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Leszek MINDUR
International University of Logistics and Transport in Wrocław
Sołtysowicka 19B, 51-168 Wrocław, Poland
Corresponding author. E-mail: lmindur@vp.pl

COMBINED/INTERMODAL TRANSPORT – THE GLOBAL TRENDS

Summary. This article presents the different intermodal transport systems in selected countries in the world, with an indication of their development and impact on environmental protection. The conducted research indicates much faster development of intermodal transport as compared to the transport of goods in other technologies. The studies were based on the latest obtainable statistics on intermodal transport from Asia, Europe, North America, and Australia. In all the cases examined, it is apparent that intermodal transport is supported by state authorities and international intermodal transport associations. The scientific and cognitive value of the article is expressed in the collection of a large number of materials, their systematization and generalization of conclusions. The literature on this subject lacks such comprehensive scientific studies, and this study will therefore clearly fill the research gap.

1. INTRODUCTION

The negative consequences of transport, such as environmental pollution resulting in climate change, noise, congestion, and accidents, pose problems to the economy and the health of people worldwide. Governments and organizations should therefore move toward reducing road transport in favor of less-polluting and more energy-efficient and human-friendly modes of transport. Intermodal transport guarantees greater flexibility and greater security of the flow of goods, leading to additional costs, which, however, compensate for the environmental protection effects achieved.

Intermodal systems in road transport are preferred when goods need to be delivered quickly to their destinations, mainly over short distances. Thus, this transport technology is commonly used when the cargo must arrive in the shortest possible time. Rail transport, on the other hand, plays an important role in the transport of goods, the implementation time of which takes several working days. Large-scale bulk transport in import and export is performed in intermodal technology by sea.

The cheapest mode of transport is sea freight intermodal transport, but it involves a relatively long transportation time. In the case of road transport, the cost is generally similar, irrespective of distance. Rail transport is more expensive the shorter the distance, but the cost decreases significantly with increasing distance. Operators must therefore have a high level of knowledge and experience in the industry to meet the customers' expectations and understand their needs. They need not only skills and knowledge but also the financial capital and access to the most modern transport technologies.

2. THE IMPORTANCE OF WORLD PORTS IN INTERMODAL TRANSPORT

Goods are transported intermodally using a single cargo unit (container, semi-trailer, swap body, truck, special container) along the entire route. Intermodal containers [9], which come in many types and standardized sizes, are the most popular in the world, with 90% of the global container fleet being so-called general-purpose containers.

Container transport is most common, for example, because of road–sea or rail–road–sea transport, which accounts for the largest share of global intermodal transport. In 2019, the world's container ship fleet (5152 vessels) was around 266 million metric tons (Fig. 1) [31].

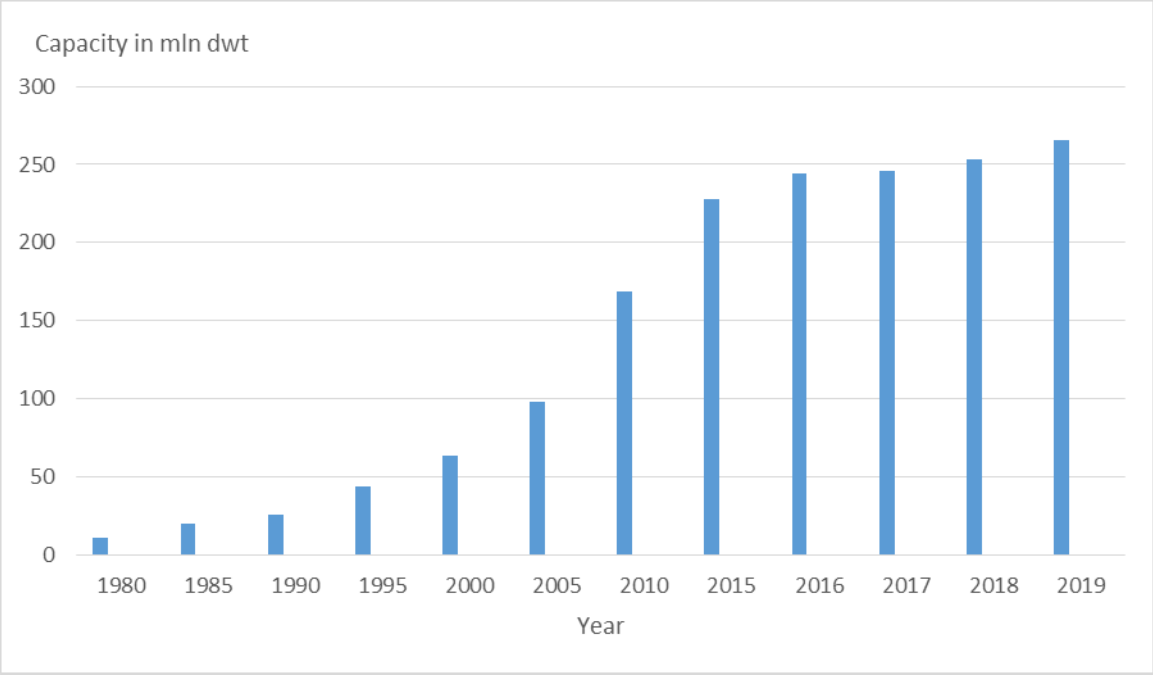


Fig. 1. Capacity of container ships in seaborne trade from 1980 to 2019 (own study based on [32])

