THE DANUBE PORTS AS MULTIMODAL TRANSPORT HUBS AND THEIR LOGISTICS SERVICES

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Received: May 14, 2019
Received revised: August 25, 2019
Accepted for publishing: August 29, 2019

Abstract

Till the first part of the 20th century inland ports used to be taken as places on the waterway where water transport met with other modes of transport. Increase of volume of cargo transported by water transport in the second part of the 20th century, building of larger and faster inland vessels caused the disproportion between the performance of water transport and transhipment capacity of inland ports. Therefore, it was necessary to increase the performance of handling equipment of inland ports, to enlarge land area of ports, to modify of shipbuilding so that transhipment of cargo could be faster and to reduce downtimes during transhipment of vessels in ports. At present inland ports are the hubs on the waterway where different logistics operations and services are carried out such as transhipment, storage, transport of cargo by different modes of transport. The Danube River is the main axis of waterways for ten European countries located in Central and East Europe. There are located 34 inland ports of different performances that provide various logistics services to their customers. The basic goal of the paper is to focus on the selected Danube ports, to analyse and to compare them from different points of view and to prepare the list of recommendations that could help them to increase their handling performances.

Key words: inland ports, hubs, logistics services, Danube River, Danube ports, performance

1. INTRODUCTION

The Danube River that is the second longest European river after the Volga flows through ten European countries of Central and Southeast Europe. It rises in Germany

and flows into the Black Sea in the Ukraine and Romania. Since opening the Main – Danube Canal in 1992 the Danube has been linked to the waterways of Western Europe and has been the part of the waterway Rhine – Main – Danube. This waterway that flows through fifteen European countries links the North and Black Seas. It is over 3,500 km long. According to European Agreement of Main Inland Waterways of the International Importance (AGN) the Danube River is classified into classes due to safety and smoothness of navigation.

Danube inland ports are also part of this agreement and have to fill some criteria, for instance, they have to be situated on the waterway of international importance, they have to be linked to the main road or railway lines or their handling capacity has to be over 0.5 million tons of cargo a year. According to this agreement there are 34 inland ports on the Danube. These inland ports differ in their handling equipment, devices or outputs. On one hand the most of them are located on the Lower Danube, on the other hand the least of them are on the Upper Danube.

The basic goal of the paper is to focus on the Danube River, its inland ports and compare them according to their transhipment.

2. THE DANUBE RIVER

The Danube originates as a confluence of two German mountain rivers (the Breg and Brigach) in the Black Forest near Donaueschingen in Germany. The total length of the Danube, from the confluence to the estuary into the Black Sea, is 2,845 kilometres (some references refer to 2,580 kilometres). The commercial navigation carries out from Kelheim in the length of 2,414 km. The total surface area of the basin is 801,463 square kilometres and belongs to the sea catchment area of the Black Sea.

Commercial navigation on the Danube is carried out from Kelheim (rkm 2,414.72). The Danube flows through ten European countries (Germany, Austria, Slovakia, Hungary, Croatia, Serbia, Romania, Bulgaria, Moldova and the Ukraine) and four capital cities (Vienna, Bratislava, Budapest and Belgrade). With this number the Danube can be included among the waterways that flows through the largest number of countries in the world. Four Danube countries are only located on one bank of the Danube (Croatia - right bank, Bulgaria - right bank, Moldova - left bank and Ukraine - left bank). Shortly before the Black Sea, it creates the Danube Delta. (Hasenbichter et al., 2013)

