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Article

How the Depths of the Danish Straits Shape Gdańsk's Port and City Spatial Development

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Abstract
The depths of the Danish Straits limit the drafts of ships entering the Baltic Sea. The largest ships calling the Baltic in a laden condition are called Baltimax. The article presents how the dredging works carried out in the Danish Straits in the 1970s enabled the development of the Port of Gdańsk and consequently also influenced the city, being a residential base for employees of the new port and shipyards. The analysed case proves that, for port cities, overcoming a distant navigational bottleneck by dredging the existing passage or constructing a new channel might lead to a significant change in their development. The article also raises a question on the current development opportunities of the Port of Gdańsk, which is again increasingly limited by the depths of the Danish Straits, as large tankers and bulk carriers have already been entering Gdańsk not fully loaded for some time, and recently the largest container ships also reached the maximum permissible drafts.

Keywords
Danish Straits; development thresholds; port economic growth; port industry; port infrastructure; Port of Gdańsk

Issue
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1. Introduction

The aim of the article is to show the relationship between the limitations caused by the depth of the Danish Straits and the Kiel Canal and the spatial development of the Port of Gdańsk. The article shows how the dredging works carried out in the Danish Straits in the 1970s enabled the development of the Port of Gdańsk and consequently also influenced the city. The work also presents an inverse relationship, which is taking place today, where the increase in the size of container ships calls into question the possibility of servicing ocean-going ships in the Baltic ports, limited by the depths of the Danish Straits.

The Port of Gdańsk is located in Poland on the southern coast of the Baltic Sea. The Port and the City of Gdańsk have been developing by interacting with each other for about 1,000 years already (Breś & Krośnicka, 2021). The spatial structure of the port currently consists of four areas (Figure 1b): the Old Port in the historic centre of Gdańsk, which is no longer in use; the Inner Port, stretching along the Dead Vistula River, capable of receiving conventional ships with a draft of up to 10.6 m (Gdańsk Harbour Master's Office, 2023); the still developing deep-water North Port, capable of handling ships with drafts up to 15.0 m; and the Central Port, which is in the pre-design phase. The handling capacity of the Inner Port is currently 13.7 million tonnes of cargo annually, while the North Port is 65.5 million tonnes annually (Port Gdańsk, 2023).

For the purpose of analysing the changes in planning decisions and their effects on the shape of the Port

of Gdańsk, the authors traced the archival navigational charts of the Hydrographic Office of the Navy from the years 1967, 1974, 1996, and 2018 with subsequent corrections. They also studied archival materials from the times of the creation of the North Port and its development, which at that time were not available for public use (Andruszkiewicz, 1976; Central Board of Polish Sea Ports, 1974; Society of Polish Town Planners, 1977). The authors also reviewed archival professional journals from the researched period (Gruszkowski & Holc, 1963; Kochanowski, 1963). As a next step, the authors analysed selected plans for the development of the City of Gdańsk: historical (Stankiewicz & Szermer, 1959) and contemporary (Gdańsk Development Office, 2023; Gdynia Maritime Office, 2023) and statistical data from the years 1945–2020 (Białecki, 2011; Gaworecki, 1976; Główny Urząd Statystyczny, 1969, 1970, 1971, 1972, 1973, 1974, 1975, 1978, 1983a, 1996, 2000, 2004, 2007, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022) in terms of the impact the decision to build the North Port had on the city structure. The contemporary bathymetric situation in the Danish Straits and the Kiel Canal has been described mainly on the basis of navigational charts and sailing directions (Danish Geodata Agency, 2023; DanPilot, 2023; National Geospatial-Intelligence Agency, 2022).

2. Sea Access to the Port of Gdańsk: The Danish Straits and the Kiel Canal

The Baltic Sea is almost a closed water area, which is naturally connected to the Atlantic Ocean only by the Danish Straits. Thus, each ship entering Baltic ports until 1895, when the Kiel Canal was built, had to pass through one of the Danish Straits, being currently a part of Danish territorial waters, shared partially with Germany (Fehrman Belt) and Sweden (Øresund). There are two basic water routes via the Danish Straits (The Danish Maritime Authority, 2022, p. 37). Smaller ships, with a draught up to 7.7 m, might pass through the shorter route via Øresund—The distance between Skagen and Bornholm along this route is 252 nautical miles (DanPilot, 2023). The route for the biggest ships entering the Baltic Sea, with a draught up to 15.0 m, leads through the Great Belt (Storebælt) and Fehmarn Belt (Figure 1a). The total length of this passage from Skagen to Bornholm Island (so-called Route T) is 377 nautical miles. Currently, the drafts of vessels entering the Baltic Sea are limited by the shallowest sections of the T Route, leading through the Great Belt, which is about 17.0 m deep (The Danish Maritime Authority, 2022, p. 37). Moreover, the depth of the Danish Straits sometimes decreases significantly due to sand accumulation or a temporary low sea level caused by the negative stow (Nissen, 1991). Therefore, the recommended under-keel clearance is around 2.0 m (PIANC, 2014).

The water connections via the Danish Straits were and still are extremely strategic for the functioning of all the Baltic ports. Since 1429, Denmark has controlled the movement of vessels and cargo, when the King of Denmark—Eric of Pomerania—established the Sound Tolls (Carneiro & Nilsson, 2013). The dues played an important political role in limiting the development of particular port cities while allowing the others to grow (Froese, 2007). The semi-closed character of the Baltic Sea and lack of the right of free passage made the Baltic Sea *mare clausum* (International Court of Justice, 1991, pp. 16–18; Theutenberg, 1984). After the rejection of the idea of *dominium maris Baltici* and the abolition of the Sound Tolls, the straits became open to international commercial shipping in 1857, pursuant to the provisions of the Copenhagen Convention (Elferink, 2000, pp. 555–566; Law of the Sea Institute, 1983, p. 600).

In the years 1887–1895, the German Empire built an artificial channel across the Jutland Peninsula in order to shorten the way and avoid passing through

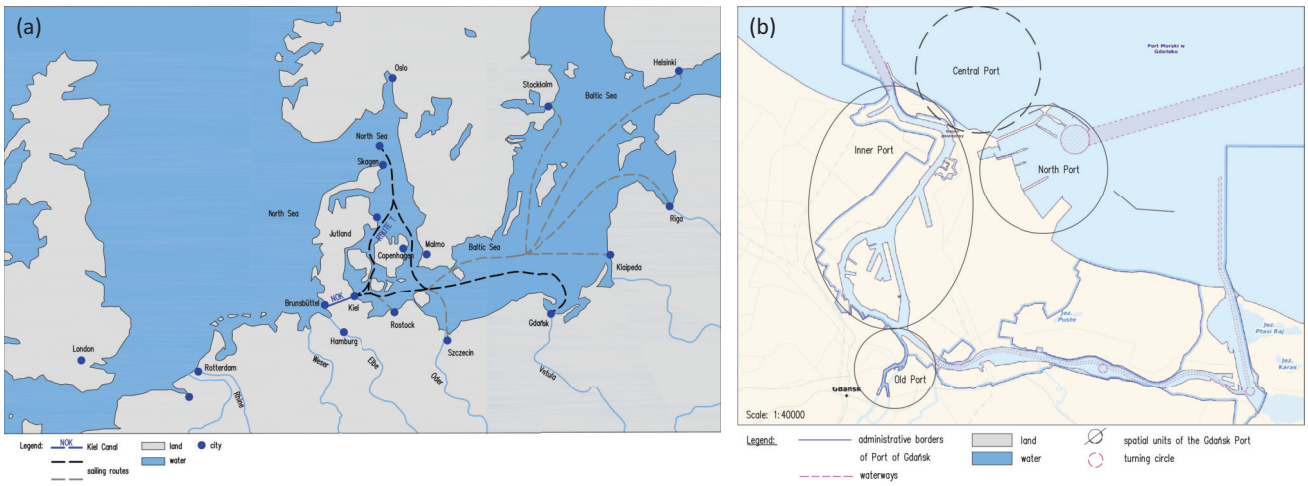

Figure 1. Location and structure of the Port of Gdańsk: (a) Access to the Port of Gdańsk by sea routes and (b) spatial structure of today's Port of Gdańsk. Source: Authors' work based on Spatial Information System of the Polish Maritime Administration (2023); Wasserstraßen- und Schifffahrtsverwaltung des Bundes (2023).