Sea container transport should be recognized as the most cost-effective and environmentally friendly solution for international freight transport, despite its non-neutral impact on the climate. As a result of the increasing demand for trade in goods via waterways, the carrying capacity of the global merchant fleet has steadily increased in recent decades, reaching over 1.9 billion tons of carrying capacity in 2018. In the same year, the volume of maritime transport was around 11 billion metric tons (compared to 8 billion metric tons in 2008). At the same time, on a global scale, sea container transport in 2019 reached over 800 million TEU, which means an increase by 178 million TEU compared to 2012.

According to estimates by the Statista Research Department, in 2019, over 30 million TEU of cargo was transported through the Pacific Ocean, making the trade routes located in this area the largest shipping zone in terms of cargo volume (Fig. 2) [31].

3. INTERMODAL TRANSPORT IN ASIA

Asian ports, which serve almost 80% of the total capacity of the world's 50 largest container ports, occupy an important place in the global containerized cargo system [18]. Transport of goods by sea is one of the cheapest, but the delivery time is long: for example, from Asia to Europe, it is about 4-6 weeks. An alternative, also in the case of expensive air transport, are intermodal rail connections, possible thanks to the intensively developing network of railway connections from China/the Republic of Korea to Europe, with implementation times from 9 to 14 days [20]. With this type of transport, it is of key importance to cross the Polish and EU border in Małaszewicze, where the railroad gauges (1520 mm/1435 mm) and consignment notes (SMGS/CIM) are changed.

The cross-border rail network currently connects 59 Chinese cities serving China Railway Express terminals to 49 cities in 15 European countries [20]. The annual volume of rail services between China and Europe is rapidly increasing (Fig. 3). The number of containers transported by Russia en route from China to the EU back and forth reached 44 200 TEU in 2014, 81 100 TEU in 2015, and 153 000

TEU in 2016. However, these volumes remain small compared to maritime transport, as, for example, in 2016, more than 10 million TEU were sent by cargo ships from China to Europe [17].

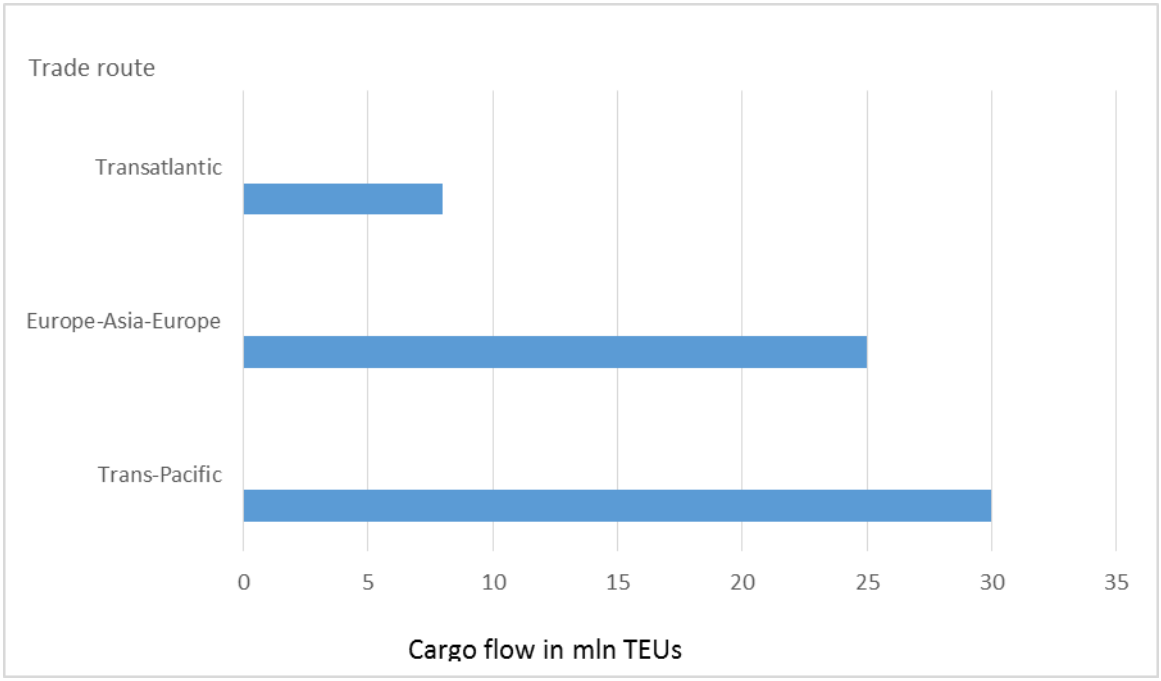


Fig. 2. Container cargo flows in 2019 on the main trade routes (own study based on [32])