2.1. The division of the Danube

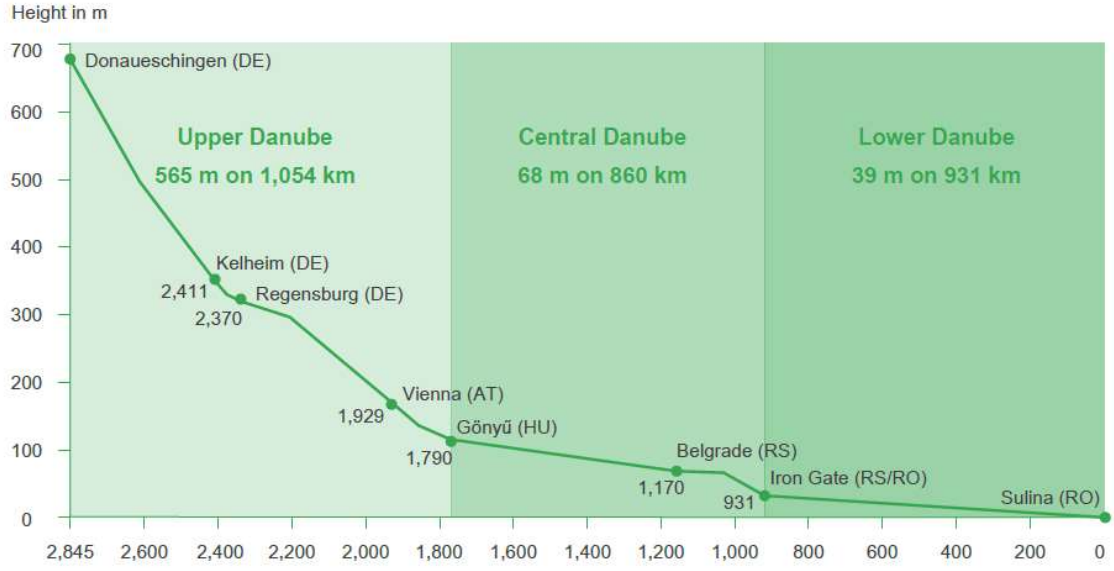
According to the gradient, the Danube River is divided into three sections (Figure 1). The Upper Danube, which is 624 kilometres long, has the character of a mountain river. It runs through Germany, Austria, Slovakia and Hungary (in the end it forms the natural border between Slovakia and Hungary). It starts in the German town of Kelheim (rkm 2,414.72), where the Danube links to the Main-Danube Canal, and ends in a Hungarian town of Gonyu (rkm 1,791.33). Its gradient is 37 cm per kilometre. There are located sixteen of eighteen dams on the Danube. Most of them are located in Austria, remaining in Germany, one of them is located in Slovakia. The

biggest dam on this stretch of the Danube is Gabcikovo in Slovakia that was put in operation in October 1992. Downstream travel speed of vessels is from 16 to 18 kilometres per hour, upstream travel speed of vessels is from 9 to 13 kilometres per hour.

On its middle and lower part, the Danube has got the character of a lowland river. The middle Danube is 860 kilometres long; it is from Gonyu (rkm 1,791.33) to Drobeta Turnu Severin (rkm 931.00). It flows through Slovakia, Hungary, Croatia, Serbia and Romania. Close to Drobeta Turnu Severin there is located the biggest dam on the Danube (Iron Gates I). Its gradient is 8 centimetres per kilometre. Downstream travel speed of vessels is from 18 to 20 kilometres per hour, upstream travel speed of vessels is from 9 to 13 kilometres per hour.

The lower part of the Danube is from Drobeta Turnu Severin (rkm 931.00) to the estuary into the Black Sea (rkm 0.00). There is one dam on this part of the Danube called Iron Gates II. Its gradient is 4 centimetres per kilometre. Downstream travel speed of vessels is from 18 to 20 kilometres per hour, upstream travel speed of vessels is from 11 to 15 kilometres per hour (Hasenbichter et al., 2013).

Figure 1. Gradient curve of the Danube



Source: Manual on Danube Navigation

According to AGN, the Danube River can be divided into some classes. Each class defines maximal dimensions of motor cargo vessels or pushed convoys due to safety and smoothness of traffic and navigation on the waterway.

The Danube is classified as class VIb from Regensburg to Budapest. On this stretch of the Danube the pushed convoys can sail that consist of a pusher (a motorized vessel used for pushing) and four non-motorized pushed barges. There is also the bottleneck (a stretch long 69 kilometres between Straubing a Vilshofen) where the Danube is classified as class VIa.

Between Budapest and Belgrade, the Danube is classified as class VIc. This stretch of the Danube is for a pushed convoy that consists of a pusher and six pushed barges.

Between Belgrade and the Danube Delta the Danube River is classified as class VII. It means, there can sail pushed convoys with nine barges and smaller seagoing vessels (between Braila and the Danube Delta) (Hasenbichter et al., 2013).

