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## **FIFTH AND SIXTH GENERATION PORTS (5GP, 6GP) – EVOLUTION OF ECONOMIC AND SOCIAL ROLES OF PORTS**

Summary: Fifth generation ports created in result of a dynamic development of containerization are characterised by a different approach to the transport, environmental, and city-forming function. The article presents the concepts of seaport development and defining their generation with the use of detailed criteria and meters. It also showcases the proposals for a prospective sixth generation port handling ships of 50 thousand TEU capacity.

**Keywords:** maritime ports, port generations, fifth generation port, 5GP, sixth generation port 6GP, 50,000 TEU vessel

**Quote:** A. Kaliszewski, Fifth and sixth generation ports (5GP, 6GP) – evolution of economic and social roles of ports, translated from Polish: “Porty piątej oraz szóstej generacji (5GP, 6GP)-ewolucja ekonomicznej i społecznej roli portów”, „Studia i Materiały Instytutu Transportu i Handlu Morskiego” (ISSN 2080-6302), 2017, no. 14, DOI: <https://doi.org/10.26881/sim.2017.4.06>

### **Introduction**

The evolution of seaports particularly those handling containerized loads, leads to the creation of an ever more complicated system of connections between the participants in the port services market both from the supply and the demand side. The importance of seaports may be expressed by categorising them to a given port generation. In accordance with the UNCTAD concept, ports of the first, second, third and fourth generation can be distinguished. In 2011, M. Flynn introduced a proposition of including two groups of stakeholders: the port users (customers) and the local community, as the trait of the fifth generation port<sup>1</sup>. The goal of the study is to present the characteristics of fifth generation seaports taking account of the

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<sup>1</sup> M. Flynn, P. Lee, The next step on the port generations ladder: customer centric and community ports, (in:) T. Notteboom, Current Issues in Shipping, Ports and Logistics, University Press Antwerp, Brussels 2011, p. 497-510.

idea of classifying seaport generations presented by P. Lee and J. Lam in 2015<sup>2</sup> and to propose criteria for distinguishing sixth generation ports handling ships with a capacity of 50 thousand TEU.

## **1. Current Seaport Generations**

Literature on the subject differentiates seaports by their capacity and throughput results as well as other parameters such as the management system, the port's effectiveness as the supply centre for creating added value and innovativeness<sup>3</sup>. The services package offered by seaports changes over time with the development of their capacity to handle various ship types and the cargo transported thereby (including unitized), means of land transport, as well as with the development of the computer link networks and the automation of the processes executed therein. The more the differentiation of the functions performed by the port, the more advanced its supply centre<sup>4</sup>.

Due to the non-linear nature of seaport development caused by the changeability of the management conditions throughout the years, it would seem that we cannot discuss the "ladder" nature of the development path of all ports. Not every seaport can ascend up the development ladder due to specific development barriers, geographical location, or the economic and political situation of its hinterland. In 1990, the United Nations Conference on Trade and Development (UNCTAD) proposed a theoretical model of seaport classification, taking account of the port development strategy, the range of provided port services, and the level of IT integration of entities functioning as part of the port services market<sup>5</sup>. This was an attempt to summarise the development of seaports in the period prior to the 1960s, after the introduction of containerization on a wider scale in the 1970s and their development starting from the 1980s thanks to the use of modern, highly efficient devices and equipment, computer technologies and intermodal operations. In accordance with the UNCTAD classification which includes three port generations, only the largest seaports in the world located at the junction of key navigation routes, are able to function as part of the most advanced global logistic plat-

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<sup>2</sup> P. Lee, J. Lam, Container Port Competition and Competitiveness Analysis: Asian Major Ports, (in:) C. Lee, Q. Meng, Handbook of Ocean Container Transport Logistics – Making Global Supply Chain Effective, International Series in Operations Research & Management Science, Springer, New York, p. 97-136.

<sup>3</sup> A. Grzelakowski, M. Matczak, Współczesne porty morskie, funkcjonowanie i rozwój, Wydawnictwo Akademii Morskiej w Gdyni, Gdynia 2012, p. 31.

<sup>4</sup>More on the transport function: H. Klimek, R. Rolbiecki, Funkcja transportowa największych polskich portów morskich, „Zeszyty Naukowe Wydziału Ekonomicznego Uniwersytetu Gdańskiego” 2017, no. 63, p. 79-90.

<sup>5</sup> Ad hoc Intergovernmental Group of Port Experts, UNCTAD, Geneva 1990, Port marketing and the third generation port, TD/B C.4/AC.7/14, UNCTAD, Geneva 1991.

forms which concentrate a large part of the unit cargo streams. The UNCTAD developed model of seaport generations is shown in table 1.