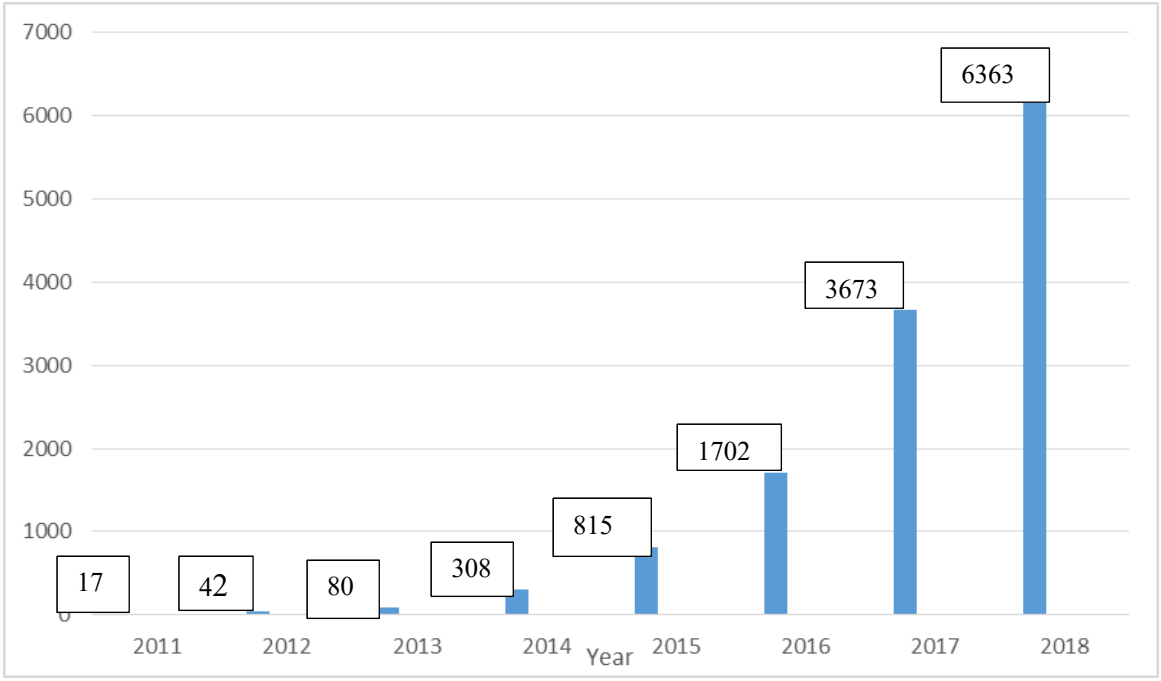


Fig. 3. Number of China-Europe freight train journeys, 2011-2018 (own study based on [20])

The development of China Railway Express revealed a number of operational problems, such as unsustainable flows of goods in opposite directions (e.g. in 2017, the number of train journeys from China to Europe was 2248, and in the opposite direction, it was 1225), high costs, and limited market competitiveness potential. Therefore, research is underway to find the optimal solution for this [20]. Today, transport corridors passing through the territory of Kazakhstan are of key importance [30].

With the support of European operators (e.g. Hupac, DB Cargo, DB Schenker), intermodal transport is also carried out between Western Europe and Russia and CIS countries. On behalf of Russia, RZD Logistics, a subsidiary of Russian Railways, is responsible for the organization of intermodal transport in the territory of the country. Russia's international cooperation with the European Union is determined by three pan-European international transport corridors running through Russian territory: Corridor 1 (Tallinn – Riga – Soviet – Kaliningrad – Mamonowo – Gdansk), Corridor 2 (Berlin – Warsaw – Minsk – Moscow – Nizny Nowgorod), and Corridor 9 (Helsinki – Buslovskaya – St. Petersburg – Moscow – Suzemka).

The most important international transport corridors through Russia are (Fig. 4) as follows:

- East-West (The Trans-Siberian Railway**), which** runs through the Republic of Korea, China/Mongolia, Russia, Belarus, Poland, and Germany/Hungary, and
- North-South, connecting Finland via Estonia, Latvia, Lithuania, Germany, Poland, Belarus, Ukraine, Russia, Turkmenistan, Kazakhstan, and Tajikistan with Iran and Oman [29].