Danish waters in case of war. The Kiel Canal (in German, Nord-Ostsee Kanal) opened the new connection between the North Sea and the Baltic Sea (in German, Ostsee) and shortened the route by about 250 nautical miles (about 463 km) in comparison to the route via the Danish Straits (Wasserstraßen- und Schifffahrtsverwaltung des Bundes, 2023). In the years 1907–1914, the Kiel Canal was for the first time widened and deepened to 11.0 m. A further expansion of the canal began in 1965 and was carried out step-by-step until 2002. In 2010, a building permit was issued for the construction of a fifth canal chamber, enabling the deepening of it to 14.0 m. The construction works are expected to be finished by the year 2026 (Wasserstraßen- und Schifffahrtsverwaltung des Bundes, 2023). Currently, the maximum length (L) of ships passing through the Kiel Canal is 235.0 m, the maximum beam (B) is 32.5 m, and the draught (T) is up to 7.0 m. However, ships with a length of up to 160.0 m can have a draught of up to 9.5 m. The clearance under the bridges crossing the canal is 42.0 m (UCA, 2023).

Although the time of passage from the North Sea to the Baltic was shortened by the construction of the Kiel Canal, the Danish Straits were and still are deeper, even after the current modernisation works of the Kiel Canal. Therefore, from about 1960, when the drafts of ships increased significantly above 7.0 m, more and more of them started to use the Danish Straits again. This has slowly led to decreasing the economic importance of the Kiel Canal. Soon after, in early 1970, along with the further growth of ships' parameters, the Great Belt, which accepts maximum drafts of 13.0 m, became a bottleneck for many vessels entering the Baltic (International Court of Justice, 1991, p. 14).

The most problematic areas of the passage via the Great Belt were the vicinity of Gedser (The Danish Maritime Authority, 2014, p. 4) and today's Storebælt bridge (Braestrup, 2016). In the year 1975, as a consequence of a long international discussion, the shallows in between Gedser and the Darss Peninsula were dredged down to 17.0 m, and the Danish government opened an international waterway under the Storebælt: Route T (International Court of Justice, 1991, p. 12). At that time, this triggered entirely new development opportunities for the Baltic countries and ports, including Gdańsk.

3. Designing the North Port in Gdańsk

Until the 1960s, the core of the Polish merchant fleet consisted of ships with a carrying capacity of up to 10,000 deadweight tonnage (DWT; Andruszkiewicz, 1976, p. 5). Also, ships entering the Inner Port of Gdańsk were relatively small, having on average only 3,171 DWT in 1960 and 3,254 DWT in 1965 (Główny Urząd Satystyczny, 1969, p. 80). The sizes of the two largest ships that were called at Gdańsk in 1965 were in the range of 20,000–30,000 DWT (Główny Urząd Satystyczny, 1969, p. 85). During this period, the first ships of the Aframax (1954) and Suezmax (1956) classes appeared in the world, followed by the very large crude carriers (VLCC) in 1966 and ultra large crude carriers (ULCC) in 1968. To survive, the Port of Gdańsk had to start adapting to this technological change, as ships over 30,000 DWT started to call in the year 1966 (three ships in 1966, nine ships in 1967, and 40 ships in 1968). Still, the development thresholds were the depths of the Vistula River, Kiel Canal, and the Danish Straits.

Initially, around 1960, the entrance to the Port of Gdańsk, as well as a fragment of the port fairway in the mouth section of the Dead Vistula, were widened and deepened to 11.5 m (Andruszkiewicz, 1976, p. 4). Later, however, the expansion of the port with new water basins began to be considered. The original designs, resulting from the need to increase the port's capacity, were based on engineering ideas originating from the interwar period and the situation where numerous mooring berths were needed for vessels with a carrying capacity of about 10,000 ÷ 30,000 DWT, which were typical at that time. These solutions referred to the concept of a basin-pier layout and the river character of the Port of Gdańsk. These designs assumed digging a new canal across the bend of the Dead Vistula and using the existing narrow entrance to the port (Figure 2a) or building a channel connecting the Dead Vistula directly with the sea (Figure 2b). The berths along the new canal would increase the transhipment potential of the Port of Gdańsk to about 20–30 million tonnes per year (Andruszkiewicz, 1976, p. 9).

The window of further development opportunities for the Port of Gdańsk opened with the process of preparations for the dredging of the Danish Straits. At that time, Poland had started to consider building a deep-water port. The chosen location was Gdańsk, as having both a convenient bathymetric situation and demographic potential. In 1973, Poland ordered a fleet of modern Baltimax tankers, the parameters of which were defined by Route T opened in 1975. They were three tankers with a capacity of over 145,000 t (L = 293.0 m, B = 48.1 m, T = 15.3 m) and three tankers with a capacity of 137,000 t (L = 284.0 m, B = 43.4 m, T = 15.2 m). In addition, for the redistribution of fuels to the shallower Baltic ports and the delivery of cargo to the Inner Port in Gdańsk, three much smaller feeder tankers (L = 170.7 m, B = 25.9 m, T = 11.1 m) with a deadweight of 31,000 DWT were ordered (InteriaHistoria, 2014). These ships entered service at the beginning of 1975.

The preparatory works related to building the deep-water port in Gdańsk were formalised in 1968 (Szwankowska, 2018, p. 58). The designs of the Gdańsk port development created after 1968 were mostly a radical innovation compared to the previous proposals. Taking into account accessibility for the Baltimax ships, the location of a new port was proposed directly on the open seashore (Figures 2c and 2d). The design selected for implementation (Figure 2d) best responded to the growing turnover of the port (Table 1) and the

