Telematics Solutions in Maritime and Inland Waterway Transport

For Maisie, my little granddaughter, with hope that humanistic values such as friendship, love, kindness and faith in other people will remain important in your world of augmented and virtual reality, systems of telematics and artificial intelligence

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Cambridge Scholars Publishing

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INTRODUCTION

Since the very beginning of mankind, both seas and rivers have been the catalyst of trade, colonisation processes, and conquests of new territories. The immanent features in which maritime transport processes take place, provide advantageous conditions for shipping large volumes of cargo for long distances. Rivers, as the lines of communication, play a complementary role in this global activity, however inland waterway transport has become more significant due to its economic and environmental features. The world's biggest port locations in river estuaries highlight this potential for further development of maritime and inland waterway transport cooperation. Therefore, the potential for increasing the modal share of inland waterway transport is still growing.

Considering the conditions of global competition, maritime shipping, inland waterway transport as well as port operations are performed in accordance with strict technological and operational standards. All these activities are subject to severe time pressure, the imperative of economisation, and to the most important principle of all: providing these operations with the highest possible level of safety and security.

The increasing worth of cargo transported on various types of vessels (oceangoing ships and barges), their significance in economic processes represented by the growing volume of cargo, and finally growing congestion have already resulted in a considerable increase in security hazards (terrorism, piracy) and safety hazards (accidents at sea and rivers, collisions, increased anthropogenic impact causing environmental loss). Hence, efficient counteraction against these hazards becomes a crucial issue. It is no longer just a local or even an international challenge; its character has become continental and much more global.

This simple observation has become a basis of some definitely more complicated concepts pertaining to safety and security of maritime and inland waterway transport. In a holistic approach, maritime safety and security come as conceptual aspects which include two most important areas where hazards appear: nautical hazards of probabilistic nature, and conscious hazards of a determined character which are caused by anthropogenic factors. The level of safety/security comes as a derivative of the ability to identify hazards, and consequent perseverance presented by the national – and nowadays more often – international community in developing integrated counteraction systems as a solution. An indispensable instrument used for providing safety and security is a number of telematics systems of maritime and inland waterway transport which have been developed over the recent years.

Telematics refers to integrated and systemic solutions in the field of ICT (Information and Communication Technology). The most important functions performed by telematics systems are the functions related to the information operating (mega-data). It involves acquiring (sensors), processing (analytical and decisional systems) as well as distributing and transmitting operations (effectors). These are the processes implemented in a determined way (e.g. automatic control) as well as the processes which result from *ad-hoc* discretionary situations (decisions made by administrators, dispatchers, operators and independent users of specific infrastructure).

Considering the context of the presented study, a particularly interesting example which illustrates the application of the *telematics* term is modern maritime and inland waterway transport. Assuming the broadest approach, modern (intelligent) transport is supported with integrated systems of performance measurement, telecommunication, IT, information and indispensable automation (and finally connected to autonomous transport solutions). This part of intelligent transport which consists of dedicated systems and, particularly, its equipment (including software) along with services provided by such equipment, is referred to as *transport telematics*.

Telematics solutions are usually characterised by open architecture, they can be extended, complemented and modernised (we say they are scalable). Their basic aim is to allow the particular elements of a system (sub-systems) to cooperate and to interact with users (stakeholders). Such cooperation provides a considerable increase in the level of transport safety and security, operational reliability, efficient use of the infrastructure and, consequently, better economic results (optimisation), limitation of ecological risks and pressure exerted on natural environment (lowering anthropopressure).

Maritime and inland waterway transport must meet numerous requirements and challenges, and it must undergo some processes involving the implementation of intelligent systemic solutions. Application of telematics solutions is a step in the right direction. Each stage of transport processes and port operations has been provided with sensor systems used for acquiring information (e.g. cloud of points). In this way, vast amounts of information are acquired and processed, hundreds of ICT applications supporting data processing and data visualisation are developed (giving us the tracking and monitoring ability). It can be assumed that the saturation level of using telematics tools in maritime and inland waterway transport has been already achieved. Unfortunately, as there is no proper coordination, the architecture of the systems is of a dispersed and inconsistent nature; the systems are multiplied, and a problem of information entropy can be observed. As a consequence, the implemented architecture does not provide a satisfying level of integration with the low potential of harmonisation. Therefore, the first attempts at integrating such systems and at achieving economies of scale have started to appear (compatibility of data and systems and systemic integration in the future).

This study comes as an attempt at presenting a holistic approach to the maritime and inland waterway transport telematics. Identifying a role performed by contemporary maritime and inland waterway transport in the modern economy, hazards occurring in transport operations and an imperative to present an intelligent response to the identified challenges leads to the implementation of transport telematics solutions. Hence, "an inventory" of telematics systems in maritime and inland waterway transport concludes the presented study. The pragmatic approach to the achievement of such an aim divides this book into four chapters.