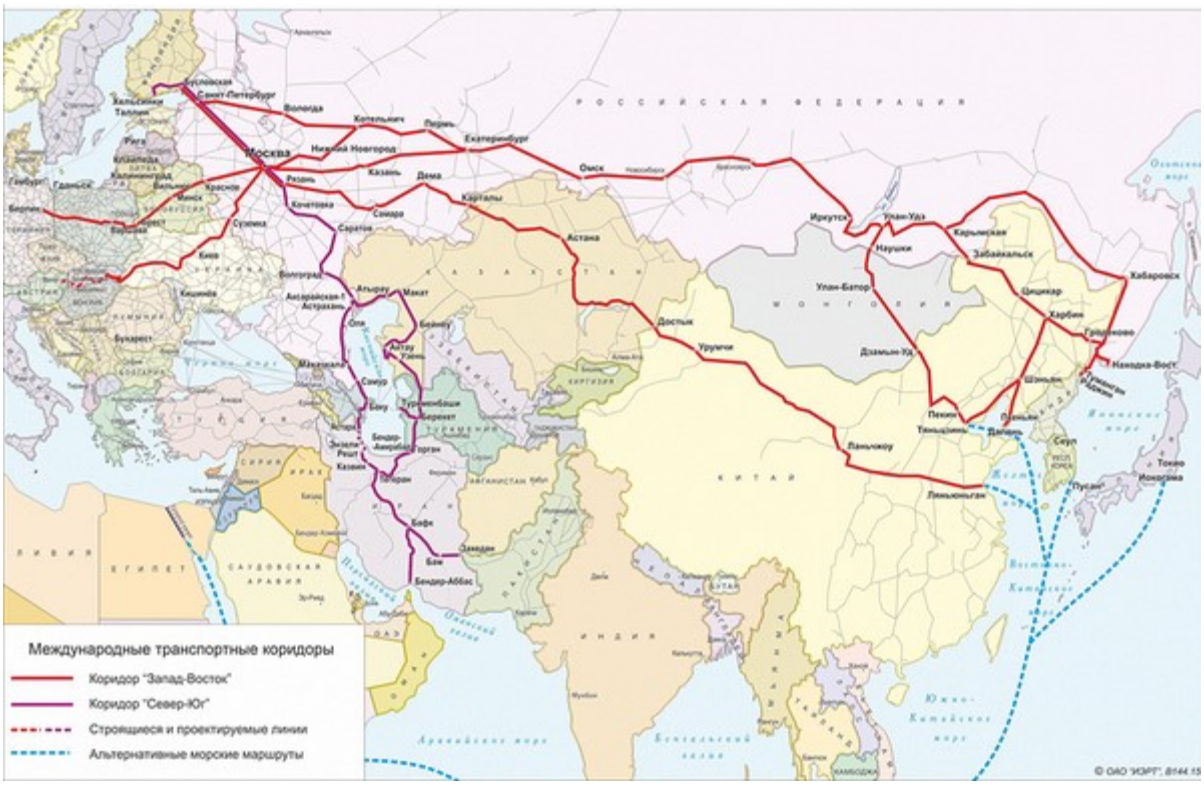


Fig. 4. International transport corridors East-West and North-South (own study based on [25])

The impact of transit and export–import transport on the development of the country's economy determines the involvement of RZD Logistics in the modernization and reconstruction of the railway infrastructure system. The activities undertaken are aimed at improving the transport service system for cargo owners, actions to increase the efficiency of commercial operations, and simplification of legal actions with customs offices for cargo transportation, as well as coordination of the development of transport and logistics activities.

4. INTERMODAL TRANSPORT IN EUROPE

In European policy, intermodal transport is seen as a factor that leads to a significant improvement in competitiveness by making more efficient use of the existing potential of the transport system, in addition to reducing environmental pollution [22]. However, in European countries, the density of the rail network and rail and road terminals varies; therefore, the European Union creates legal and

financial incentives to increase the competitiveness of intermodal transport. As a result, the share of intermodal transport in the freight market is growing every year, and the range of services provided is expanding. Within the EU, rail and road systems are most often used, but the important role of seaports cannot be overlooked.

In Europe, intermodal transport is carried out by the National Associations of Combined Transport, which play a leading role in organizing intermodal transport. At the same time, these societies are members of the UIRR, an international organization actively promoting intermodal transport, primarily toward European decision-makers, facilitating and supporting the strengthening of the sector [16].

According to statistics, intermodal transport services performed by operators associated with UIRR are systematically growing. In 2018, intermodal transport companies affiliated to the UIRR carried 4,288.3 thousand parcels and carried out transport of 75,7 billion tkm (Table 1).

Table 1

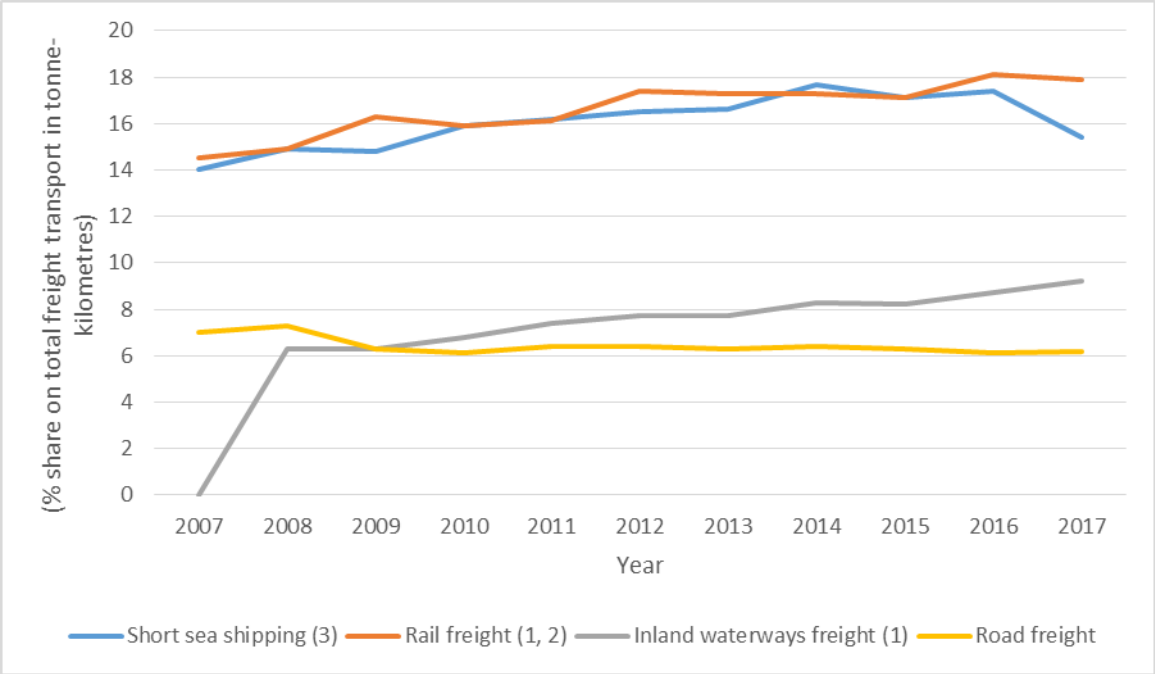
Volume of services of European intermodal transport operators affiliated to the UIRR between 2005 and 2018 (number of consignments and transport work)