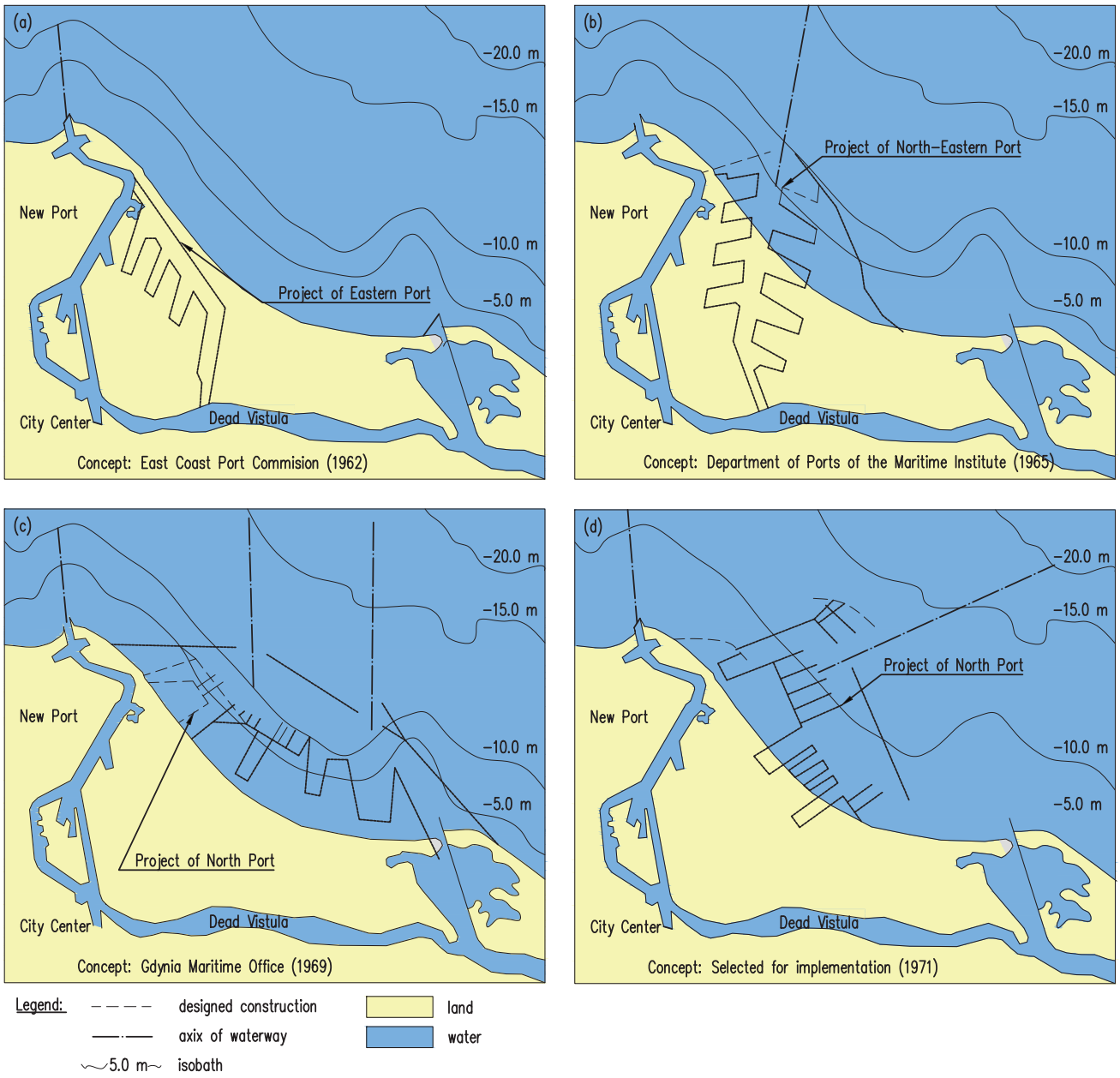

Figure 2. Port of Gdańsk development concepts: (a) Concept of Eastern Coast Port Commission (1962), (b) concept of Gdynia Maritime Office (1965), (c) concept of Department of Ports of the Maritime Institute (1969), and (d) concept selected for implementation (1971). Source: Authors' work based on Białecki (2011).

local hydrological conditions and was characterised by a more favourable soil-water balance (it required the displacement of smaller earth masses both during dredging works and landfilling of the water area). The design of the North Port also covered the access from the waterside. The planned port demanded a new approaching channel via the Gdańsk Gulf and new vast anchorage areas, both with depths responding to the needs of the Baltimax ships.

4. Building the North Port in Gdańsk

The construction of the North Port was planned to be divided into three stages. The first stage of the development of the North Port included the construction of coal, crude oil, and ore terminals (Figure 3). For this reason, this complex of terminals (then referred to as the transhipment depots) was initially called the Bulk Transhipment Area (in Polish, Rejon Przeładunków Towarów Masowych). Its construction began in 1970 (Andruszkiewicz, 1976, p. 17). The second stage of the construction of the North Port assumed the construction of a repair and a production shipyard to the east of the Bulk Transhipment Area. The next stage assumed the use of the land reserve located to the east of both shipyards for the development of the port's future cargo handling functions. Initially, the project assumed that it would be an area for the transhipment of crude oil products

Table 1. Turnover of the Port of Gdańsk divided into the turnover of the Inner Port and the Northern Port, and the gross handling time in the years 1945–2020.

Year	Total Gdańsk Port turnover (1,000 tons/year)	Gdańsk Inner Port turnover (1,000 tons/year)	Gdańsk North Port turnover (1,000 tons/year)	Gross handling time of 1,000 tons of cargo in Polish ports (hours/1,000 tons of cargo)		
				Average	Coal handling	General cargo handling
1945	354	354	n.a.	n.d.	n.d.	n.d.
1950	4,819	4,819	n.a.	n.d.	n.d.	n.d.
1955	5,244	5,244	n.a.	19.84*	13.5*	33*
1960	5,914	5,914	n.a.	22.5* (20.7)	15.5* (13.7)	42.1* (43.3)
1965	6,318	6,318	n.a.	18.1	10.5	35.4
1970	10,199.5	10,199.5	n.a.	16.8	8.1	41.2
1971	10,047	10,047	n.a.	15.5	6.9	39.8
1972	11,404	11,404	n.a.	14.6	6	36.8
1973	12,778	12,778	n.a.	14.8	5.6	41.4
1974	**15,892.1**	**14,018.9**	**1,873.2**	13.6	5.1	47.6
1975	18,558.1	11,255.4	7,302.7	**12.2**	**3.6**	**44.4**
1976	22,940.3	11,947.7	10,965.6	12.2	3.3	46.2
1977	25,153.4	**12,204.9**	**12,948.5**	11.3	3.6	42.5
1978	28,247.7	13,033.3	15,214.4	11	3.1	41.3
1979	27,008	12,305.8	14,702.2	11	3.4	46.1
1980	23,005.6	11,261	11,744.6	10.6	3.3	44.3
1981	12,375.4	8,872.3	3,503.1	12	2.3	44
1982	13,178.8	7,651	5,527.8	11.1	2.7	42.7
1983	17,972.8	7,737.8	10,235	6.6*	1.8*	57.8*
1984	21,333.4	8,926	12,407.4	n.d.	n.d.	n.d.
1985	17,830.1	8,349.1	9,481	n.d.	n.d.	n.d.
1990	18,283.6	7,760.7	10,522.9	n.d.	3.97*	34.2*
1995	18,261.8	**6,048.1**	**12,213.7**	n.d.	n.d.	n.d.
2000	16,080.6	5,210.1	10,870.5	n.d.	n.d.	n.d.
2005	23,341.4	5,875.1	17,484.3	n.d.	n.d.	n.d.
2010	27,182.1	6,513.7	20,668.4	n.d.	n.d.	n.d.
2015	31,684.9	n.d.	n.d.	n.d.	n.d.	n.d.
2020	40,574.7	n.d.	n.d.	n.d.	n.d.	n.d.

Notes: In the years marked with an asterisk (*), the statistical yearbooks specify data for the Gdańsk Port Authority only together with the other Polish Ports Authority; n.a.—not applicable; n.d.—no data available. Source: Authors' work based on Główny Urząd Statystyczny (1969, 1970, 1971, 1972, 1973, 1974, 1975, 1978, 1983a, 1996, 2000, 2004, 2007, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022).

(Figure 3). The last two stages of the construction of the North Port were not implemented in the form described by the project.

As the first investment while building the Bulk Transhipment Area (the first stage of the construction of the North Port), the coal handling and storage base was opened in 1974. Its storage yards had a capacity of 600,000 t and a daily efficiency of 50,000 t. The depot was equipped with modern railway infrastructure, including a wagon tippler (Andruszkiewicz, 1976, p. 19; Podgórski, 1997, p. 82). It was equipped with one mooring berth with a depth of 16.5 m (Andruszkiewicz, 1976, p. 26). Equipping the pier with highly efficient loading devices and belt conveyors with a capacity of 1,800 t/h meant that the time of handling and transport of coal in the terminal was significantly shortened compared to the service time in the inner port, where the stations were operated with grapple cranes with a capacity of 700 t/h (Table 1).

In 1975, a crude oil terminal was launched. It was connected by pipelines with the newly built refinery in Gdańsk (located south of the Dead Vistula, east of the city centre of Gdańsk), the refinery oil base (located on Stogi Island), and the "Friendship" Pipeline, running through Russia, Belarus, Poland, and Eastern Germany (Andruszkiewicz, 1976, pp. 19–20; Piskozub, 1986, p. 190).