2.2. Cargo transport on the Danube

According to Danube Commission, the volumes of cargo transported on the Danube River have increased in the last few years (Table 1). In 2016, about 59,729 thousand tons of cargo was transported on the Danube, it was more about 4.86 % in comparison with previous year. In this value there are also included transports of cargo not only in the Danube countries but also on the Danube branches and its canals (the Main-Danube Canal and the Canal Danube-Black Sea). The most cargo was transported in Romania (22,018 thousand tons). It was 36.86 % of total volume of cargo. Romania was followed by the Ukraine (5,399 thousand tons) and Hungary (3,590 thousand tons). In the same year 1,800 thousand of cargo was transported in Slovakia that was 3.01 % of total volume of cargo (Danube navigation statistics).

Table 1. The volume of cargo transported on the Danube between 2011 and 2016 (in thousand tons)

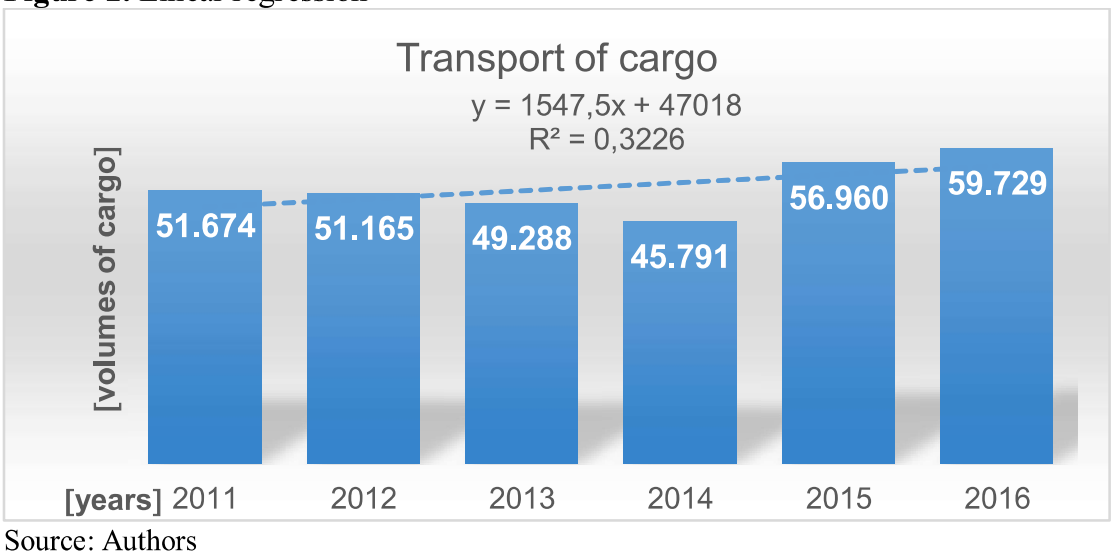
year	2011	2012	2013	2014	2015	2016
Volume of cargo (t)	51,674	51,165	49,288	45,791	56,960	59,729

Source: Danube Navigation Statistics

2.3. The prediction of development of transported cargo on the Danube River

We used the method of least square for linear regression and prediction of development of transported cargo on the Danube River until 2020. We used the values of transported cargo on the Danube between 2011 and 2016 for the calculation of equation (Table 1).

Figure 2. Linear regression



Source: Authors

The coefficient of correlation has got the value of 0,57. According to generated equation

$$y = 1547,5x + 47018 \quad (1)$$

where y is the volume of cargo that was transported on the Danube, and x is a year when the volume of cargo was transported, we can calculate the development of transported cargo on the Danube for 2019 and 2020. In 2020 we predict that about 62,493 thousands of tons will be transported on the Danube (Table 2).