Indicating its place in the branch structure, the first chapter highlights the role of maritime and inland waterway transport in the contemporary regional and global economy. To emphasize the significance of maritime and inland waterway transport in the economy, the elements of their potential are documented in figures; also, further anticipated directions of their development are outlined as the derivatives of the identified regional/global geo-political and economic trends. The first chapter also introduces the concept of key parameters pertaining to maritime and inland waterway transport, based on their immanent operational features, such as universality, accessibility and degression of unit costs. These features are closely linked to the taxonomy and morphology of maritime and inland waterway transport (including the lighter aboard ship – LASH technology). To describe the modality of the discussed means of transportation, the containerisation challenges are pointed out and a concept of a container as a loading unit in maritime and inland waterway transport is presented. Finally, all types of containers used in maritime and inland waterway transport operations are described in detail. The identification of all these factors allows the Author to introduce safety/security challenges as the main determinants in the implementation of telematics systems in maritime and inland waterway transport.

Consequently, the second chapter refers to two fundamental groups of factors: safety and security in maritime and inland waterway transport. The risk factors in maritime and inland waterway transport are clearly identified, leading to a discovery of an explicit phenomenon of shifting the balance point from direct counteraction against hazards towards active prevention against them. Another important aspect discussed in this chapter refers to problems connected with the efficient management of safety/security processes in maritime and inland waterway transport, particularly to the questions of a unified structure of the management system, and precise indication of instruments which support this process (including emission control). The second chapter also presents the architecture of safety management systems in the maritime and inland waterway domain, and their transition into an institutionalised/quasi-integrated structure. Additionally, all the regularities and cause-and-effect schemes are pointed out as well.

Defining hazards makes it possible for the Author to exemplify them, to identify risks and to present the mechanisms and instruments of their assessment. It leads us to further considerations which refer to systemic mechanisms and instruments of preventing hazards in maritime and inland waterway transport. And finally, it gives us an opportunity to present the origin and significance of telematics systems in maritime and inland waterway transport (introduction/genesis of transport intelligence). All the systemic aspects of maritime and inland waterway transport safety/security defined at the local, national, regional and global levels have their internal, sensory, analytical and decisional components. These components enable us to map, to monitor (to follow the regularities and detect anomalies) and to provide the analysis of the processes in the function of risk assessment, and to assume appropriate preventive and counter-measure solutions. The indication of a typical architecture of telematics systems introduced in maritime and inland waterway transport safety/security comes as the conclusion of this chapter.

Having indicated tasks and morphological elements of telematics solutions, the third chapter presents a taxonomic division of these systems, based on the original identification and the criteria which have been assumed particularly for maritime transport. The main attention is paid to the VTMIS (Vessel Traffic Monitoring and Information Systems) with their basic sub-systems of the VTS, AIS, SRS, MAS types and the DGPS, as well as INMARSAT, which are the systems supporting their basic operations.

The consideration of the subsequent criteria referring to the division of the monitoring systems of maritime transport safety/security has made it possible for the Author to identify a group of partially integrated systems including, among others: IMDatE (EMSA – EU), BRITE (as an experimental tool of the MSA concept developed by NATO); complementary systems which include the following international systems: GMDSS (Global Maritime Distress and Safety System), MSSIS (Maritime Safety and Security Information System), NAMESIS (Naval Merchant Shipping Information System), VMS (Vessel Monitoring System), and national systems, e.g.: PHICS (Polish Harbours Information and Control System). The common character of the standards has made it possible for the Author to provide some examples of full commercialisation of some ICT solutions. Hence, some commercial monitoring systems of maritime transport safety have been identified (represented by such applications as: AIS Live, Marine Traffic, Vessel Tracker, exactAIS™ as well as based on a satellite signal: AIS-S, Gatehouse AIS Display System). Another group of systems which has been defined on the basis of the assumed division criteria includes terminal and ship owner systems which comprise TOS (Terminal Operation System), applications supporting processes which take place at the level of fleet management (for example: AMOS – Asset Management Operating System), CBM applications (Condition-based Monitoring) used for monitoring the parameters of propulsion operation, fuel consumption and GHG emission and GSOP (Geo-informational System of Port Protection) which meet the ISPS Code requirements.

The last identified category includes monitoring systems of container cargo units in maritime transport – solutions of the ECTS type (Electronic Container Tracking Service).

The variety and comprehensiveness of the application fields and processes referring to the commercialisation of standards pertaining to telematics systems in maritime transport safety/security (for example the AIS at the sensory level) have resulted in a massive dispersion of systems. Subsequently, the dispersion has resulted in some measurable negative effects, such as the lack of coordination, difficulties in communication and data use, multiplication of initiatives and incurrence of multiplied costs (the same systems are multiplied by particular operators, countries and regions). Observed particularly in the EU seas, this situation has released the potential for conceptual work on the development and implementation of a unified, integrated telematics system of maritime transport safety/security. Therefore, the development of the concept of CISE (Common Information Sharing Environment) as well as the IMDatE instrument (Integrated Maritime Data Environment) have been pointed out as a window of opportunity for further systemic integration.