Another reloading pier was dedicated to serving the ore terminal. It was 600 m long and 16.5 m deep at the mooring. The ore terminal was designed on an area of 40 ha, of which about 14 ha was newly refilled land (Piskozub, 1986, p. 227) and planned for serving five

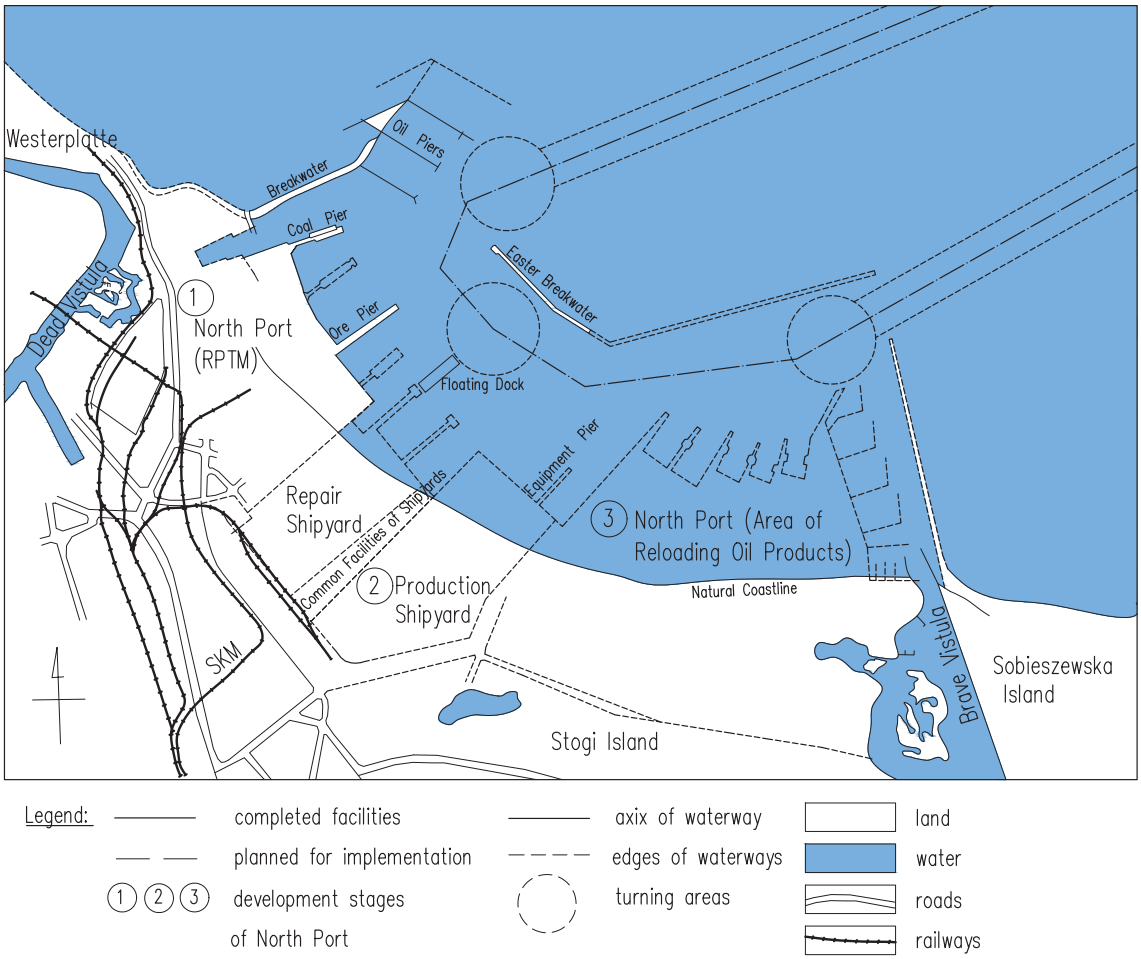

Figure 3. Functional structure of the North Port: The agreed division of land. Notes: The existing parts are marked with a solid line; RPTM indicates the Bulk Transhipment Area; SKM stands for fast commuters railway line (in Polish, Szybka Kolej Miejska). Source: Authors' work based on Society of Polish Town Planners (1977, p. 31).

million tonnes per year (Białecki, 2011, p. 171). The terminal was served its first ship in 1979 (Białecki, 2011, p. 171), but, in 1981, as a result of the declaration of martial law in Poland, the construction of the pier was stopped with the project implementation at the level of about 50%.

The concept of the North Port assumed, in a second stage, the construction of two shipyards: one for production and one for repairs (Białecki, 1977, p. 11) and industry related to the work of these shipyards (Figure 3). The repair shipyard, requiring a long mooring line, was to cover an area of 100 ha, and the production shipyard was 150 ha (Szymański, 1977, p. 27). Both shipyards were to produce and repair Baltimax and Panamax vessels (Szymański, 1977, p. 31). Due to the fuel crises of 1973 and 1979–1982 and the period of political transformation of the Polish state in 1989–1991, the shipyards were not built. Shipbuilding activity is still concentrated in Gdańsk in the Inner Port on the Dead Vistula.

Changing the structure of the Port of Gdańsk from having a fragmented spatial mosaic and served by conventional methods in the Inner Port to covering large areas in the deep-water North Port required a change in the way of thinking about transport links. The design of the North Port assumed connecting Stogi Island from the south with railway and road bridges. However, at that time, a tunnel connection between Stogi Island and the western bank of the Dead Vistula was already planned (Society of Polish Town Planners, 1977, pp. 11, 28). A new railway freight station, Gdańsk North Port, was also built in the central part of Stogi Island for cargo handling of the port. An SKM commuter railway line was also planned to transport employees from other districts of the city to the port (Figure 3). Communication of the North Port project was developed simultaneously with the Development Plan of the Stogi Island and was correlated with the Plan of the Communication System of the Gdańsk Agglomeration and the Development Plan of the Gdańsk Urban Area (Society of Polish Town Planners, 1977, p. 28).

Although the vision of development of the North Port was not fully realised then, after its launch, Gdańsk joined the small group of about 10 European ports that could accommodate ships with a draft of up to 15.0 m (Society of Polish Town Planners, 1977, p. 18). According to the concept, after only the first stage of development, the North Port was planned to enable transshipments

at the level of 70–100 million tonnes per year (Central Board of Polish Sea Ports, 1974, p. 6) and even up to 200 million tonnes per year after further stages of development (Andruszkiewicz, 1976, p. 9). Hence, the handling capacity of the first phase of the North Port was already at least three times more than the capacity provided by the concepts of the Eastern Port from 1962 and 1965 (Figure 2). Moreover, most of the assumptions of the first phase of the plan (except building the commuter railway line) were fulfilled up to the year 2012.

Gradually, the Inner Port, located on the Dead Vistula, lost its importance, and the North Port became increasingly significant in terms of cargo handling. In 1974, when the first coal base was launched, the North Port handled 1,873,000 t of cargo, while the Inner Port handled 14,019,000 t of cargo. As quickly as 1977, the North Port slightly exceeded the turnover of the Inner Port (Table 1).

5. Influence of the Construction of the North Port in Gdańsk City in the Years 1974–1989

Both the Port and the City of Gdańsk were completely destroyed during the Second World War (Tölle, 2008). Re-activation of the port and the process of rebuilding the basic housing substance lasted until 1955 and took place simultaneously with the re-population of the city. Created just after the Second World War, in 1947, the Development Plan for Gdańsk (GD Plan) provided for the nodal-strip development of the Tri-City agglomeration, where the hubs were the downtowns of Gdańsk, Gdynia, and Sopot (Stankiewicz & Szermer, 1959, p. 331). The crucial centres of development of this urban layout were the seaports of Gdańsk and Gdynia (Figure 4). The development of the Port of Gdańsk was at that time planned as the construction of a new port canal, i.e., the so-called