Years	Total services		International traffic		Domestic traffic	
	number of shipments	million tkm	number of shipments	million tkm	number of shipments	million tkm
2005	2 457 579	36 957	1 551 380	28 871	906 199	8086
2006	2 717 751	45 394	1 794 434	35 558	923 317	9836
2007	2 937 542	46 069	1 916 808	36 273	1 020 734	9796
2008	2 994 625	45 971	1 897 358	35 722	1 097 267	10 249
2009	2 818 349	38 898	1 614 935	30 455	1 203 414	8443
2010	3 030 865	42 366	1 759 815	33 238	1 271 050	9128
2011	3 214 167	44 710	1 932 821	36 080	1 281 346	8630
2012	2 529 264	39 080	1 603 630	31 100	925 634	7970
2013	2 645 950	40 740	1 721 656	32 200	924 294	8540
2014	2 819 606	52 170	1 833 011	42 580	986 596	9590
2015	2 876 585	54 980	1 938 155	45 870	938 430	9100
2016	3 024 860	58 960	2 075 709	50 260	949 151	8700
2017	4 085 455	75 120	2 801 377	64 690	1 284 079	10 500
2018	4 288 344	75 710	2 954 366	65 110	1 339 265	10 670

(own study based on [35])

Statistics on intermodal transport in the EU and EFTA countries show the increasing importance of transporting goods in containers and other intermodal transport units, such as swap bodies, trailers, and semi-trailers (Fig. 5). It should be noted that the number of containers transported between 2007 and 2017 by short-sea shipping and rail remained roughly the same. In 2007, the unit indicator for rail transport was 14.5% and in the analyzed period, it fluctuated, with the largest share in 2016, and then it reached 18.1% (for the purposes of statistical research in rail transport, only freight and swap bodies containers are taken into account). For short-sea shipping, the unit index growth was relatively stable, reaching 14% in 2007 and 17.7% in 2014, before falling to 15.4% in 2017. In contrast, the statistics for road freight and inland waterway transport are much lower. Freight transport by inland waterways has grown relatively steadily, but the transport of containers by inland waterways is significant only in four Member States (Belgium, Germany, the Netherlands, and Switzerland). In road freight transport, the analyzed indicator had the highest value in 2007 and 2008, 7.0% and 7.3%, respectively, and since 2009, it has remained slightly above 6% [11].

The key objective of European transport policy is to achieve a 60% reduction in greenhouse gases generated by transport by 2050 compared to 1990 levels. One strategy to achieve this is to shift 30% of freight transported over distances of 300 kilometers or more from road transport to modes of transport with lower CO_2 emissions, including the relocation of containers and other cargo units from road to rail and inland waterway transport.



Based on gross weight, including weight of packaging, but without tare weight of containers.
(¹) Gross weight estimated. (²) Containers and swap bodies. (³) Ton-kilometers estimated

Fig. 5. Containers transport by mode of transport, 2007-2017 (% share on the total freight transport in ton-kilometers) (own study based on [11])

5. INTERMODAL TRANSPORT IN NORTH AMERICA

As already mentioned, most of the trade in the world takes place by sea. The strategic role of the countries of North America in the global maritime network is governed by the geographical location providing access to the maritime routes running through both the Pacific and the Atlantic. As everywhere in the world, container transport has also changed the dynamics of ports significantly on the American continent, promoting the emergence of specialized container ports.

Canadian ports, which are an important part of the country's economy, are managed by the Canadian port authorities. They were established under the Canada Marine Act (CMA) [14], passed by the Canadian Parliament, according to which the Canadian port authorities must be financially self-sufficient (they do not receive federal funds to cover operating costs or deficits). They finance their equity projects from their own income, and they can work with the private sector, apply for loans from a commercial lender, or for special federal grants related to infrastructure, environment, or security.

