inland waterways as a means of transport.[43]

2.1.9 Duisport

Duisport in Duisburg is the largest trimodal inland port in Europe with an annual turnover of more than 3 billion euros. The port connects water, rail and road transport and offers an industrial and logistics area of 14 million m². In 2019, 123.7 million tons of goods and 4 million TEUs were handled in the Port of Duisburg (including private company ports). 20,000 ships and 25,000 trains passed through the Port in 2019. Due to its favorable geographical location, Duisport offers connections to more than 80 destinations in Europe and Asia. Due to its extensive logistic know-how, various services such as container stuffing or stripping and pre-packing as well as services for industrial areas and real estate are offered.[44]

3 Inland Waterways in China

China has the largest inland waterway network in the world, due to its waterway network with a total length of 110,000 kilometres. The waterway network consists of more than 5,000 rivers. In addition to large seaports such as Shanghai, there are about 2,000 inland ports that connect inland waterways with other modes of transport.[45] There are also geographical differences due to China's size that affect inland waterway transport. In the south there are larger rivers with stable fairway

[42] Cf. Wellbrock, Unterharnscheidt , 2013; World Wide Inland Navigation Network, URL: https://www.wwinn.org/volga [26.04.2020].

[43] Cf . Port of Rotterdam: Facts & figures about the port, URL: https://www.portofrotterdam.com/en/the-port/facts-figures-about-the-port [24.04.2020].

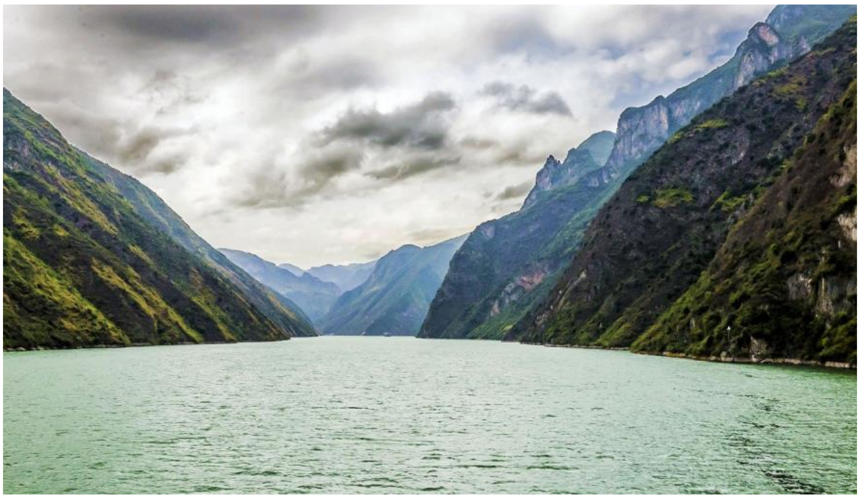
[44] Cf. Duisport, URL: http://www.duisport.de/en/ [24.04.2020]

[45] Cf. Indexmundi, URL: http://www.indexmundi.com/map/?t=10&v=116&r=as&l=en [24.04.2020].

conditions that are not affected by ice. In contrast, rivers in the north are smaller and have unstable fairway conditions. In addition, the occurrence of ice in winter can affect inland waterway transport in this region.[46] Compared to other countries, China, in particular the port of Shanghai, has the highest container turnover. In 2018, 42 million TEUs were handled in Shanghai.[47] In 2007, more than three quarters of Chinese inland waterway freight was transported on three main waterways. These are the Yangtze River, the Grand Canal and the Pearl River. As can be seen from the table, the Yangtze River carried the highest volume and the average transport distance in kilometres was also the highest compared to the other rivers. In terms of goods transported, China's main cargoes were construction materials and steel.[48]

3.1 Yangtze River

As already mentioned, the Yangtze is the most important inland waterway for freight transport in China. This is why it is also called the "Golden Waterway". The route of the Yangtze runs from the Himalayas to Shanghai and has a total length of 6,300 km, of which 3,000 km are navigable. Therefore the Yangtze is the third longest river after the Nile and the Amazon. The Yangtze is the most important connection between rail, road and the high seas in China and enables a broad intermodal transport network. Thus, even hinterland regions, where more and more industries are located, are connected to seaports via the Yangtze. In order to provide connections to other modes of transport, there are many ports, of which Chongqing, Wuhan, Shanghai and Nanjing can be named as the most important for the Yangtze. The famous Three Gorges Dam is also located on the Yangtze.[49]