Table 2. The prediction of the development of transported cargo on the Danube River for 2019 and 2020

Year	2019	2020
Volume of transported cargo (t)	60,945,5	62,493

Source: Authors

3. INLAND PORTS

3.1. Inland ports in the role of logistics hubs

In the first part of the 20th century inland ports used to be places on the waterway where inland water transport met with other modes of transport (rail and road transport). Transport of cargo used to take about two thirds of operating time and transhipment of cargo in inland ports used to take only one third of this time. The situation changed after the Second World War due to the increase of volume of cargo which was transported by water transport, the introduction of pushed technology, the increase of transport capacity of vessels and their speed. These factors caused the disproportion between the performance and efficiency of inland water transport and handling facilities and devices of inland ports. Therefore, it was necessary to increase their efficiency, to enlarge of port area and to build a new generation of inland vessels. Nowadays inlands ports are transport hubs on the waterway (a navigable river, lake or canal). They consist of transhipment areas where cargo is handled by cranes, is stored in warehouses or on open storage areas or is transported by other modes of transport to the customers. Inland ports also offer other functions and services (Dávid, 2017; Skočibušić et al., 2011).

An important part of each inland port is its connection to other modes of transport (road and railway transport). Railway transport mainly carries out transport of bulk cargo for longer distances. Road transport mainly carries out transport of general cargo and containers. It is used by companies which are located in its surrounding.

Inland ports should be designed and constructed to provide:

- a fast and safe navigation of vessels from a waterway to a port,
- smooth and safe manoeuvring of vessels on water area of port, their anchoring, formation of convoys,

- a fast loading / unloading of cargo between vessels and the land of port,
- a direct connection with other modes of transport.

A lot of factors influence on the location of inland ports. From the point of economic view inland ports are situated near industrial and commercial centres. From the point of ground view, the configuration of ground and its geological structure are very important for its final construction. From the point of territorial view, the total area and its surrounding are important for the location of basins, transhipment areas, handling and storage facilities (cranes, warehouse), infrastructure (roads and railways) and other building which are important for operation of inland port (Dávid, 2017).

3.2. Division of inland ports

According to the purpose inland ports can be divided into:

1. Business (public) ports that transfer bulk, general, liquid cargo including containers between vessels and other modes of transport by cranes. They also store cargo in the warehouses or on the open storage areas, transport, pack them to the customers. They usually consist of water and land area. Land area of port is equipped by handling facilities (gantry or container cranes) and infrastructure (roads and railway) which enables transport of cargo between port and its customers. Business ports are situated near large commercial and industrial areas. They are usually divided into various transhipment sectors according to cargo which are transferred there, for instance transhipment areas for bulk, general and liquid cargo, container terminals, Ro-Ro Ramp for cars, areas for transhipment of oversize or overload cargo.
2. Industrial ports are used for transhipment of raw materials, semi-finished o finished products between vessels and the land of port by private companies. They are usually equipped by specialized handling facilities.
3. Passenger ports are used for embarking or disembarking of passengers between vessels and the area of port. They are usually situated in the city centres. Their area does not take up too much space.
4. Shipyard ports are used for mending or reconstruction of vessels. They are equipped by gantry cranes, ship lifts, dry or floating docks, warehouses and workshops.
5. Specialized ports are designed for special purposes and special vessels such as military, army, sport, fishing or recreation ports.

Business (public) and industrial ports are the most import ports from the point of transport view (Dávid, 2017; Kubec, 1993)

3.3. Production indicators of works in the ports

The economic goal of works in the port is to fulfil its financial profit. The individual items of the profit have got direct or indirect bonds on the operational activity indicators.

The budget items are:

- cargo turnover: amount of cargo in tonnes that is transhipped by handling devices of port during the reporting period,
- cargo structure: the structure of the particular type of transhipped cargo,
- turnover of passengers: total number of passengers transported to a passenger port by the passenger fleet for the reporting period,
- vessel turnover: number of vessels divided into vessels and boats which the port serves during the reporting period,
- dwell of vessels: time that vessels dwell in port, it is related to transhipment of cargo, waiting for loading or unloading of cargo, formation of convoys and the provision of services,
- turnover of wagons: number of manipulated all types of freight wagons for the reporting period,
- dwell of wagons: dwell time of railway wagons in the port private sidings in hours (calculated from the takeover of the wagon by workers of the port to its handover by the railway undertaking staff),
- port throughput: the ability of transhiment areas of port to handle of cargo in a particular required structure and work variation over the reporting period,
- navigation period: the number of days when a vessel can carry cargo or persons to the port,
- inter-navigation period: number of days during voyage is stopped due to low or high water level, freezing of the waterway,
- labour productivity: expresses physical units per worker in main activity, ie. in tonooperations for the reporting period (month, quarter, half year, navigation period) (Záležák, 2000).