Table 1. Specification of seaport generations according to UNCTAD

<b>Port characteristics</b>	<b>1<sup>st</sup> generation</b>	<b>2<sup>nd</sup> generation</b>	<b>3<sup>rd</sup> generation</b>
Development period	prior to 1960	1960-1980	after 1980
Main cargo	Semi-bulk cargo	Dry semi-bulk cargo and liquid bulk cargo	Bulk, general, and containerized cargo
Attitude and strategy of port development	Conservative, means of transport change point	Expansive, transport, industrial, and commercial centre	Commercial, logistic-distribution centre for international trade
Scope of operations	[1] Loading, unloading, storage, navigation services	1 + [2] Cargo processing, industrial and commercial services - territorial expansion	1 + 2 + [3] Cargo and information distribution, logistic operations
Organisational features	Independent operations within the port, informal connections between the port and its users	Closer ties between the port and its users. No connections between different types of operations within the port, provisional ties between the port and the city	Unified port community. Port integration with the transport-commercial chain. Close connections between the port and the city. Extensive port organisation.
Specific production features	Cargo flow, simple, single services. No/low added value	Cargo flow, cargo processing. Various services, higher added value	Cargo and information flow. Cargo and information distribution. Wide package of various services. High added value
Deciding factors	Work/capital	Capital	Technology, know-how

Source: Port marketing and the challenge of the third generation port, UNCTAD, TD/B/C.4/AC.7/14, Geneva 1991, p. 23.

The main feature of the first generation seaport according to UNCTAD is the uncomplicated operational activities consisting of stevedoring cargo between land and sea-based means of transport. The seaport operates in isolation from transport and the commercial function. Taking advantage of the strong position on the local market and often having monopoly, it does not have to endeavour to satisfy the needs of the users<sup>6</sup>. The information, document, and statistical system of the first generation port operates separately from the port users. The relations between the seaport and the port city are loose enough so that both entities need not coordinate spatial development plans. The operations of various entities within the port regions are also uncoordinated. Decisions were made independently from one another, as prior to containerization the stevedoring rate was not high and the cargo displacement was slow. An exception to this were seaports located near places where natural resources were being extracted which serviced liquid and bulk cargoes and where intermodal displacement of the cargo onto ships, either by pipeline or conveyor, was carried out<sup>7</sup>.

The first generation ports operate in the area of uncontested hinterland which due to economic or political (country borders) factors can handle cargoes without competition. This category should include raw material ports as well as seaports from the “B” and “C” group<sup>8</sup>. Small seaports, constituting fishing ports or marinas, do not require costly information systems, significant storage areas, nor planning activity coordination. Even now, we cannot dismiss their importance, both in the economic development of underdeveloped countries, and in the functioning of the local community in developed countries.

The second generation ports, according to UNCTAD, integrate with their surroundings via their transport, industrial, and commercial function. Within the port areas, industrial parks are created which receive imported raw materials delivered by sea such as iron ore, steel, crude oil, aluminium, paper pulp, artificial fertilizers, sugar, flour, and other agricultural cargoes. In the 1960s, sea transport started to make use of huge tankers and bulk carriers, which required the ports do increase the depth of their water areas<sup>9</sup>. Expanding the scope of port

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<sup>6</sup> Port marketing and the third generation port, TD/B C.4/AC.7/14, UNCTAD, Geneva 1992, p. 13.

<sup>7</sup> UNCTAD gives the example of the ports in Saudi Arabia (crude oil exports) and Australia (bulk cargo exports). Ibidem, p. 13.

<sup>8</sup> Within the EU, the category “A” seaport being an element of the TEN-T transport network is a facility with annual volume capacity of at least 1.5 million tonnes or handling 200 thousand passengers. Other ports, where cargo volumes do not meet the above criteria, constitute medium and small ports, i.e. category “B” and “C” accordingly. They are of regional or local importance.

<sup>9</sup> S. Szwanowski, *Funkcjonowanie i rozwój portów morskich*, Wydawnictwo Uniwersytetu Gdańskiego, Gdańsk 2000, p. 39.

operations with the industrial and commercial function created the conditions for an increase of the added value created in ports<sup>10</sup>. The development of the industrial function is connected with access to land, efficient land transport, as well as worker and utility (power and water) availability. The intensification of industrial production had negative consequences for the natural environment. From the operational perspective, efficient functioning of the port supply centre requires a degree of coordination of activities with the port city and region. Due to the increasing volumes, the significance of cooperation between the various service providers within the seaport in order to handle cargo efficiently also increases<sup>11</sup>.