Picture 7: The Yangtze River – Source: www.pixabay.com

46 Cf. World wide Inland Navigation Network, URL: https://www.wwinn.org/china-inland-waterways [27.04.2020].

47 Cf. Statista, URL: https://www.statista.com/chart/1488/china-has-the-worlds-busiest-container-ports/ [27.04.2020].

48 Cf. World Wide Inland Navigation Network, URL: http://www.wwinn.org/china-inland-waterways [27.04.3020].

49 Cf. World Wide Inland Navigation Network, URL: http://www.wwinn.org/china-inland-waterways [27.04.2020].

3.2 The port of Chongqing

The port of Chongqing is the largest inland port on the Yangtze River, with a transhipment volume of 1.1 billion tonnes (2012). This corresponds to an increase of 50% within six years compared to 2006. In addition, three million TEUs per year pass through Chongqing. In Chongqing, inland navigation is of great importance, which is also reflected in the annual growth rate of the waterway of 16.8%. Due to its strategic location, Chongqing serves as a logistical gateway to connect Western China with the rest of the country and international destinations.[50] In fact, 90% of the products manufactured in Chongqing and destined for export are transported via the Yangtze River. The main advantage of the port of Chongqing is that it offers a multimodal infrastructure. Goods can be reloaded at the port and can be transported further by rail, road or air. To remain competitive, Chongqing continues to invest in infrastructure development. Around 150 billion euros are to be invested in infrastructure by 2020.[51]

3.3 The Three Gorges Dam

The Three Gorges Dam was built to control the flooding of the Yangtze River. With a length of 2.3 km and a height of 200 meters, the dam is five times larger than the Hoover Dam in the USA.[52] The name is based on the three gorges that were flooded because of the dam: In addition to its importance for the transportation of ships on the Yangtze, 26 hydroelectric turbines contribute to China's electricity production. With a generated electricity volume of 18.2 million kilowatts, the dam produces twenty times more energy than the Hoover Dam. This corresponds to about 7% of China's total energy demand.[53]

Picture 8: The Three Gorges Dam – Source: Logistikum of the FH OÖ

50 Cf. Consulate General of the Kingdom of the Netherlands in Chongqing/ Netherlands Business Support Office in Chengdu, Sichuan, „Transport & Logistics in Chongqing and Sichuan“, (2014), p.3/4,

51 Cf. nlambassade, URL: http://china.nlambassade.org/binaries/content/assets/postenweb/c/china/zaken-doen-in-china/chongqing/transport-and-distribution-in-chongqing--sichuan_sept-2014pdf [24.04.2020].

52 Cf.. China Trade Research, URL: http://china-trade-research.hktdc.com/business-news/article/Fast-Facts/Chongqing-Market-Profile/ff/en/1/1X000000/1X06BPV2.htm [24.04.2020]; Worldwater, URL: http://worldwater.org/wp-content/uploads/sites/22/2013/07/WB03.pdf [24.04.2020]

53 Cf.. Ship lift at Three Gorges Dam, China–design of steel structures., in Steel Construction 2, No.2, p.61-71, 2009, p.61, Online: http://probeinternational.org/library/wp-content/uploads/2011/01/Ship-lift-at-Three-Gorges-Dam-China-design-of-steel-structures.pdf [27.04.2020].

4 Inland Waterways in Brazil

Brazil has the most inland waterways in South America (60,000 km). Compared to other modes of transport, the broad Brazilian river system covers almost all territorial extensions. This results in lower transport costs compared to rail and road on short transport routes. Nevertheless, only 22% of Brazil's inland waterways are used for freight transport. This is partly because the main rivers are not located in the centres of production and consumption. On the other hand, there is little investment in inland waterway infrastructure compared to China and Europe. Inland waterway transport therefore makes only a small contribution to the Brazilian economy. The mode of transport that is most frequently used in Brazil is the truck. Agricultural and mineral goods are transported on inland waterways in Brazil. In 2019, 65.7 million tons of goods were transported on inland waterways in Brazil. As mentioned in the previous slide, only 22% of inland waterways are currently used for freight transport. The potential transport volume of inland waterways in Brazil could reach 180 million tonnes per year.[54] There are three main routes for inland waterways Amazon, Sao Francisco and Tocantins-Araguaia. Although inland waterways are not frequently used as a means of transport in Brazil, the ports are of international importance. The main products transported on Brazilian inland waterways are soya, iron ore and containers.[55] The Amazon is 6,280 km long and is the longest river in the world. The route runs from Peru through northern Brazil to the Atlantic Ocean.[56] The banks of the Amazon consist largely of tropical rainforest. This increases the risk of theft - in 2015 there were thefts in the Amazon region which resulted in losses of 27 million dollars. Vessels can easily be attacked or stolen and thieves can easily hide in the tropical rainforests.[57]