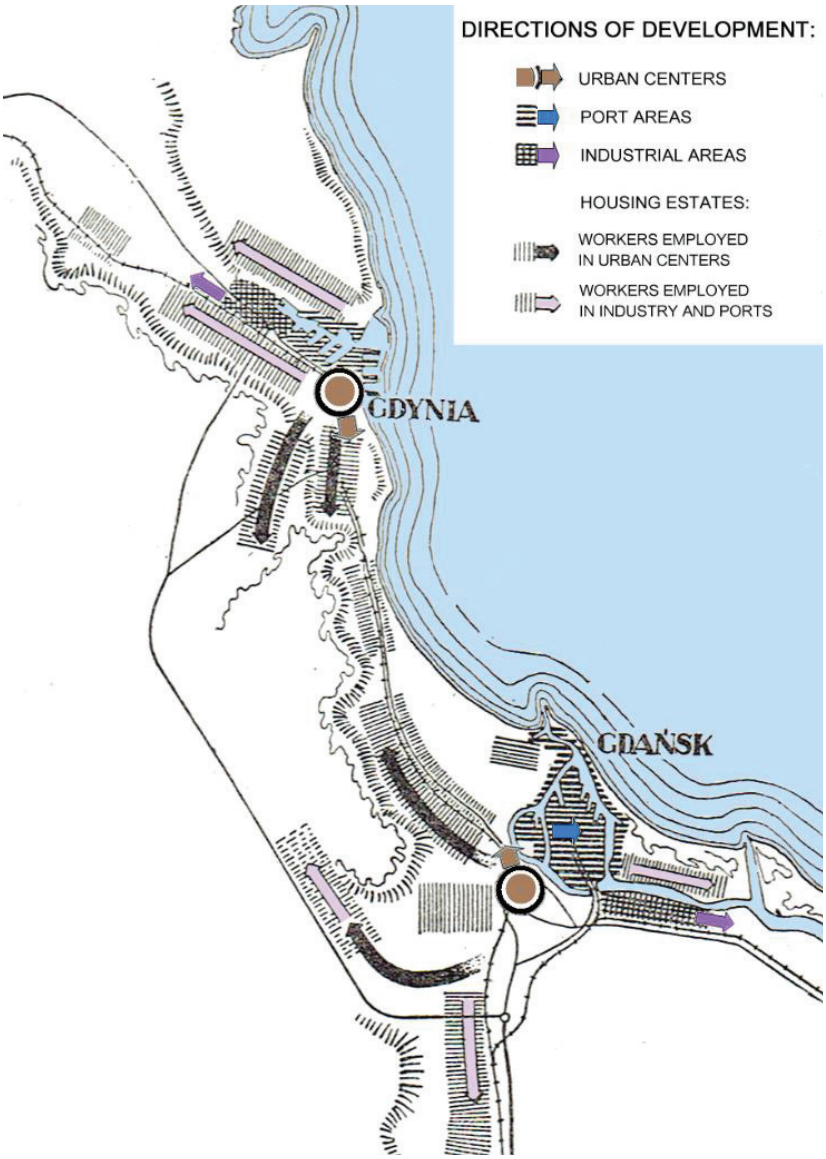

Figure 4. GD Plan for the development of the Tri-City agglomeration of Gdańsk, Gdynia, and Sopot from the year 1947 with new housing estates introduced to the plan after its revision in 1962. Source: Authors' work based on Stankiewicz and Szermer (1959, p. 331).

"Eastern Port" (Figure 2a). In accordance with the modernist principle of separation of functions, the authors of the plan assumed the development of an industrial and port district along the Dead Vistula (industrial district "East"). In parallel, they proposed bands of residential development dedicated to workers employed both in industry and the Port of Gdańsk (Figure 4).

In the years 1956–1981, of a centrally planned economy, due to intensive industrialisation and one of the highest birth rates in Europe taking place, Poland experienced massive urbanisation. The population growth in Poland in this period was so rapid that the cities experienced constant shortages of housing and urban infrastructure (Parysek, 2006). Therefore, the GD Plan was revised in 1962 (Szermer, 1977, p. 63) in order to enlarge the housing capacity of the quickly growing city (Table 2). The plan introduced new housing estates along the seashore, easily accessible in terms of daily commuting due to the vicinity of railway infrastructure (Figure 4). As stated by Kochanowski (1963, p. 455) and Gruszkowski and Holc (1963, p. 453), the needs of the maritime economy were one of the two main causes (apart from war damage) of the housing crisis in the 1960s in the urban area of Gdańsk. To support the housing needs of employees, the national companies established their own housing funds and sometimes were even opening their own housing associations. In Gdańsk, based on a maritime economy, such large companies as shipyards and the port authority played a significant role in developing new housing districts (Table 2). Often, the construction of housing estates in Gdańsk was carried out with funds obtained through loan agreements concluded with enterprises holding housing funds, e.g., with the Gdańsk Shipyard (Kochanowski, 1963, p. 455) or Port of Gdańsk Authority.

Intensive development of the maritime economy based on the development of shipyards existing in the Inner Port, refinery and the North Port (Figure 5), as well as industry based on their activities and banded in technological chains (Aftanas et al., 1974), required an appropriate population potential and intellectual capital. In parallel to employing local residents in the newly

Table 2. Number of inhabitants of Gdańsk city in the years 1945–2020, employment in the Gdańsk Port Authority, and the corporate housing fund of the Port of Gdańsk Authority in the years 1960–1975.

Year	Number of inhabitants in Gdańsk (thousands of persons)	Employment in the Gdańsk Port Authority (persons)	Corporate housing fund of the Port of Gdańsk Authority—Expenditure on financing cooperative and company housing construction (thousands of PLN)
1945	139.09	*	n.a.
1950	172.7	*	n.a.
1955	242.9	4,431	n.a.
1960	286.9	4,554	6,002
1965	321.3	5,776	1,356
1966			1,497
1967			1,561
1968			2,424
1969			2,500
1970	365.6	5,946	3,581
1971			773
1972			**19,133**
1973			0
1974			109
1975	414.2	n.d.	154
1980	456.7	6,947	*
1985	468.6	6,338	*
1990	**465.1**	5,050	n.a.
1995	463	*	n.a.
2000	456.6	*	n.a.
2005	458.05	*	n.a.
2010	460.5	*	n.a.
2015	461.79	*	n.a.
2020	471.52	*	n.a.

Notes: In the years marked with an asterisk (*), the statistical yearbooks specify data for the Gdańsk Port Authority only together with the other Polish Ports Authority; n.a.—not applicable; n.d.—no data available. Source: Authors' work based on Główny Urząd Statystyczny (1969, 1970, 1971, 1972, 1973, 1974, 1975, 1978, 1983b, 1996, 2000, 2004, 2007, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022).