Despite the attempt to go beyond the prevailing operational isolation, second generation ports cooperated with their immediate surroundings, the transport sector and municipal authorities, in a rather narrow capacity. Actually, seaport activity was limited to the narrowly defined micro-surroundings<sup>12</sup>. Also, the information exchange process with the surroundings in the 1960s and 1970s did not take account of electronic data exchange systems<sup>13</sup>.

The third generation seaports first appeared in the 1980s in the period of accelerated development of containerized cargo volumes, the creation of an intermodal connections network, and increasing requirements resulting from the development of international transport. They are characterised by higher activity than the previous generations, in connection with searching for cargoes by implementing the strategy of development which fosters the creation of integrated logistics centres and even logistics platforms supporting international trade<sup>14</sup>. In the operational area, third generation ports are characterised by a much larger scope of services which includes four areas of business operations<sup>15</sup>. The first includes stevedoring, storage, and navigation services with the use of modern technologies, organisation and management. A significant role in this generation is played by skills (know-how), electronic data processing and exchange. The second area comprises the expansion of the industrial function of the second generation ports with environmental functions pertaining to operating ships and devices necessary for environmental protection. There are industrial zones (so-called export processing zones) being created around the ports, where imported cargoes are refined and shipped out via the seaport. The third area includes an effective administrative-commercial

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<sup>10</sup> R. Marek, Przemiany w portach morskich Unii Europejskiej na przełomie XX i XXI wieku, „Logistyka” 2012, no. 2, p. 890.

<sup>11</sup> Port Marketing and the Third Generation Port, TD/B C.4/AC.7/14, UNCTAD, Geneva 1992, p. 14.

<sup>12</sup> R. Marek, Przemiany w portach morskich Unii Europejskiej..., p. 890.

<sup>13</sup> IBM PCs were not implemented until the 1980s.

<sup>14</sup> Port marketing and the third generation port..., p. 15.

<sup>15</sup> K. Misztal, S. Szwanowski, Organizacja i eksploatacja portów morskich, Wydawnictwo Uniwersytetu Gdańskiego, Gdańsk 1999, p. 58.

handling of cargo information, the necessary bank, insurance and legal services for the port. UNCTAD points out that excessive document-related and regulatory requirements, and the uncoordinated work schedule of port services may contribute to the increase of non-tariff barriers in trade<sup>16</sup>. The fourth area focuses on the new logistic-distribution function which results from including seaports in the integrated concept of the land-sea transport chain. The distribution service at the third generation seaport consists of effective management of the cargo stream and information pertaining thereto in order to enable deliveries under the “just in time” system. Faster container rotation within the seaport as well as fast intermodal connections prevent “adding value” to the cargoes therein. Port distribution centres may supplement the package of port services, enable LCL (less than container load) cargo deconsolidation, and organise cargo distribution via land transport, as well as contribute to the return of empty containers to the port.

Third generation ports are unable to continue the development policy and not cooperate with the authorities of port cities and regions, as well as the national government. The high volume of containerized cargoes handled at ports requires good quality road connections, rail connections with facilities, modern warehouses and distribution parks, as well as a full symbiosis between the port and the city for the purpose of rational use of resources and joint spatial planning<sup>17</sup>.

A certain weakness of the third generation port is the functioning of the port supply centre as an entity separate from the distribution chain. This may lead to making commercial decisions which are favourable for the port, however without sufficient stakeholder participation. The stevedoring capacity is not a developmental determinant for seaports in the UNCTAD classification. Small ports may have difficulty with ensuring high quality ship handling even with a small cargo volume which in underdeveloped countries may prove insufficient to justify the costly investments, including in IT. Another criterion for UNCTAD classification is an active role of port decision-makers in the search for modern cargo handling solutions, introducing organisational and informational improvements<sup>18</sup>. The development of computer sciences since the 1980s has been so fast that the EDI data exchange systems developed in this period seem inadequate in the 21<sup>st</sup> century for two reasons. First, they did not allow the use of the Internet which became a common, global medium functioning as support for international

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<sup>16</sup> Port marketing and the third generation port..., p. 16.

<sup>17</sup> Ibidem, p. 21.

<sup>18</sup> Ibidem, p. 22.

trade and finances<sup>19</sup>. Secondly, the systems and procedures connected with online information security require modernisation, ensuring resilience of port turnover participants to hacker attacks which may put the port at risk of temporary or complete shutdown of stevedoring activities<sup>20</sup>.