In 2017, the five largest Canadian ports (Vancouver, Montreal, Prince Rupert, Halifax, Saint John) had a total container capacity of 6.33 million TEU, which is an increase of 11.4% (0.65 million TEU) [14]. The largest container port in Canada, Vancouver, handled 3,252,223 TEU in 2017, which was an 11% increase compared to 2016 (2,929,585 TEU). This is partly due to an increase of 46% in empty containers transshipped in 2016. The total number of filled containers in 2017 (2,779,445 TEU) showed an increase of 7% compared to 2016 (2,606,628 TEU).

The most heavily loaded American ports are Los Angeles (in terms of containers handled in 2018, it was 17th in the world), Long Beach, and New York-New Jersey (respectively, 20th and 23rd among the largest container ports in the world). In addition, Savannah was ranked 35 among the 40 largest container ports in the world [36].

More than 300 ports along the U.S. coasts integrate coastal and inland waterway, rail, road, and air transportation. This intermodal transport network plays a key role in shaping the economic position of the United States in the world [34].

Intermodal rail transport around Canada and the mid-western and southern states of the USA is operated by the Canadian National Railway (CN) based in Montreal. The company operates on the only transcontinental network in North America, with more than 20,000 miles of track. CN offers integrated transport services not only in the field of intermodal transport but also rail, road transport, forwarding, warehousing, and distribution [18].

The Canadian rail freight sector specializes in heavy goods, bulk, and long-distance container traffic. In 2018, over 331.7 million tons of cargo was transported by rail, of which container cargo accounted for 14%. The structure of intermodal transport of units transported by rail in 2004-2018 is shown in Fig. 6 [14]. In 2018, over 3.5 million intermodal units were transported in total, including semi-trailers and containers.

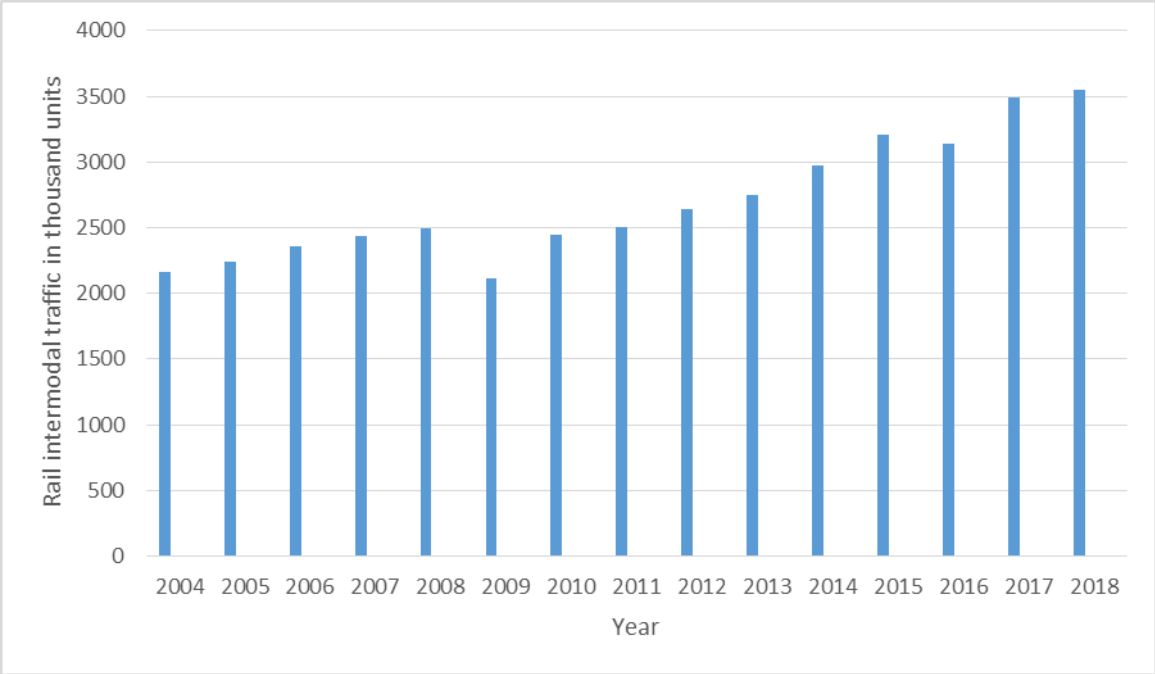


Fig. 6. Rail intermodal traffic in Canada from 2004 to 2018, in thousands (own study based on [32])

In the United States, intermodal transport is the fastest-growing segment of the rail market: the volume of intermodal transport has tripled in the last 25 years [12]. Intermodal transport services are perfect for long-distance rail cooperation, with door-to-door road transport dominating in the United States. In 2018, freight railways transported 14.5 million intermodal units [2]. On the other hand, in 2017, the share of intermodal transport in the structure of domestic cargo transport was 48.7%, and that in foreign cargo transport was 48.0% [2].

The North American rail system is the most-performing freight distribution system in the world, and intermodal transport generates the most revenue of major US railways (approximately 25%) of any freight group. Freight rail owners are therefore particularly involved in maintaining and developing this form of transport [2].