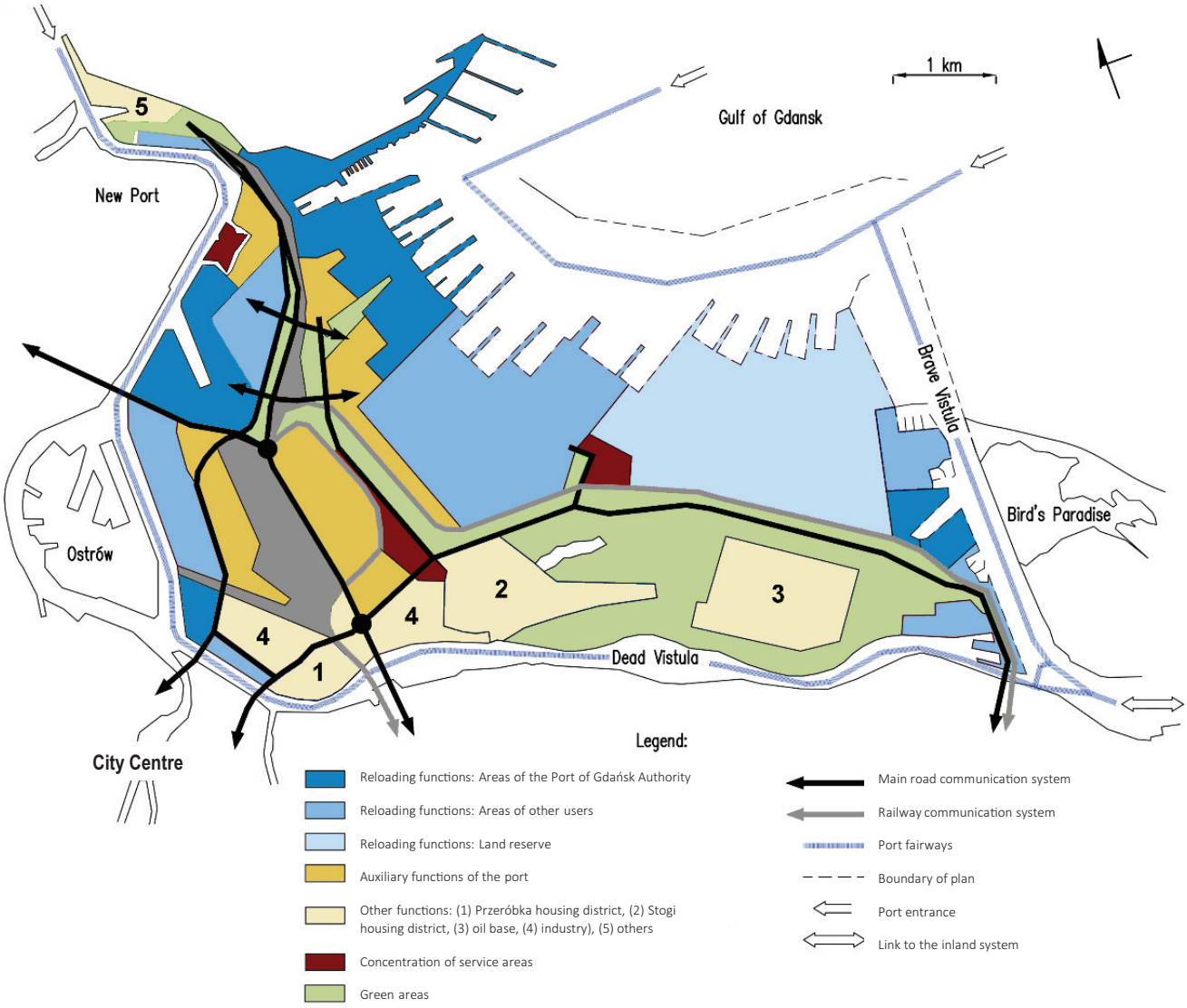

Figure 5. Planned functional and spatial structure of the North Port and the port-industrial district developed by the Spatial Planning Bureau of the Gdynia Maritime Office and approved by the president of Gdańsk in 1978. Source: Authors' work based on Białecki (2011, p. 135).

planned maritime cluster, workers and specialists representing various industries from all over the country were brought to Gdańsk. In turn, along with the newly employed workers, their families came to the city and settled permanently, occupying indirect and induced jobs. According to Gaworecki (1976, p. 72), the number of people employed in the maritime economy in the years 1965–1973 in the urban area of Gdańsk accounted for more than 8% of the total population, with approximately 50% of the population being professionally inactive at that time. It was planned to employ about 25,000 people to service the North Port and the East Industrial District (Tubielewicz, 1977, p. 46). The increase in the housing needs of future employees of the Port of Gdańsk related to the construction of the Northern Port was planned to be satisfied by a significant increase in expenditure on the construction of new apartments in 1972 (Table 2). The development of maritime industries and transportation, including planning and construction of the North Port was therefore without a doubt one of the triggers for the rise of the Gdańsk population, which increased from 286,940 inhabitants in 1960 to 365,600 in 1970 and 456,707 in 1980 (Table 2).

Simultaneously with the plan of the port district, the Development Plan of Gdańsk Urban Area was released (Gruszkowski, 1977, p. 55). The plan continued the idea of the GD Plan from the year 1962 by building Gdańsk's new residential districts based on a fast commuter railway network called SKM (Gruszkowski, 1977, p. 58; Tarkowski et al., 2022). Soon, on the strip of coastal lowlands north of the centre of Gdańsk, large modernist housing estates began to gradually emerge (Młyniec in 1965, Małe Przymorze in 1965, Wielkie Przymorze in 1970, Zaspa in 1973–1975, and Żabianka in 1972–1975; Gruszkowski & Holc, 1963; Kochanowski, 1963; Rembarz, 2009). These mono-functional housing

districts accommodated among other inhabitants the new employees of Gdańsk's industry with their families, including those servicing the North Port and the East Industrial District.

6. Developing the North Port After 1989

After the declaration of martial law in Poland in 1981, the process of industrial and housing development proceeded very irregularly until 1989. In the period 1981–1983, the Port of Gdańsk experienced a significant decrease in transshipments due to an embargo of Poland (Table 1). The fall of the socialist system in 1989 and the introduction of a free-market economy necessitated the restructuring of the country's economy. In the 1990s, the process of industrialisation stopped and, as a consequence, migration to the urban centres declined (Parysek, 2006). In Gdańsk, the biggest shipyard went bankrupt, causing sudden and large unemployment in the city and region. Big national companies (including those serving the maritime economy of the Port of Gdańsk) went through the process of privatisation by creating many smaller subsidiary companies. In many cases, this process led to companies closing down (Gomułka, 2016; Kolodko, 2009, 2011) or to the reorientation of companies' profiles towards small and medium private enterprises, as well as a large wave of economic emigration from Poland to Western Europe. The number of inhabitants of Gdańsk decreased (Table 2). The Act on Privatization of Port Enterprises of 1990 made it possible to commercialise the Port of Gdańsk (Szwankowska, 2018, p. 63) and separate the sphere of technical infrastructure from the sphere of operations.

After these deep economic and technological transformations took place in the Port of Gdańsk in the years 1994–1996, the Port of Gdańsk Authority SA in consultation with the Gdańsk Development Office of the City of Gdańsk initiated elaboration of the Masterplan of Gdańsk Port and Industrial Areas (Szwankowska, 2016). The masterplan reduced the area planned for the transhipment and storage function in relation to the original plan of the North Port—The maximum eastern border of the investment was now placed almost in the middle of the shoreline of Stogi Island (Figure 6). This shift was the result of a social discussion and took into account the recreational needs of the inhabitants of the Stogi housing estate and the protection of the city beach (Szwankowska, 2018, p. 65). The masterplan also