We use the port throughput for the comparison of cargo transhipment in the Danube ports (see subchapter 4.1.).

3.4. Direct and indirect transhipment of cargo

In the ports, cargo can be transhipped by two ways. In the first way (direct transhipment of cargo) cargo is transhipped between vessels and other means of transport (trucks or wagons) by handling devices of the port. It is very hard to harmonize cargo transport between vessels and other means of transport; therefore, the part of cargo is stored in the warehouses or on the open storage areas before it is transported to the customers by other modes of transport. It is called indirect transhipment of cargo (Záležák, 2000).

3.5. Inland ports of the international importance

According to AGN (European agreement on Main Inland Waterways of the International Importance) inland port have to fill some criteria:

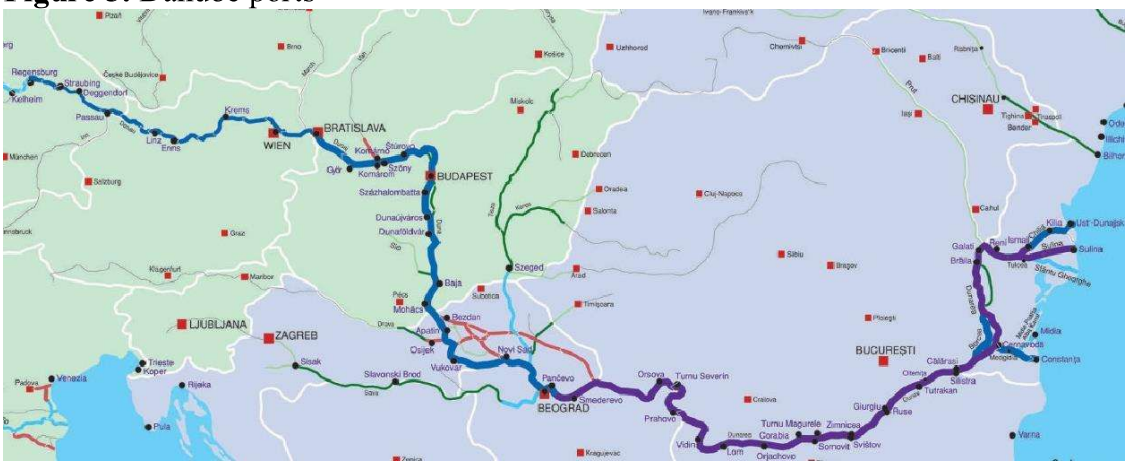
- ✓ they have to be situated on a European waterway,

- ✓ they have to be capable of accommodating vessels or pushed convoys used on the relevant European waterway in conformity with its class,
- ✓ they have to be connected to main road and railway lines,
- ✓ its total cargo handling capacity has to be at least 0,5 million tons of cargo a year,
- ✓ they have to offer suitable conditions for the development of a port industrial zone,
- ✓ they have to provide handling of standardized containers,
- ✓ they have to have all the facilities necessary for usual operations in international traffic (Dávid, 2017).

4. THE DANUBE INLAND PORTS

On the Danube there are 34 inland ports of the international importance (Fig. 3) that differ in the volume of transhipped cargo, technical equipment, transhipment technology etc.

Figure 3. Danube ports



Source: via donau

4.1. Biggest Danube ports

According to Danube Commission, the Danube inland ports transhipped about 36,939 tons of cargo in 2016 (see Table 3). In this table there are included only the ports that transhipped over 1.0 million tons of cargo per year.

Table 3. The Danube ports that transhipped over 1,0 million tons of cargo between 2013 and 2016 (in thousands of tons)

Port	Year			
	2013	2014	2015	2016
Izmail	2,654	3,021	4,521	5,327
Reni	2,729	1,465	248	201
Galati	3,515	3,515	4,318	4,466