6. INTERMODAL TRANSPORT IN AUSTRALIA

Australian intermodal transport is most often associated with the export of goods to Asia, especially to China and Japan. It is the carriage of railway-sea containers, which is subject to a special transport organization (quarantine, relevant requirements for the labeling of goods), differentiated customs duties, goods and services tax (GST), and other taxes. Over the past two decades, container transhipments at major Australian ports (Brisbane, Sydney, Melbourne, Adelaide, and Fremantle) have

generally been characterized by consistent growth dynamics (Table 2). Their efficiency was increased by reducing transport costs and investment in port expansion.[1]

When analyzing the volume of transshipments at Australian container ports between 2004 and 2019, it should be noted a decline occurred in 2009, 2011, and 2020. While the reduction in transshipments in 2009 was triggered by a global economic crisis, in 2011, it was the result of a reduction in port capacity caused by the accumulation of empty containers in port terminals. In addition, the stagnation in imports caused by the Covid-19 outbreak first in China and then in Australia, and the associated economic blockades, as well as adverse weather conditions along the east coast, delayed the arrival of ships at ports in the region. It is worth noting that congestion in Australian container ports, which are unable to accommodate larger, more energy-efficient ships carrying more than 14,000 TEU (currently large ports in the world serve ships with a capacity of more than 20,000 TEU), reduces the efficiency of supply chains; thus, the priority is to create a network of deep-water ports, especially along the eastern coast, which would eliminate barriers resulting from port constraints, but also relating to road and rail infrastructure.

Australia's freight transport has doubled in the past 20 years, with an average growth rate of 3.5% per year, with the intermodal sector recording the fastest growth rate [33]. Intermodal terminals and port-rail connections are important to take full advantage of rail transport and to maximize the productivity of Australia's freight network.

The location of intermodal terminals results from the natural conditions of Australia, i.e. the need to organize interstate transport and deliver cargo to ports. Australia has a more developed interstate transportation system that is organized by the movement of goods from terminals to distribution centers and then final destinations. To ensure the efficient operation of the system, three axes of transport organization between terminals have been adopted:

- from north to south *(North-South* corridor),
- from east to west *(East-West* corridor), and
- crossing the continent *(Adelaide -Darwin* corridor).

Intermodal terminals are located near six major state cities: Brisbane, Sydney, Melbourne, Adelaide, Perth, and Darwin. In total, intermodal transport carriers can use 27 terminal locations, five of which are located directly at the ports [6], while two, located in New South Wales, function as short sea "dry harbors", serving as links to Sydney's Botany Harbor [19].

In the rail transport of containerized cargo, the commonly used intermodal transport system in Australia (also in the United States) is Double-Stack, i.e. stacking containers, involving their stacking (one on top of the other) on a special wagon-platform. The biggest advantage of this form of transport includes the possibility of transporting twice as many transport units as that in the case of traditional trains. Such a system enables significant reduction of transport and environmental costs [37]. The second most popular transport system used in Australia is *road trains.* In this system, heavy goods vehicles consist of several or even a dozen semi-trailers. This system applies primarily to the transport of goods over long distances between cities and production centers.

Australian road trains are the largest and heaviest in the world and used for the longest distances on all types of roads [13]. They are mainly used for the transport of loose materials (most often mine spoil), but also e.g. fuels. Road trains are banned from entering cities; hence, trains are divided into smaller vehicles before their borders. Their use strictly in intermodal transport is therefore possible when the transport unit includes a semi-trailer forming part of the road train [27].

The Australian government has allocated 100 billion dollars to the development of transport infrastructure throughout Australia for the next decade (from 2019). Most funds are allocated to the construction and modernization of roads. The plans also include the construction of a $5 billion rail link with Melbourne airport, of which $2.5 billion will come from the National Railway Program and $2.5 billion from the Infrastructure Investment Program. This funding is in addition to the $30 million donated by the Australian Government to develop an infrastructure expansion project. The preliminary

[1] https://www.infrastructure.gov.au/infrastructure/publications/files/Trends_to_2040.pdf.

business analysis of the project was completed in August 2018 and the detailed analysis is expected to be completed in 2020. Construction will start in late 2022.

Table 2

Container handling at Australia's largest container ports, at TEU

Year	Brisbane	Sydney	Melbourne	Adelaide	Fremantle	Total
2004-05	705 865	1 331 682	1 553 100	186 768	471 600	4 249 015
2005-06	734 618	1 393 824	1 579 534	195 977	454 980	4 358 933
2006-07	851 501	1 606 373	1 779 904	223 999	511 674	4 973 451
2007-08	921 250	1 786 362	1 934 527	288 308	580 643	5 511 090
2008-09	883 460	1 805 360	1 843 436	272 821	564 126	5 369 203
2009-10	906 975	1 949 393	1 946 561	282 056	557 650	5 642 635
2010-11	962 029	2 045 170	2 090 785	300 043	606 971	6 004 998
2011-12	1 016 410	2 040 543	2 236 727	330 518	658 458	6 282 656
2012-13	1 062 587	2 128 488	2 172 720	338 410	668 097	6 370 302
2013-14	1 106 715	2 233 103	2 221 420	385 312	691 938	6 638 488
2014-15	1 142 137	2 413 702	2 293 251	368 029	728 945	6 946 064
2015-16	1 148 202	2 340 099	2 340 985	390 423	714 329	6 934 038
2016-17	1 221 144	2 451 956	2 402 773	401 699	711 307	7 188 879
2017-18	1 346 888	2 637 068	2 699 598	413 452	767 327	7 864 333
2018-19	1 310 407	2 654 964	2 707 685	420 179	790 028	7 883 263
2019-20	1 273 827	2 507 736	2 575 681	423 933	786 967	7 568 143