Due to the changes occurring in the vicinity of ports in the 1990s connected with the introduction of the “just in time” concept, seaports started to mimic the changes occurring in maritime transport chains, improving the process of cargo and information flow in a manner aimed at eliminating wastefulness of resources and energy, as well as limiting downtimes<sup>21</sup>. In 1999, the UNCTAD defined the notion of a fourth generation port. The following criteria have been considered: quality of port services, IT usage, developing the port community, the presence of the port cluster and logistic centre, quality of connections with the hinterland on the land side and the foreland on the sea side<sup>22</sup>. In contrast to the third generation ports, the fourth generation ones play a super-regional role creating a hub, i.e. the main regional port wherefrom cargo is transported by sea to smaller outlying ports. Port authorities may be interconnected by a common administration (such as in the case of ports in Copenhagen and Malmo) or a common operator of the container terminal. UNCTAD emphasises that investments in port-hubs are usually implemented by the private sector and in particular by strong international organisations specialised in operating port terminals (mainly container terminals). It would seem that an appropriate involvement of private capital under a public-private partnership allows to create modern third, fourth, or fifth generation ports from scratch by constructing modern container terminals employing cutting-edge stevedoring technologies and IT solutions, as well as a modern approach to steering economic processes in the port market circle.

In connection with the above trend of direct engagement of the private sector with seaports, UNCTAD proposes that port authorities shift their attention from seaport operations to more long-term forms of shaping their future. These include fulfilling ownership and stra-

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<sup>19</sup> A. Kaliszewski, *Perspektywy rozwoju usług finansowych w Internecie*, „Zeszyty Naukowe Instytutu Badań nad Gospodarką Rynkową”, Gdańsk 1999, no. 102.

<sup>20</sup> After a weeklong interruption due to a successful cybernetic attack, the automatic container terminal APMT Maasvlakte 2 commenced operations. J. Baker, *APM Terminals resumes Rotterdam operations*, *Lloyds List*, 6 July 2017, <https://lloydslist.maritimeintelligence.informa.com/LL109017/APM-Terminals-resumes-Rotterdam-operations> (last access: 8 July 2017).

<sup>21</sup> A. Paixão, P. Marlow, *Fourth generation ports – a question of agility?*, „*International Journal of Physical Distribution and Logistics Management*” 2003, No. 33, p. 356-357.

<sup>22</sup> The fourth generation port, UNCTAD Ports Newsletter, 1999, No. 19, p. 10, <http://unctad.org/en/Docs/posdтетibm15.en.pdf> (last access: 25 November 2017).

tegic functions in five areas: planning port policy, regulatory towards port service providers (licensing) and supervisory in the area of ensuring fair competitive conditions (risk of excessive tariffs of private operators) and ensuring a minimum level of quality of services offered at the port (security), monitoring the port's vicinity and promoting the port outside, as well as training the staff necessary for operations of the port service providers<sup>23</sup>.

The fourth generation port model is not without methodological defects, mainly connected with the previous categories, due to the difficulties with a clear delimitation between each of the port generations. In 1999, UNCTAD outlined the possibility of creating such ports, however failed to present specific meters which could help in classifying ports into the 4<sup>th</sup> generation. Due to the rapid development of IT technologies, the Internet, smartphones, or social networks at the outset of the 21<sup>st</sup> century, we can expect the UNCTAD port classification to undergo another change.

The division of seaports into generations by UNCTAD has been criticised in literature on the subject due to gross oversimplifications. A. Beresford points out the abstract UNCTAD classification due to a need of a definitive transition of a port between the categories over time, which makes the port classification inaccurate, fuzzy, and not reflective of the realities of the functioning of e.g. European ports<sup>24</sup>. Port generations according to the UNCTAD model ignore factors which are vital according to A. Beresford and determine the level of development of commercial facilities, such as the size of the port, its geographical location, and the degree of engagement of the public and/or private sector in providing port services<sup>25</sup>. A. Beresford notes that the benefits resulting from the port's location influence previous stages of its development as well as plans for its development, market strategies, and the scope of port services offered. In that way, the port is less technologically advanced, however, its advantageous location in respect of the hinterland may make it proper for handling the existing cargo stream while preserving the economical cost level<sup>26</sup>. Therefore, constructing ports of the newest generation to substitute existing ones does not seem necessary in every location.

In 1998-1999, the EU financed the WORKPORT research project which, in contrast to the 1990 UNCTAD model, showed changes occurring in seaports<sup>27</sup>. The development of European ports since the 1960s was evolutionary in nature, which means that ports, and more pre-

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<sup>23</sup> Ibidem.