Starting with the same methodology, the fourth chapter presents an attempt at the identification of telematics systems in intelligent inland waterway transport. The classification of telematics and vessel/barge monitoring systems in inland waterway transportation processes opens a discussion on their role and significance in this particular mode of transport. Taking into account the specific transportation environment of inland waterway transport, the morphological elements and taxonomy of applied telematics and vessel monitoring systems (including river terminal operating system Improved Port Ship Interface – IPSI) have been described. The main focus is on the RIS (River Information Service) as an EU-originated telematics system of inland waterway transport management. Apart from the identification of the main tasks of the RIS, the organisational and operational structure is widely described. Furthermore, the main functions (functionalities) of the RIS are identified for some better understanding of the advantages coming with this telematics system. It allows the Author to provide readers with some examples of benefits resulting from the application of the RIS system in inland waterway transport management. One of the main features of the RIS system is an application of the Inland ECDIS (Electronic Chart Display and Information System for Inland Navigation), which equips skippers with a much more accurate and reliable navigation tool. In order to avoid the same mistakes (a massive dispersion observed in maritime transport telematics) in inland waterway transport telematics systems, the problem of integration and compatibility has been indicated since the very beginning. Thus, a concept of the Navigation and Inland Waterway Action and Development in Europe (NAIADES II) and the PLATINA supporting platform clearly indicates how important the integration and cooperation of the VTMIS (maritime) and RIS (inland waterway) transport systems becomes.

While working on this study and carrying out his scientific research, the Author has benefited from consultations and bibliographic materials provided by various foreign civilian and military institutions, the most supportive of which have been: International Maritime Organisation (IMO), European Maritime Safety Agency (EMSA), NATO Headquarters of Maritime Command in Northwood (a unit of NCAGS – Naval Cooperation and Guidance for Shipping), NATO Shipping Centre (NSC), Eurostat, Rolls-Royce (Ship Intelligence Division), Scottish Canals, Kongsberg and software companies such as Tide Works, SpecTec, Avante, StarCom, Orca.

The considerations included in this study come as a continuation of the research on maritime transport safety which has been published as a monograph *Maritime Transport Safety*. It should be also noted that expert literature of the subject does not provide any synthetic monograph study on the issues presented in this book. Considering dynamic changes in the area of maritime shipping and inland waterway transport monitoring systems and systemic support of managerial decisions that took place during the last decade (dynamic development of the telematics systems), it has been so far difficult to follow these transformations in a comprehensive way. At present, the sophistication level of advanced systems allows us to state that it all comes as the near-ultimate functional architecture; therefore, an attempt at their comprehensive presentation is well-justified. The Author hopes that his publication will fill the gap in expert literature, and also that “an inventory” of telematics systems with a synthesis of their architecture presented in this study will prove to be useful in better understanding of intelligent maritime and inland waterway transport processes.

CHAPTER 1

MARITIME AND INLAND WATERWAY TRANSPORT

1.1. A notion of maritime and inland waterway transport

1.1.1. The domain of maritime transport

Since the beginning of our civilisation, transport has been an element which allows people to travel and to move their products and raw materials indispensable for the development of societies. The *transport* term comes from a Latin word *transportere* which means to move, to relocate. The term is ontologically related to another notion, namely, *communication* (*communicatio* in Latin) which means providing information, talking, a form of communication but also – transporting.[1]

The notion of transport is defined as … *a chain of actions related to movement of people and material goods with the use of relevant means; it includes translocation from one place to another place, as well as any other actions required to reach the intended aim, i.e. loading actions (loading, unloading, cargo handling) and manipulation operations*.[2]

At present, transport is implemented practically in all the fields of human natural environment, and considering this fact, it presents some distinctive immanent features attributed to the particular environment and the specificity which affects the division made in the field of transport. Expert literature diversifies transport by applying various features which constitute the criteria for transport classification. The most recognised and commonly accepted classification is the one which takes the criterion of vertical and

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[1] I. Kamińska-Szmaj, M. Jarosz [et al.] *Słownik Wyrazów Obcych*, Wydawnictwo Europa, Wrocław 2001, p. 390 and 820.

[2] http://encyklopedia.pwn.pl/haslo/transport;3988780.html [accessed on 12th October 2015].

horizontal division into consideration. The first criterion divides transport into transport modes; the second one divides transport into types.[3]

Considering the vertical classification, the division criterion is the specificity of the environment in which means of transport are operated, and it is determined by the type of a transportation way and a technique of moving along such a way, which ultimately affects the type of the applied means of transport.[4] The first level of the vertical classification divides transport into land, water and air transport (three elemental types of environment). Then, the division takes place in accordance with the specific character of the particular environment (considering a possible transportation way and means of transport), and there are six main modes of transport. These are namely: road transport (vehicles), rail transport, air transport, inland waterway transport, maritime transport and pipeline transport.[5] During the last decades, as a result of civilisational advancement and "conquest" of space, some development in cosmic transport could be observed; however, it has not been commonly recognised as a typical mode of transport yet. The full picture of the vertical classification of transport is presented in Figure 1-1.

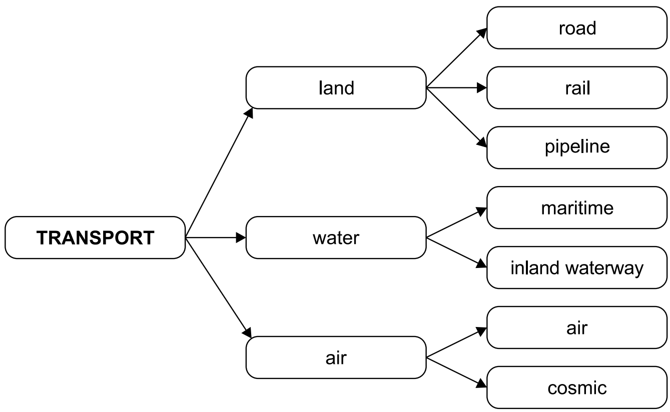

Figure 1-1. Vertical classification of transport

Source: adapted from A. Koźlak, *Ekonomika transportu. Teoria i praktyka gospodarcza*, Wydawnictwo Uniwersytetu Gdańskiego, Gdańsk 2008, p. 13.