(own study based on [5])

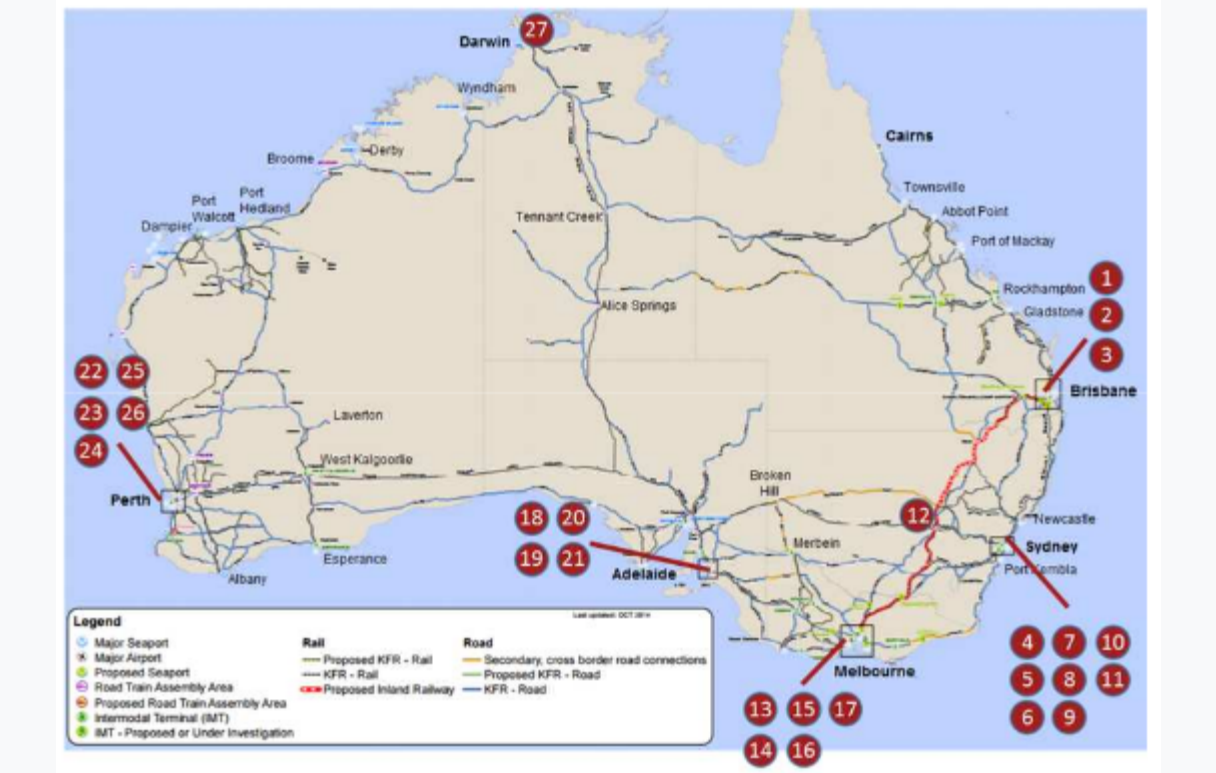


Fig. 7. Location of intermodal terminals in Australia (own study based on [6])

7. CONCLUSIONS

The conducted research shows that the issue of sustainable development is becoming increasingly more important in the transport policy of the world, especially in the context of the constant increase

in the level of greenhouse gas emissions. To minimize the negative impact of transport on the environment, individual countries around the world pursue a policy promoting the use of multimodal transport, with an emphasis on the mechanization and automation of its individual phases. At the same time, great importance is attached to ensuring smoothly functioning supply chains, and thus rational satisfaction of users' needs. In this respect, efficient logistics services play an important role. Governments as well as organizations and unions dealing with intermodal transport strive to create incentives for the development of logistics services, while paying attention to the implementation of modern technologies and concepts of logistics solutions in this sector of the economy, which will contribute toward the improvement of the efficiency and effectiveness of goods flows.

On a global scale, further development of intermodal transport will be significantly influenced by the actions of both governments and organizations promoting intermodal transport aimed at the following:

- standardization of transport infrastructure adapted to the needs of intermodal transport and the use of the latest technologies in its construction,
- standardization and unification of land transport for the purposes of intermodal transport,
- standardization of technical, organizational, operational, and economic solutions in multimodal CL terminals,
- standardization of used loading machines and devices,
- introducing and unifying the latest intermodal, organizational, economic, and financial systems in the processes of cargo movement in intermodal technology, and
- security and promotion of intermodal transport.

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