Braila	2,358	2,358	2,217	849
Tulcea	2,159	2,159	2,550	1,559
Giurgiu	..	..	..	1,012
Calarasi	..	..	..	1,130
Lom	..	..	..	3,216
Russe	1,166	1,166	..	3,797
Vidin	1,224	1,224	..	..
Svishtov	1,213	1,213	..	..
Oriahovo	2,613	2,613	..	..
Smederevo	..	1,553	1,813	2,466
Belgrade	..	1,056	831	828
Novi Sad	1,545	1,278	980	1,325
Pančevo	1,103	1,281	651	1,040
Dunaújváros	1,053	1,046	1,341	962
Budapest	789	1,109	1,118	1,367
Bratislava	2,373	1,793	1,362	1,483
Vienna	1,665	1,372	970	1,068
Linz	4,356	4,335	3,814	3,995
Regensburg	1,645	2,198	1,579	848
Total	34,160	35,755	28,313	36,939

Source: Danube navigation statistics

On the Upper Danube there were four ports, which of one port was in Germany, two ports were in Austria and one port was in Slovakia. These ports transhipped about 20 % of total volume of transhipped cargo. The port of Vienna transhipped the largest volume of cargo on this part of the Danube in 2016.

On the Middle Danube there were six ports, which of two of them were in Hungary and four of them were located in Serbia. These ports transhipped about 21.6 % of total volume of transhipped cargo. The port of Smeredevo transhipped the largest volume of cargo on this part of the Danube in 2016.

On the Lower Danube there are located the most Danube inland ports that transhipped the largest volume of cargo (about 58.4 % of total volume of transhipped cargo) in 2016. The most inland ports were in Romania (five of them), then in Bulgaria (four of them) and the Ukraine (two of them). The port of Izmail that is the combination of inland and maritime port transhipped the biggest volume of cargo on this part of the Danube in 2016 (Danube navigation statistics).

Generally, the Danube inland ports provide huge scale of logistics services. They do not only tranship or store all types of cargo but they also transport it by other modes of transport and do other services related to cargo, fleet or passengers. (Danube navigation statistics) (Galieriková & Sosedová, 2018).

4.2. Inland ports on the Upper Danube

On the Upper Danube there are nine inland ports of the international importance. Two of them are located in Germany, five of them are in Austria, the only one is in Slovakia and Hungary.

The port of Regensburg is the largest port in Germany that is located on the right side of the Danube (river kilometres (rkm) 2,373 -2,379). The total area of the port is about 180 ha, there are three basins. In the port there are also a Ro-Ro ramp and Ro-La terminal. Bulk and general cargo are transhipped by gantry cranes between inland barges and trucks or wagons. There is also a transhipment area for transhipment of oversize and overload cargo (up to 200 t). The port has got some open storage areas and warehouses, there are also a car terminal, oil tanks and grain storage silos.

The port of Vienna is the largest Austrian port that is located in three parts such as Lobau (rkm 1,917), Albern (rkm 1,918) and Freudenau (rkm 1,920) on the right and left bank of the Danube. The total area of the port is about 300 ha. In each part of the port there is located a basin. In the parts Freudenau and Albern there are transhipped bulk and general cargo such as agriculture products, building materials, metal, cars and containers. Mineral products are transhipped in Lobau. In Freudenau there are located a Ro-Ro ramp and container terminal, in Albern there is also grain storage silos. The port also has equipment for cargo storage.

The port of Bratislava is the largest port in Slovakia that is located on the left bank of the Danube (rkm 1,867 and 1,865). The land of the port, which is about 144 ha, is divided into two parts: winter harbour (old part of the port) and Palenisko (a new part of the port). In winter harbour there are two basins used for transhipment of bulk and general cargo (especially pellets and fertilizers). In Palenisko there is a basin that was built in the 1970s and 1980s. In the basin there are located transhipment sections for transhipment of containers, cars, oversize and overload cargo and liquid cargo. The port also has equipment for cargo storage and has got a good connection to other modes of transport (Dávid, 2017; Seitz et al., 2003; Danube ports).

4.3. Inland ports on the Middle Danube

On the middle Danube there are ten inland ports of the international importance. Two of them are located in Slovakia, five of them are in Hungary, one of them is in Croatia and two of them are in Serbia.

The port of Budapest is the largest Hungarian port that is located on the left side of the Danube (rkm 1,640). The total area of the port is 152 ha, it has got three basins (one of them is used for protection and wintering of vessels). The port is used for transhipment of bulk, general, liquid cargo, cars and containers. There is also a Ro-Ro ramp and a pneumatic device with covered warehouses. The port is directly connected to public transport network of the city of Budapest.