4.1 Manaus port

The port of Manaus is the most important traffic junction for transports in the upper part of the Amazon basin. The freight volume per year is 11.8 million tons. In 2007, the total trade volume of the port of Manaus was 4.92 billion US dollars, while exports amounted to 1.15 billion US dollars.[58] In 2014, the port of Manaus handled 492,000 TEUs, an increase of 24.6% over the previous year.[59] Fruit, seeds, machinery, timber and fuels are products that were mainly loaded in the port of Manaus. Imported products include machinery and electrical goods, vehicles, chemicals and plastics. Machinery and electrical appliances are mainly imported because of the industrial tax exemption of

[54] Cf. World Wide Inland Navigation Network,URL: http://www.wwinn.org/brazil-inland-waterways [27.04.2020].

[55] Cf.. World Wide Inland Navigation Network,URL: http://www.wwinn.org/brazil-inland-waterways [27.04.2020]

[56] Cf.l.Container terminals in jungle city Manaus face growing pains, URL: http://www.joc.com/trucking-logistics/cargo-thefts-rise-brazil-economy-shrinks_20150903.html [01.07.2016]

[57] Cf. The free dictionary, URL: The free dictionary, http://www.thefreedictionary.com/Transport+on+the+Amazon [18.08.2016]

[58] Cf.. Ministry of External Relations Brazil, URL: https://repositories.lib.utexas.edu/bitstream/handle/2152/13799/PUBRevistaBrasilMEPortosI.pdf [28.04.2020]

[59] Cf. World Port Source, URL: http://www.worldportsource.com/ports/review/BRA_Port_of_Manaus_3506.php [27.04.2020]

Manaus. Companies in this zone enjoy tax concessions, especially in the electrical and electronic sector.[60]

Picture 9: The Amazonas – Source: www.pixabay.com

5 Comparison

All the figures discussed in the figures discussed are summarised in the following table. As can be seen in the table, the figures differ significantly from one another. China has the most navigable waterways, the highest volume transported on waterways and the highest volume traded in ports compared to Europe and Brazil. Although Brazil has more waterways at its disposal than Europe, the volume transported on European inland waterways is about 12 times higher.

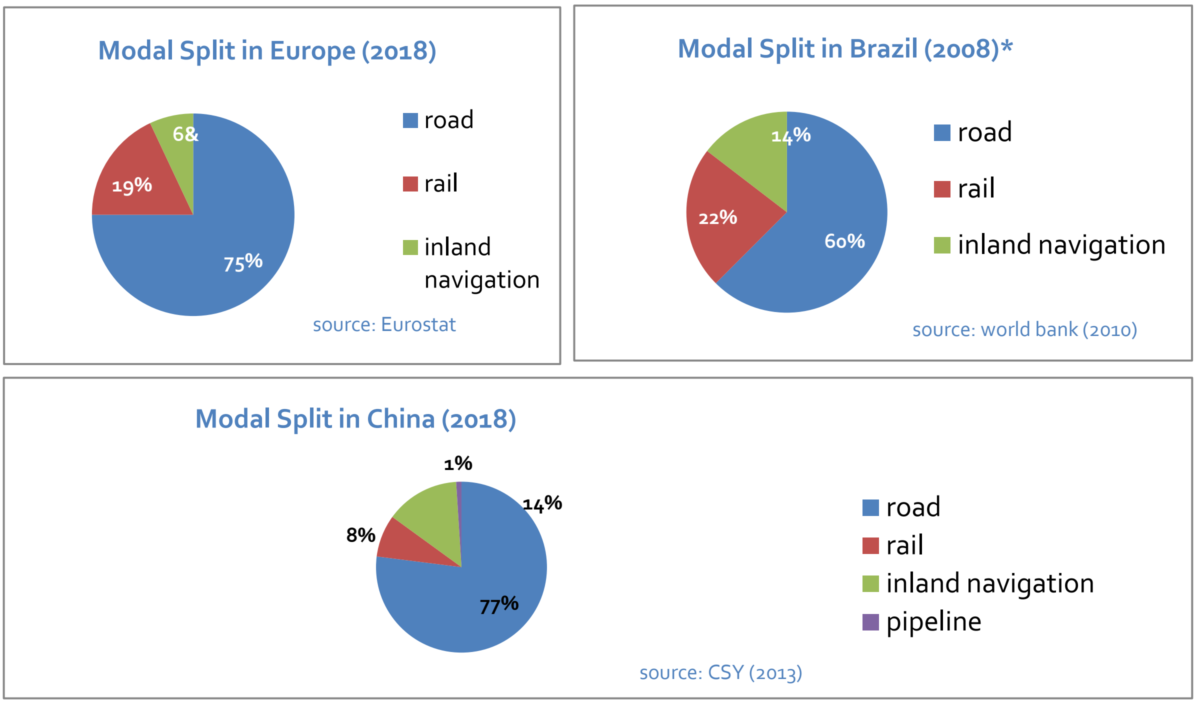
60 Cf.. Container terminals in jungle city Manaus face growing pains,URL: http://www.joc.com/port-news/south-american-ports/container-terminals-jungle-city-manaus-face-growing-pains_20150702.html [27.07.2020].