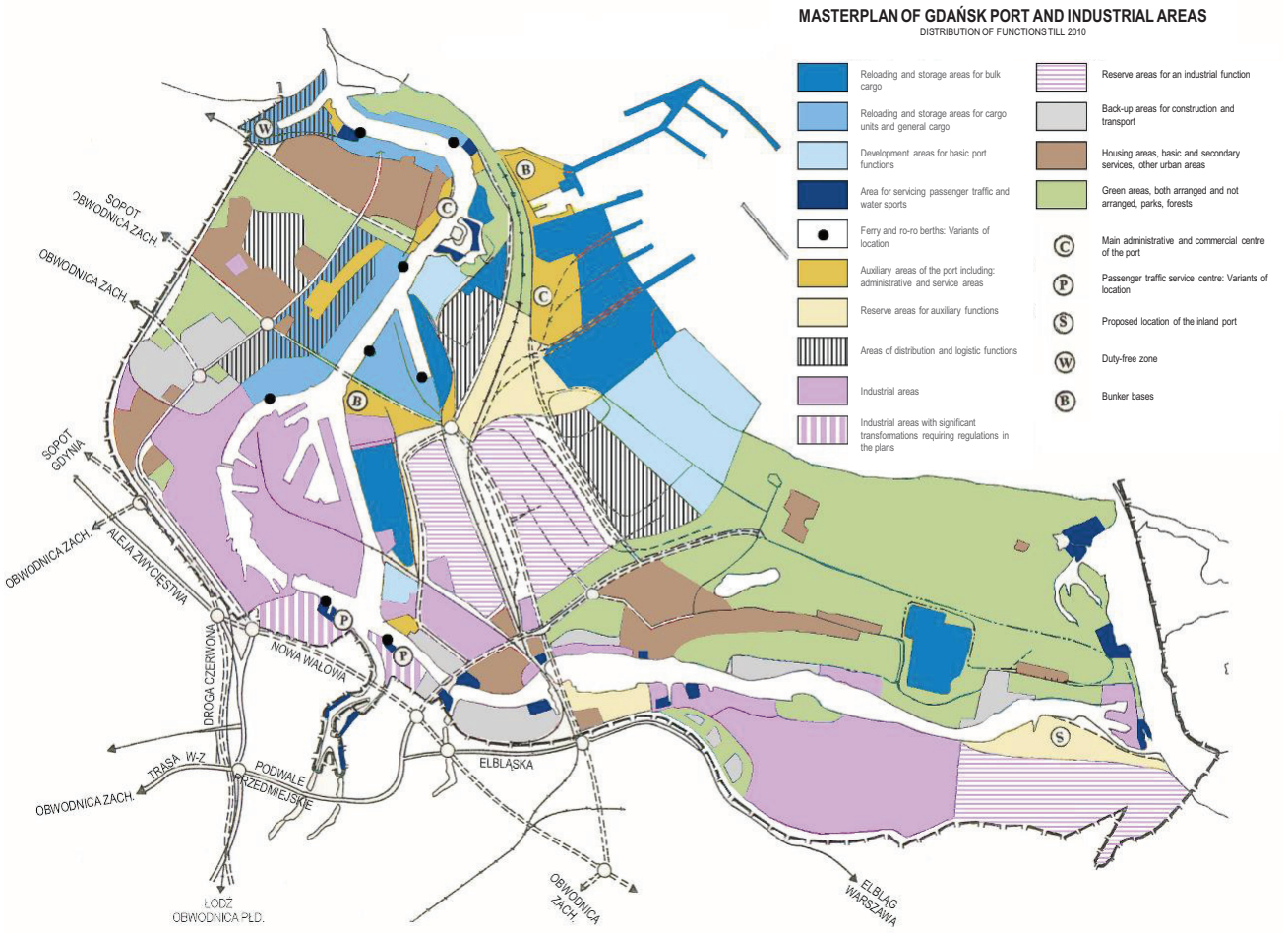

Figure 6. Masterplan of Gdańsk port and industrial areas (1996): Spatial distribution of functions until 2010. Source: Authors' work based on Szwankowska (2018, p. 66).

indicated the approximate locations of the future logistics functions and the container terminal (Kondratowicz, 2003; Szwankowska, 2018, p. 64).

In this period, the investments ending the first phase of the North Port development plan from 1968 were finally implemented. At the end of 1992, the next berth in the crude oil terminal in the North Port was commissioned, and in the following years, two additional ones (Podgórski, 1997, p. 87). In 1998, an LPG gas terminal was launched in the North Port between the coal and ore piers, serving gas tankers with a length of 280 m, a draft of 9.5 m, and a capacity of up to 20,000 DWT (Szwankowska, 2018, p. 64). Around 1995, the approach fairway to the North Port was widened and equipped with new communication and signalling systems (Szwankowska, 2018, p. 64). In 2001, the North Port was connected to the south across the Dead Vistula by a new road bridge and a modernised railway bridge. Therefore, also the transportation system planned in 1978 was almost finished (Szwankowska, 2018, p. 65).

In 2004, Poland joined the EU and, with the support of national and EU funds, the country rebuilt the basic infrastructure (Havel, 2022; Rachwał, 2011) enabling the activation and further development of enterprises. In 2002, a local spatial development plan was adopted by the City of Gdańsk for the area of the North Port. The plan took into account the possibility of building a deep-water container terminal (MATROS, 2001), in the area foreseen in the masterplan from the year 1996 as an extension of the North Port (Figure 6) and in the previous plan from 1968 as an area of two shipyards (Figure 2). Finally, in 2007, a wide pier (800 × 315 m) of a deep-water container terminal (DCT) was launched (Figure 1b). At that time, the DCT terminal had 650 m of mooring line and a depth of 16.5 m (Buca & Mitrosz, 2016). The area of the terminal was 44 ha (Szwankowska, 2018, p. 65). The DCT was built to increase the economic growth of its hinterland and transport connectivity of the Port of Gdańsk. However, without a decision on dredging the Danish Straits several decades before and building the deep-water North Port, the Port of Gdańsk would not be able to serve large ocean container ships and become a container hub, as the Inner Port was and still is able to serve only the feeder vessels. Currently, the terminal can handle ultra-large-container-ships-type container ships (caring more than 20,000 twenty foot equivalent unit). As a consequence of building the DCT, the Pomeranian Logistics Centre began construction in its vicinity in 2012. In 2016, a tunnel under the Dead Vistula joined the Stogi Island transportation system (along with the DCT and Pomeranian Logistics Centre) with Gdańsk from the west direction. In the years 2015–2016, due to the rapid increase in container turnover, another 650.0-m-long section of the quay was added to the DCT. The area of the terminal also increased by another 27 ha (Szwankowska, 2018, p. 65). Currently, the DCT has changed its name to Baltic Hub and is undergoing the next expansion phase, this time by reclaiming new water areas (Baltic Hub, 2023).

The development of the North Port and the collapse of the Gdańsk shipyard rendered the areas located on the west bank of the Dead Vistula obsolete. The development strategy of 2014 for the Port of Gdańsk until 2027 envisaged a gradual deepening of this process, and ultimately the release of the left-bank side of the river from port functions (Szwankowska, 2018, p. 68). A similar situation occurred in the post-shipyard areas (Lorens & Bugalski, 2021; Nyka & Szczepański, 2008; Szmytkowska, 2022), where new housing estates and cultural services have slowly appeared within the last 10 years. In the case of the Inner Port, this process was however stopped due to the deepening and modernisation of the Inner Port in the years 2016–2022.

The plan of the North Port assumed development to the east—In the most ambitious assumptions, it was to reach as far as the Brave Vistula and Sobieszewska Island (Andruszkiewicz, 1976, p. 46). After the gradual transfer of transhipment functions from the Inner Port to the North Port, as well as limiting the eastern direction of the North Port development by the masterplan from 1996, the concept of the Central Port was elaborated in 2019 (Czermański et al., 2021; Postoła, 2019). The location of the Central Port (Figure 1b) between two already existing port complexes (Inner and North Ports) might allow for the development of the Port of Gdańsk in a more compact way. The concept of the Central Port provides for further entry into the sea and the creation of new piers by landfill of the sea in order to build deeper reloading berths. The concept of the Central Port is included in both the current Study of Conditions and Directions for the Development of the City of Gdańsk from 2019 and the Plan of Maritime Areas of the Port of Gdańsk, currently being prepared by the Gdynia Maritime Office (Maritime Office in Gdynia, 2021).

7. Depth Limitations in Designing the Central Port

The assumptions for the design of marine structures of the Central Port currently require the adoption of basic guidelines regarding, above all, the depth of approach channels and the mooring berths. To define these, the maximum parameters of ships that will be served in the Central Port are needed (PIANC, 2014; Thoresen, 2018, p. 9). Typically, port design takes into account a long-term perspective of several decades, taking into account ships that are very often still in the design concept stage. Currently, the North Port is accessible for fully loaded ships of Baltimax class. However, according to the recommendations of the Harbour Master's Office in Gdańsk, the largest ships that could currently be handled in the North Port are vessels with a carrying capacity of 300,000 t and a draft of 15 m (Gdańsk Harbour Master's Office, 2023). The biggest ships that have entered the North Port of Gdańsk so far are the crude oil tanker Atlantas (International Maritime Organisation [IMO] number: 9389899) in 2016 with a capacity of 321,300 DWT, length of 290.0 m, breadth of

60.0 m, and a draught of 16.7 m ("Gigantyczny tankowiec niedługo w Gdańsku," 2016); container ship MSC Gülsün (IMO: 9839430) in 2019 with a capacity of 23,756 TEU, length of 399.9 m, breadth of 61.5 m, and a draught of 16.5 m (Baltic Hub, 2023); and the bulk carrier Agia Trias (IMO: 9241657) in 2020 with a capacity of 185,820 DWT, length of 290.0 m, breadth of 47.0 m, and a draught of 17.9 m (Portal Morski, 2020). All of them were, however, not fully loaded.