[3] W. Grzywacz, J. Burnewicz, *Ekonomika Transportu*, WKŁ, Warszawa 1989, p. 46.
[4] Such a division is of a technical and operational character, however, in expert literature it is often referred to as the mode of transport division – the Author's note.
[5] A. Piskozub, *Gospodarowanie w transporcie*, WKŁ, Warszawa 1982, pp. 19–20.

The horizontal division includes a number of additional criteria which allow us to make further specifications for operational, statistical and economic requirements.[6] The division of transport with the consideration of some diversified horizontal criteria is presented in Table 1-1.

Table 1-1. Horizontal classification of transport

Division criterion	Categories
considering the object of transport	passengers and cargo
considering functional and organisational aspects	scheduled (line) and non-scheduled (charter)
considering continuity of the transportation process	direct and indirect
considering the geographical criterion and transportation distance	national and international
considering transportation distance	short-range, middle-range and long-range transport
considering availability for users	public, sectoral and own
considering ownership forms	state, public, cooperative, private

Source: adapted from A. Koźlak, *Ekonomika transportu. Teoria i praktyka gospodarcza…*, op. cit., pp. 14–17.

An inherent attribute of transport is also its anthropopressure, because each transport activity involves exploitation of environment in the form of emission, noise, occupation of land (for transport infrastructure), congestion and accidents. The structure of such negative phenomena which result from transportation processes is presented in Figure 1-2.

One of the oldest and most frequently used mode of transport, as stated by the vertical (branch) classification, is maritime transport. Benefits obtained from this mode of transport have been appreciated since the beginning of our civilisation, hence it has been described in a Latin adage: *navigare necesse est* – navigation is necessary.[7] Maritime transport has been present on almost all the waters of the world (referred to as the World Ocean), including oceans, mediterranean and marginal seas, straits, sea and river channels,

[6] R. Miler, *Bezpieczeństwo transportu morskiego*, WN PWN, Warszawa 2015, p. 24.

[7] *Navigare necesse est vivere non est necesse* (*Pompeius*, circa 60 BC),– *navigation is necessary but life is not* – translated from Greek by Plutarch; Pompeius said that during a storm to the helmsman on a ship which was carrying grain to Rome during a great famine. He probably meant: *We have to leave right now, even if it means risking our lives.* – the Author's note.

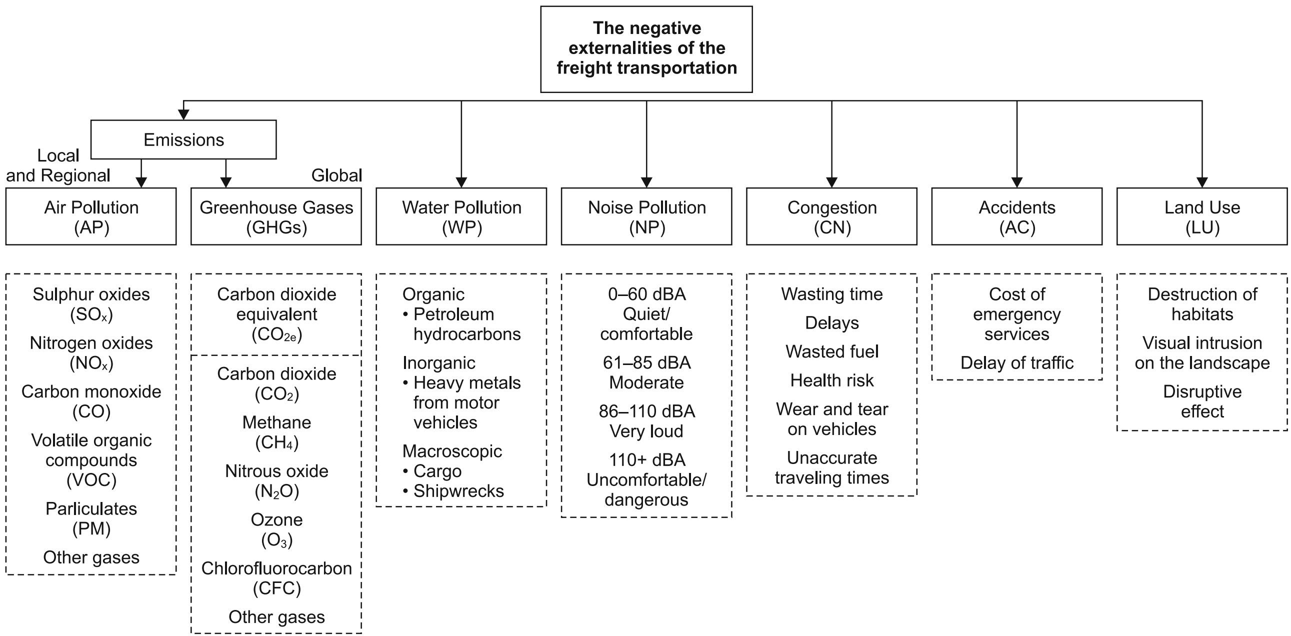

Figure 1-2. Negative externalities of transport

Source: adapted from https://tomvanwoensel.com/2015/02/26/externalities-of-freight-transportation/ [accessed on 27th July 2017].