	Europe	China	Brazil
Available waterways	40,000 km	110.000 km	60,000 km
Important waterway in region	Rhine-Main-Danube Corridor	Yangtze-River	Amazon
Transported volume on waterways in total	544 million tons	51,527.63 million tons	37.5 million tons
Transported goods	dry & bulk cargo, construction material	dry & bulk cargo, construction material	mainly agricultural and mineral goods
Important inland ports in region	Duisport	Chongqing	Manaus
Importance of inland navigation in region (political/economical)	High	High	Low

Table 1 – Comparison of inland waterways in Europe, Brazil and China

These differences can be seen in the context of the importance of inland navigation in different countries/regions. In Europe and China inland waterways are considered as important transport modes and various measures are taken to promote the use of inland waterways. As examples of such measures, besides financial support, promotional actions can be mentioned. In this context, investments in waterway infrastructure can be seen as the most important measure to ensure the competitiveness of inland navigation.[61]

[61] Cf. China Statisticaö Yearbook 2019, URL: http://www.stats.gov.cn/tjsj/ndsj/2013/indexeh.htm [27.04.2020]



Picture 9: Comparison of Modal Split in Europa, China and Brazil

When comparing the modal split of Europe, China and Brazil, it becomes clear that road transport is the most frequently used mode of transport in all three countries/regions. The share of inland navigation in the modal split is highest in China. Although the share of inland waterways in the modal split in Brazil is the same as in Europe, more volume is transported by inland waterways in Europe. This may be due to the difference in total freight volumes between Europe and Brazil.[62]

In addition, the following comparisons can be made between Brazil, China and Europe:
-When comparing the length of the available waterways, the length of the European waterways corresponds to the circumference of the earth, which is about 40,000 km. The length of the Brazilian waterways corresponds to 1.25 times the circumference of the earth. The length of the waterways in China is three times the circumference of the earth.

[62] Cf. Worldbank,URL: http://siteresources.worldbank.org/BRAZILINPOREXTN/Resources/3817166-1323121030855/FreightLogistics.pdf?resourceurlname=FreightLogistics.pdf [27.04.2020]; Eurostat, “Freight transport statistics – modal split”, (2018), URL: http://ec.europa.eu/eurostat/statistics-explained/index.php/Freight_transport_statistics_-_modal_split [28.04.2020]; Statista (2020): Freight traffic in China from 1980 to 2018, by transport carrier (in million metric tons), URL: https://www.statista.com/statistics/264809/freight-traffic-in-china/ [27.04.2020]; Sustainable Development Department, “How to decrease freight logistics costs in Brazil”, URL: http://siteresources.worldbank.org/BRAZILINPOREXTN/Resources/3817166-1323121030855/FreightLogistics.pdf? resourceurlname=FreightLogistics.pdf [27.04.2020].

6 Conclusion

In summary, waterway infrastructure can be mentioned as the main competitive factor of inland navigation. Even if many waterways are available in a country or region, infrastructure and maintenance are necessary to ensure the navigability of waterways. In this context fairways, bridges and ports can be mentioned as important infrastructure elements: Fairways and bridges have a major impact on waterway traffic, while ports ensure that inland waterways are connected to other modes of transport and that goods can be transhipped. Regular maintenance of the infrastructure is necessary to ensure safety and increased use of inland waterways. The political and economic framework can be crucial to enable measures such as investment in waterway infrastructure. Topography and, in this context, the available waterways can also be mentioned as important factors. Weather conditions may also vary due to geographical location and have different effects on inland waterway transport. Proximity to urban centres can also be mentioned as an important external factor for the competitiveness of inland waterway transport. When ports are located close to important economic regions, enterprises are more likely to use inland waterways for transport.

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