The port of Vukovar is the only one port in Croatia that is located on the right bank of the Danube River. The total area of the port is about 3.5 ha and it can tranship bulk, general, liquid cargo including containers and oversize and overload cargo. It is equipped by gantry and mobile cranes, pneumatic devices, open and covered storage areas.

The port of Belgrade is one of the biggest ports in Serbia that is located on the right side of the Danube (rkm 1,168). The total area of the port is 100 ha, and it has got the only one port basin. The port handles bulk, general cargo and containers by gantry or mobile cranes. It also has open storage areas and warehouses for cargo storage. A container terminal, which is also located in the port, offers different services like maintenance, storage, filling or emptying of containers. The port is directly connected to public infrastructure of the city of Belgrade (Dávid, 2017; Seitz et al., 2003; Danube ports).

4.4. Inland ports on the Lower Danube

On the Lower Danube there are fifteen inland ports of the international importance. Ten of them are located in Romania, three of them are in Bulgaria and one of them is in Serbia and the Ukraine.

The port of Ruse is the largest Bulgarian port that is located on the right bank of the Danube (rkm 491). The port transhipts bulk, general and liquid cargo, containers and cars. Except transhipment and storage of cargo the port offers different services such as filling of fuels, water, and sewage collection. The port is directly connected to other modes of transport of the town of Ruse.

The port of Galati is the largest Romanian inland port which can also accommodate smaller seagoing vessels. It consists of three parts that are located on the left bank of the Danube between rkm 160 and 140.8. Handling devices of the port (gantry, mobile or floating cranes) transhipt bulk, general, liquid cargo including oversize and overload cargo. Except cargo transhipment and its storage, the port offers different services such as filling of fuel and water, sewage collection, shipbuilding. The parts of the port are directly connected to public road and railway transport of the city of Galati.

In Moldova, there is the only one inland port (the port of Giurgiulesti) located on the left bank of the Danube (rkm 133.8). The total area of the port is about 120 ha, and it transhipts all types of cargo. It is also accessible for small seagoing vessels.

According to AGN there is the only one Ukrainian inland port (the port of Reni) located on the left bank of the Danube (rkm 127.8). The total area of the port is about 93 ha and it transhipts bulk, general, liquid cargo, containers, cars, oversize and overload cargo. The port is equipped by gantry, mobile and floating cranes, conveyor belts, Ro-Ro ramp, open storage areas and warehouses. It is also accessible for smaller seagoing vessels (Dávid, 2017; Seitz et al., 2003; Danube ports).

5. CONCLUSIONS

The Danube is the most important inland river for ten European countries located in Central and Southeast Europe. Since completing the Main – Danube Canal, which links the Danube with the waterways of Western Europe, motor cargo vessels or pushed convoys have been transporting cargo between the North and Black Seas. In spite of the fact that it is the second longest European river the volume of transported

cargo is lower than on the Rhine River. Since the 1990s most Danube countries have undergone the political and economic changes that have influenced on navigation badly.

Till the first part of the 20th century inland ports used to be places where inland water transport met with other modes of transport (road or railway transport). They only transhipped cargo between vessels and means of transport of road and railway transport or stored it on open storage areas or in warehouses. Since the second part of the 20th century inland ports have undergone significant transformation processes as the result of changes that have happened in global market. They have become transport hubs that offer different logistics services to their customers.

On the Danube there are more than 30 inland ports of the international importance, most of them are located on the Lower Danube in Romania and Bulgaria. According to Danube Commission these ports transhipped the highest volume of cargo in 2016. On the other hand, the lowest number of inland ports are located on the Upper Danube these ports also transhipped the smallest volume of cargo. Generally, the Danube inland ports play the function of transport hubs. Except transport, transhipment and storage of cargo they provide a lot of different logistics services according to the customers' requirements.

ACKNOWLEDGEMENTS

The paper is supported by the VEGA Agency by the Project 1/0791/18 "The Assessment of Economic and Technological Aspects in the Provision of Competitive Public Transport Services in integrated Transport Systems", that is solved at Faculty of Operations and Economics of Transport and Communications, University of Žilina

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