estuaries, artificial sea waterways and enclosed seas.[8] It particularly refers to transportation of passengers and cargo by vessels across the sea in order to make profit.[9] It has been assumed that contemporary maritime transport is composed of two factors, namely: maritime navigation and seaports. In both these environments it is possible to observe complicated transport and logistic processes of a postulated level of technological advancement, which naturally tend towards unification and standardisation. They occur under strong competition and a growing level of risk related to broadly understood safety/security of these processes.

Summing up, for the requirements of this publication, it is possible to present a definition of maritime transport which describes it as a process consisting of a set of activities related to translocation of passengers and material goods by means of maritime transport (oceangoing vessels), which include maritime navigation and all the necessary port operations (loading, unloading, cargo handling and manipulation operations), implemented by specialised entities (maritime transport operators), equipped with telematics systems in the environment of the World Ocean (telematics systems of maritime transport).

Implementation of maritime transport (considering the aspect of maritime navigation) is based on a fundamental legal principle of freedom of the seas and a related concept of *freedom of navigation* (FoN).[10] The principle of freedom of navigation constitutes two key terms in this aspect: *high seas*, which refers to all international conventions, and *territorial seas* with internal waters, which are characterised by the complete sovereignty of a coastal state.[11] Figure 1-3 presents a method applied to the qualification of the *high seas* term.

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[8] Cf.: R. Kacperczyk, *Transport i spedycja,* Wydawnictwo Difin, Warszawa 2010, pp. 74–75.

[9] Cf.: W. Rydzkowski, K. Wojewódzka-Król (eds), *Transport*, PWN, Warszawa 2007, pp. 201–202.

[10] The *freedom of the seas* term is based on a generally accepted law stating that no state is entitled to rule over any part of high seas exercising its sovereign authority, and freedom of navigation at high seas comes as the crucial principle of the contemporary law of the sea, the principle included in the United Nations Convention on the Law of the Sea (UNCLOS), referred to as the Constitution of Seas and Oceans. The convention consists of 320 articles and 9 appendices. It comprehensively regulates the use of seas and oceans through the codification of common maritime standards and principles. It states new concepts and legal regimes and provides regulations for further development of the particular fields of that law – the Author's note.

[11] In accordance with Article 2 of the United Nations Convention on the Law of the Sea (UNCLOS) – the Author's note.

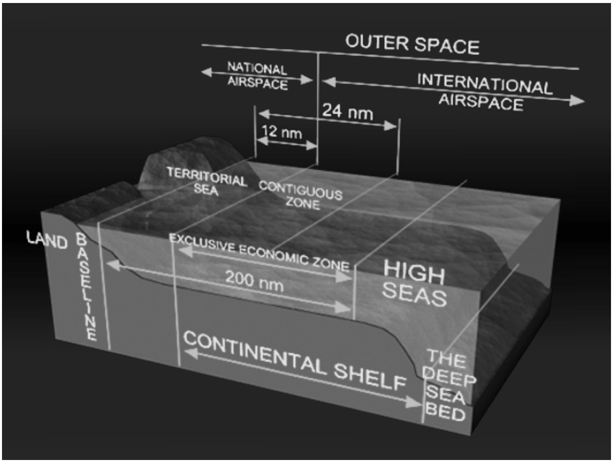

Figure 1-3. Division of sea areas in accordance with the range of legal regulations and jurisdiction of the coastal states

Source: adapted from *Global Maritime Security Cooperation In The Age Of Terrorism And Transnational Threats At Sea*, Maritime Security Primer, Copenhagen 2008, p. 6.

An important feature of maritime transport is its ecological aspect, especially considering waters of the European Union. We can clearly observe formal and legal support provided to the development of pro-ecological transport solutions in maritime navigation. Despite the fact that maritime transport is the mode with the lowest level of anthropopressure, mechanisms of higher control and charges for greenhouse gas emission to the atmosphere are still being developed.

Maritime transport occurs in the specific environment of the World Ocean which significantly affects the potential, efficiency and safety/security of this mode of transport. The basic features of maritime transport which are of immanent nature, that is: attributed to the mode of transport performed in maritime environment and positively affecting global economy, are as follows:[12]

- access to global transport and logistics centres located at large seaports and terminals (e.g. container terminals),
- strong cost degression per unit in translocation of goods, which is related to the function of the road and the volume of cargo,

[12] T. Szczepaniak (ed.), *Transport i spedycja w handlu zagranicznym*, PWE, Warszawa 2002, p. 30.

- high accessibility of transport resulting from the specific character of transport vulnerability pertaining to most cargo shipped by maritime transport and high supply of maritime transport services,
- the distance range that can be covered by vessels, which is unrestricted by any barriers of linear infrastructure.[13]

Apart from the undeniable and significant positive features mentioned above, and with the consideration of the low operating speed of vessels and time-consuming cargo handling operations, at present maritime navigation does not meet transport requirements for small batches of cargo and goods which must be delivered quickly.[14] Hence, it is efficiently replaced by other modes of transport, for example, road transport or, more and more often, by air transport.