In the case of Atlantas (Portal Morski, 2016), before entering the Baltic, she had to be partially discharged by ship-to-ship transfer to another tanker and came to Gdańsk along with the feeder tanker to discharge. Therefore, serving such large ships in Gdańsk demands either that the ship is not fully loaded with cargo on the ocean route or that it is partially discharged before passing through the Danish Straits (in a port or by ship-to-ship transfer). Both solutions increase transportation costs. While the size of ULCC crude tankers and bulk carriers has not increased since the late 1970s, the parameters (including drafts) of container ships are still increasing to benefit from economies of scale. Prokopowicz and Berg-Andreassen (2016) defined the "very large container ships" class with a capacity of 10,000–20,000 TEU and the ultra-large container ships, which could carry over 20,000 TEU. The largest recently built container ships are Ever Alot (IMO: 9893955), built in 2022 with a capacity of 24,004 TEU, and MSC Irina (IMO: 9929429), with a capacity of 24,346 TEU, having drafts that increasingly call further into question the possibilities of Gdańsk and other ports of the Baltic Sea as ports serving ocean connections and being container hubs. And here again, after almost 60 years, the question arises about the possibility of further deepening the Danish Straits.

The Port of Gdańsk and all ports of the Baltic Sea are thus in a situation where the further increase in the size of ocean-going vessels (especially their drafts) will limit the possibility of their passage via the Danish Straits. In the process of planning the Central Port, the question becomes extremely important: What parameters should be used when planning its layout? The assumption of designing depths typical of Baltimax will, by definition, eliminate the possibility of servicing the next generation of ocean-going ships. So, in the longer term, is there a possibility of another deepening of the Danish Straits and maintaining the development perspectives for Baltic ports as ocean hubs? Is a more likely scenario a return to the situation known in Gdańsk from around the mid-16th century, when the bottleneck for ships entering the Port of Gdańsk was the depth of the river passing the Old Port? The waterways of the port were too shallow at that time to serve ocean-going galleons, and this fact reoriented the system of sailing routes starting in Gdańsk into a network of feeder connections served by much smaller vessels (Krośnicka, 2005, p. 30).

8. Conclusions

The deepening of the Danish Straits and the opening of the T Route to the Baltic Sea in 1975 opened a development window for the Port of Gdańsk (Figure 7). Overcoming this single development threshold (which, it is important to point out, is very distant from Gdańsk itself) allowed for the construction of a deep-water North Port, able to serve modern ships of Baltimax class. This investment was crucial for the continued existence of the Port of Gdańsk as an important ocean transportation node, as the old Inner Port, even after its deepening,

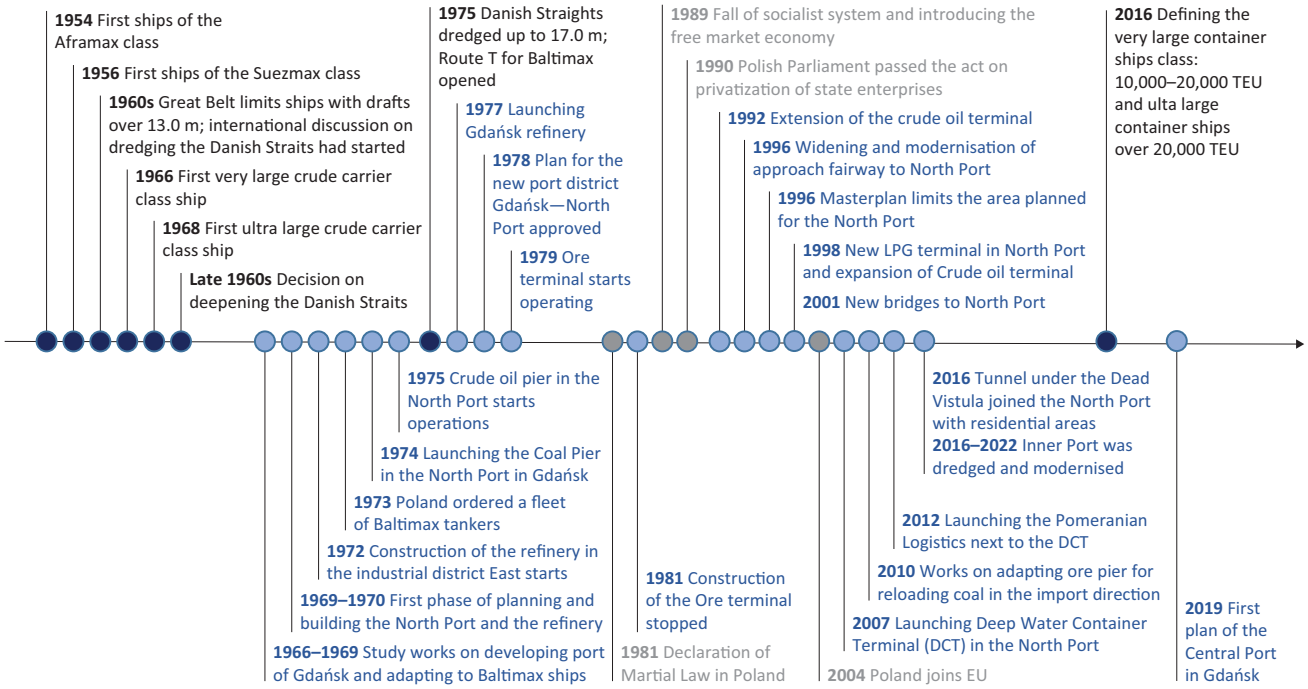

Figure 7. Timeline of the evolution of the North Port in Gdańsk.

would not be able to serve ships larger than 30,000 DWT. As quickly as 1977 (after four years of operations), the North Port slightly exceeded the turnover of the Inner Port, and in 1995 (after the difficult period of marshal law and politica l transformation for the Polish economy), the North Port's turnover was twice as big as the Inner Port's (the Inner Port served 6,048,100 t, while the North Port 12,213,700 t of cargo).

Launching the North Port along with the port's industry (crude oil refinery, oil bases), as well as plans for building two new shipyards in its vicinity re-orientated the economy of the Port of Gdańsk, but it also strongly influenced the development of the city. During the times of the centrally planned economy, the plan was to employ about 25,000 people to service the North Port and the East Industrial District. Such a high number of potential employees required the development of residential districts along with the servicing of urban infrastructure. Therefore, both the authorities of the Port of Gdańsk, the Gdańsk Refinery, and of shipyards still located in the Inner Port established their own housing funds, in which expenditure on financing cooperative and company housing significantly increased while constructing the North Port (Table 2). As a consequence, these maritime economy entities participated in building the new, modernistic residential districts in Gdańsk.

The suitability of a given water body in a port, and therefore also its closest region, for cargo handling and storage usually depends on the depth of the water body. The decision to carry out dredging works in a given water area, as was the case in the area of the Inner Port in Gdańsk in the years 2016–2022, therefore not only leads to the maintenance of transhipment functions but also slows down the process of moving port functions towards deeper waters—described by Bird (1971) as "down-stream" movement—and results in delaying the process of urban recycling. From the point of view of reducing the environmental impact, it is a beneficial process. Also, from the point of view of the city's development, it is a positive phenomenon, giving both the authorities, city, and port time to react and rethink the investment and transformation process.

Reducing the land reserves for the development of the Northern Port by the masterplan from 1996 made it possible to rationally use the port space and preserve coastal recreational areas, but at the same time, it forced today's reorientation of the development of the Gdańsk port towards deeper waters and the emergence of the concept of the Central Port. The design of the Central Port needs careful consideration of the parameters of ships that might enter the Baltic, even if not fully loaded. At present, the draughts of ultra-large container ships approach the limits of permissible depths enabling passage through the Danish Straits, thus various far-reaching economic and spatial effects can be expected for Gdańsk and other ports of the Baltic Sea.

To sum up, for port cities, overcoming even a very distant development threshold by dredging the existing navigational passage (Danish Straits) or by constructing a new channel (Kiel Canal) results in a significant change in the development conditions (in positive or negative terms) through the reorientation of maritime routes. The case study of the North Port in Gdańsk confirms, therefore, that the port-city relations are among those shaped by accessibility to the global sea routes (Ducruet et al., 2018; Ducruet & Lee, 2006; Russo & Musolino, 2023).

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Conflict of Interests

The authors declare no conflict of interests.

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