Despite the above-mentioned limitations, and with the consideration of the progressive processes of globalisation and standardisation of transport (containerisation), maritime transport comes as the main mode in the developing field of containerised general cargo shipping (inter- and multimodal), especially in intercontinental trade.[15] Table 1-2 presents the representative features of maritime transport.

Table 1-2. Representative features of maritime transport

Features	
Positive	**Negative**
capability of transporting any kind of cargo	relatively low punctuality and low operating speed
the cheapest mode of transport for long distances	high susceptibility to weather conditions
easy access to global economic markets	necessity of using additional means of transport (the logistics structure of a hub and spokes which imposes cargo handling to smaller vessels, e.g. feeders, at hub ports)

[13] Oceangoing vessels can freely navigate at seas and oceans, choosing the shortest way to their destination ports. All the limitations to maritime traffic are defined by the principles of navigation in port approach fairways, natural and artificial channels and straits – the Author's note.
[14] Maritime transport is characterised by a catalogue of quality properties which are described in detail in the publication edited by I. Urbanyi-Popiołek (ed.), *Ekonomiczne i organizacyjne aspekty transportu morskiego*, Wydawnictwo Uczelniane Wyższej Szkoły Gospodarki w Bydgoszczy, Bydgoszcz 2012, pp. 69–70 – the Author's note.
[15] Cf.: D. Marciniak-Neider, J. Neider (eds), *Podręcznik spedytora*, Wydawnictwo Polskiej Izby Spedycji i Logistyki, Gdynia 2011, p. 35.

Table 1-2. cont.

Features	
Positive	**Negative**
capability of covering long distances at a large degression of the unit cost	risk undertaken during transport of cargo susceptible to humidity
capability of transporting heavy cargo in large quantities and oversized cargo	high costs incurred at the loss of cargo during unfortunate accidents (general average)
global character	high risk of piracy, terrorist attacks and asymmetric threats
strategic character	necessity of providing international regulators and legislation

Source: adapted from M. Michałowska (ed.), *Transport w gospodarce opartej na wiedzy*, Wydawnictwo Akademii Ekonomicznej, Katowice 2009, pp. 242–245; S. Markusik, *Infrastruktura logistyczna w transporcie,* Wydawnictwo Politechniki Śląskiej, Gliwice 2009, p. 152.

Summing up, maritime transport has been used by people for thousands of years, and it can be easily stated that it is a mode of transport which is deeply rooted in global economic and social processes. At present, maritime transport is still in the stage of dynamic development, and it has been attracting a lot of interest because of the above-mentioned processes of regionalisation (Europeaisation) and globalisation. However, further dynamic development of maritime transport will be impossible without focusing our attention on the elements of complementary transport. One of the most natural types of transport which are complementary to maritime transport is inland waterway transport.

1.1.2. The domain of inland waterway transport

Undoubtedly, rivers are the oldest transport routes in the world. Inland waterway transport has been developing on all the continents inhabited by people. Due to the development of river systems and their supplementation with artificial waterways, in some countries a dynamic development of inland waterway transport can be observed. As a result, this mode of transport becomes competitive to other modes of transport, particularly for land (rail and road) transport. Similarly to maritime transport, in inland waterway transport the cargo is shipped in the specific environment (rivers, lakes and channels, including artificial ones), with the use of specific vessels (self-propelled barges, non-self-propelled barge convoys with a tugboat) and technologies characteristic for this mode of transport (including port technologies) and telematics systems. Hence, the definition of inland waterway navigation is understood as any translocation of vessels along a particular navigable inland waterway.

However, in contrast to maritime transport, the immanent features of inland waterway transport allow us to identify this mode of transport as definitely much more local (regional) and of less economic significance (the volume of cargo shipped in this way is relatively lower than the volume of cargo shipped by maritime transport). On the other hand, however, when compared to the land modes of transport, inland waterway transport of cargo can be more advantageous because pushed barge convoys can transport more cargo, when converted to a distance unit (tonne-kilometer – tonkm). Table 1-3 presents the key parameters of inland waterway transport (IWT) and of land (rail and road) transport.

Table 1-3. Comparison of the parameters characteristic for inland waterway transport and land (rail and road) transport

Parameters	IWT	Rail	Road
Energy efficiency: 1 kW can move what weight of cargo [kg]	4,000	500	150
Fuel efficiency: 1 liter of fuel can move how much freight [tonkm]	105	85	24
Equivalent single unit carrying capacity	1 barge	15 rail wagons (standard)	60 trucks (standard)
Air pollution	Low	Medium	High
Land acquisition	Low	High	High
Capital required	Low (relatively low for bigger scale investments)	High	High

Source: adapted from http://blogs.worldbank.org/endpovertyinsouthasia/india-great-yet-unexplored-potential-inland-water-transportation [accessed on 27th July 2017].

Furthermore, the carrying capacity of the largest barges used in inland waterway navigation equals the carrying capacity of hundreds of trucks and railway carriages, which may bring about considerable savings in transportation costs and reduce road and rail traffic (decrease congestion). The comparison of the parameters referring to the size and carrying capacity of a pushed convoy consisting of four river barges (7k tonnes net) in relation to its equivalent in rail and road transport is presented in Figure 1-4.

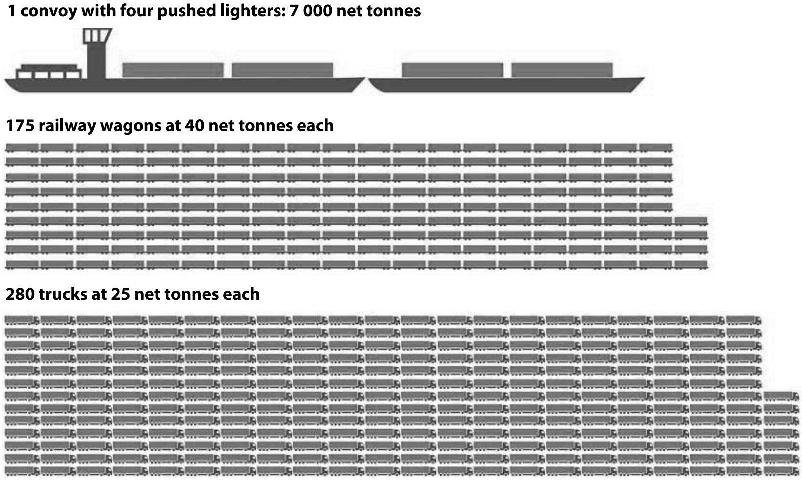

Figure 1-4. Comparison of the parameters characterising the carrying capacity of a pushed convoy of four river barges (7k tonnes net) to its equivalent in rail and road transport

Source: adapted from *2015 Special Report No 01 Inland Waterway Transport in Europe,* European Court of Auditors, Luxembourg: Publications Office of the European Union, 2015, p. 11.

Inland waterway transport is also energy-efficient because a vessel of inland waterway navigation may carry one tonne of cargo almost four times further than a truck at the same energy consumption level (the distance is respectively 370 km for an inland vessel, 300 km for a train and 100 km for a truck). In this way, vessels of inland waterway navigation achieve very good results in the field of the lowered GHG (greenhouse gases) emission, noise and a higher level of safety. Figure 1-5 presents a comparison of the anthropopressure parameters of inland waterway transport, road and rail transport.

Considering the fact that inland waterway transport is more time-consuming (slower and presenting a higher rate of distance extension) than road transport, it is broadly used for transportation of goods which do not require quick delivery. However, it should be noted that shipping containerised cargo with the use of inland waterway transport has been increased over the last several years (in the USA, India and Europe, especially in the Rhine basin). Inland waterways, however, have a limited geographical range. Moreover, whenever any problems occur along a transportation route, such as

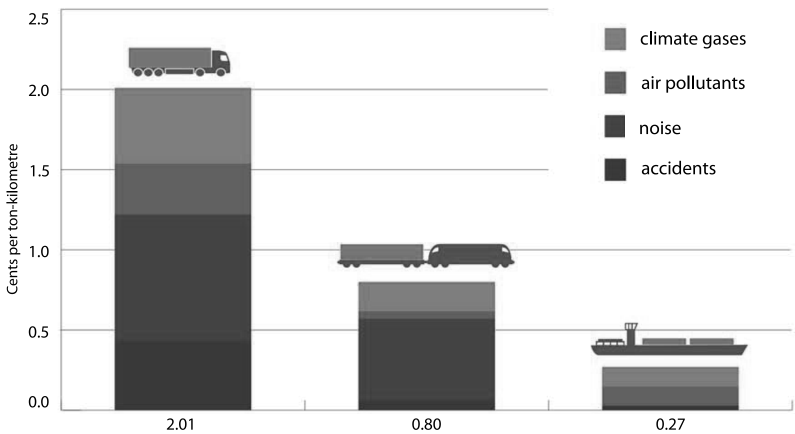

Figure 1-5. Comparison of the anthropopressure parameters characteristic for inland waterway, road and rail modes of transport

Source: adapted from *2015 Special Report No 01 Inland Waterway Transport in Europe*, European Court of Auditors, Luxembourg: Publications Office of the European Union, 2015, p. 11.

accidents, bad weather conditions, too low or too high levels of water, it is hardly possible to change that particular shipping route of a vessel for an alternative one. Moreover, the advantages resulting from lower costs can occur only in some particular circumstances – depending on the distance covered by the goods transported by waterways and the distance of a sender or a receiver to the cargo handling point, where the goods are unloaded from a barge or loaded on a barge. Hence, the unit cost is decreased with an increase in the distance covered by inland waterway transport, with simultaneous attempts made to minimise the distance covered by complementary transport, e.g. road transport in comprehensive door-to-door relations (Table 1-4).

Table 1-4. An example of transport costs when converted to a tonne-kilometer [ton-km] for the transportation distance of 200 km and 1000 km (presented in Eurocents)

Freight transport mode	200 km	1,000 km
Road	14.30	8.80
Rail	16.04	7.40
IWT	2.73	1.95

Source: adapted from Planco Consulting GmbH, *Economic and Ecological Comparison of Transport Modes: Road, Railways and Inland waterways*, November 2007.

The specific character of inland waterway transport defines the structure of demand for water transport and relations in which this transport mode becomes particularly competitive; hence, at the same time it defines the basic field of its application which traditionally refers to the following types of cargo shipping:

- large batches of bulk cargo between their sending and receiving locations based in the vicinity of waterways, including transport handling services of:
  - seaports (sea-river transport, including ro-ro),
  - mines and other places where raw materials are acquired (e.g. wood) and industrial plants located in the vicinity of waterways,
  - larger agglomerations (services provided to cities and city logistics centres, including supplies, waste collection, urban transport, etc.),
  - industrialised agriculture (transport of plants, fertilisers and biofuels);
- cargo the transportation of which excludes the use of any other transport modes, e.g. sand dredged from a river bed (during dredging operations);
- oversized and heavy cargo, shock-susceptible cargo;
- containerised cargo related to a considerable increase in the turnover of regional and international logistics centres (often located at inland ports, considering the fact that they are conveniently connected with the hinterland, and they have land reserves for further development).

Summing up, for the requirements of this monograph, it is possible to provide a definition of inland waterway transport presenting it as a process involving a set of operations related to translocation of material goods (less often passengers) with the use of inland waterway means of transport (river barges), including river navigation and all the necessary port operations (loading, unloading, manipulation operations) performed by specialist entities (inland waterway transport operators) equipped with telematics systems (telematics systems of inland waterway transport) in the river environment. Table 1-5 presents the representative features of inland waterway transport.

At present, despite the indication of numerous immanent features of inland waterway transport which clearly distinguish the inland waterway domain from the maritime domain, the complementarity features of both these modes of transport have become particularly significant. Hence, an important attribute of inland waterway transport is its complementarity in sea-river shipping. As a result, the share of inland waterway transport in services provided at seaports has already reached a considerable level, and for example, it has

Table 1-5. The representative features of inland waterway transport

Features	
Positive	**Negative**
a low level of emitted pollution, low energy consumption, low noise, high efficiency in the occupancy of additional area	high susceptibility to hydrological and hydro-meteorological conditions (high and low level of water, ice covers, currents)
the cheapest mode of transport in the regional scale which is correlated with maritime transport (maritime-river transportation)	relatively low punctuality and low operational speed
possibility to use rivers as natural communication routes	necessity of providing international regulators and legislation and separate legal regulations
covering long distances at a considerable degression of the unit cost	a high rate of distance extension
capability of transporting heavy and oversized cargo	low security/safety of cargo and vessels
a small number of collisions and related costs of eliminating accident damage recovery	mostly total loss coverage insurance, additional premiums for other types of insurance
high durability and longevity of vessels and infrastructure	very high costs of waterway maintenance

Source: adapted from M. Michałowska (ed.), *Transport w gospodarce opartej na wiedzy*, Wydawnictwo Akademii Ekonomicznej, Katowice 2009, pp. 242–245; S. Markusik, *Infrastruktura logistyczna w transporcie,* Wydawnictwo Politechniki Śląskiej, Gliwice 2009, p. 152.

been recorded at the level of almost 80% in Rotterdam which handles the largest oceangoing vessels.

The current tendencies in the development of transport in Europe have been directed towards the growing significance of the role performed by inland waterway transport in a new field of application, namely, in the field of handling container turnover of seaports/terminals, because:

- the share of containerised cargo transported by sea has been growing;
- larger container vessels are able to enter European seaports (19–22 k TEU (Twenty Equivalent Unit)), and as a result, cargo handling processes have faced serious challenges;
- road congestion has been growing (road transport as an element of the implementation of feeder transport processes has almost reached its capacity limits);

- rail transport at seaport hinterlands has almost reached the limits of its capacity.

Having defined the specificity of the environment, immanent features, strengths and weaknesses of maritime and inland waterway modes of transport, it is possible to move on to another field of their characteristics, namely to the identification of their taxonomic features and morphological elements.

1.2. Taxonomic and morphological elements of maritime and inland waterway transport

1.2.1. Taxonomy and morphology of maritime transport

Morphological elements, that is namely the main elements of the systemic structure pertaining to each mode of transport, include transport infrastructure, superstructure and means of transport.[16]

Broadly understood, transport infrastructure (identical for all the modes) can be divided into the following groups, considering its spatial location:[17]
- nodal infrastructure – including transportation nods and hubs, all the equipment and facilities (such as ramps, warehouses, stock yards, cargo handling equipment, ports, runways, terminals, stops, etc.);
- linear infrastructure – any type of transportation roads, industrial facilities (e.g. power lines) required for translocation (roads, railways, rivers and any other navigable waters with necessary facilities);
- informational and IT infrastructure – any type of informational systems and auxiliary IT systems required in order to provide efficient and effective transport management (e.g. ITS – intelligent transport systems, navigation monitoring systems, air and railway traffic monitoring and management systems, generally: transport telematics).

Similarly to other modes of transport, maritime transport includes linear and nodal elements of infrastructure and elements of informational and IT infrastructure (including satellite systems). The first group includes natural and artificial routes of maritime communication, along which vessel traf-

[16] A. Piskozub (ed.), *Ekonomika transportu*, WKŁ, Warszawa 1979, p. 200.
[17] A. Koźlak, *Ekonomika transportu. Teoria i praktyka gospodarcza…*, op. cit., p. 34.