<sup>24</sup> A. Beresford, B. Gardner, S. Pettit, A. Naniopoulos, C. F. Wooldridge, The UNCTAD and WORKPORT models of port development: evolution or revolution?, „Maritime Policy and Management” 2004, No. 2, p. 97.

<sup>25</sup> Ibidem, p. 94.

<sup>26</sup> Ibidem, p. 97.

<sup>27</sup> Ibidem, p. 94.

cisely, container terminals of various generations (distinguished in accordance with the UNCTAD concept), coexisted in later years (in regards to terminals, this pertained to individual supply centres in ports<sup>28</sup>. UNCTAD models disregarded the criteria of port distinction, significant from the perspective of European port development, concerning the changing conditions of handling larger vessels, organisation culture, occupational safety and health, and environmental protection which has been showcased in table 2. The ever-growing scope of European integration enabled the introduction of common legal regulations on the work conditions in seaports and environmental protection. The increasing degree of mechanisation, automation, and computerisation of ports requires adjusting the scope of worker skill, carrying out training programmes, and taking care to improve organisational culture. The WORKPORT project emphasises the human side of organisational progress by a team-based work organisation with a significant degree of decision-making autonomy which enables the provision of port services in a flexible manner and making use of the multi-skilling aspect of its participants (multi skilled teams).

It would seem that in contrast to the UNCTAD port generation model, WORKPORT, introduced in March 2000, takes into consideration a substantially larger number of criteria as well as their mutual relations (e.g. influence of organisational changes in ports on work safety and hygiene, the natural environment, new technologies). The WORKPORT model seems to be anthropocentric due to emphasis on the role of port staff in the port evolution process (both on the managerial and execution level). The project also included aspects of work quality in the scope of constant improvement of port service quality (studies focused on the use of: kaizen, TQM, learning organisation systems in ports).

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<sup>28</sup> An example of a combination of fourth and first generation ports is Dubai. Next to the modern Jebel Ali container terminal, a first generation port is still in operation in the old part of the city, where packages and sacks are transhipped from small vessels in a traditional manner, like they were dozens of years ago.

Table 2. The change processes in European ports according to WORKPORT

Port division criteria	1960s	1970s	1980s	1990s	2000s
1	2	3	4	5	6
<b>Property</b>	<p>Infrastructure is commonly public property (exception - Great Britain). Superstructure and operational activities - both private and public, depending on the country and/or seaport.</p> <p>The increasing involvement of the private sector in the provision of port services with the use of the superstructure.</p>	<p><b>The increasing involvement of the private sector</b></p> <p>1980s Seaport privatisation in Great Britain. Ownership concentration in British ports. Increase of commercialisation of seaport managements. Ports become more focused on users. Further privatisation of Great Britain seaport.</p> <p>1990s Increasing ownership concentration of container terminals due to their partial acquisition by international terminal corporations.</p>			
<b>Forms of cargo</b>	<p>Conventional cargo. Commencement of the phase of replacing semi-bulk cargo with unitised cargo. Conventional cargo has been divided into: container, ro-ro, palletised, LASH, neo-bulk, semi-bulk. Small changes in the form of bulk cargoes Small changes in the form of liquid cargo.</p>	<p><b>Replacement of semi-bulk cargo with unitised cargo</b></p> <p>1980s Ships are increasingly bigger</p> <p>2000s Unification of conventional cargoes is nearly finished</p>			
<b>Cargo manipulation process</b>	<p>Conventional cargo</p> <p>Dry bulk cargo      High level of mechanisation</p> <p>Liquid bulk cargo      High level of mechanisation and automation</p>	<p>Increasing automation and mechanisation. Subject to mechanisation and automation along with cargo unification.</p> <p>Specialised terminals for handling dry bulk cargoes</p> <p>Specialised terminals for handling liquid bulk cargoes</p>	<p>Increasing automation of dry bulk volume</p> <p>Full automation of liquid bulk volume</p>	<p>Full automation of operational activity on quays and in storage operations in certain container terminals (robotics).</p>	

1	2	3	4	5	6
<b>Processes supporting load-unloading operations, including information processes</b>	Conventional methods of information and document exchange  Data on paper, entered by hand.	<b>Dissemination of non-conventional methods of information processing and transfer</b>			
		Increasing use of information technologies and the increasing complexity of the communication network			
		Post, phone, telex, fax.	Post, phone, telex, fax, EDI.	Post, phone, telex, fax, EDI, Internet, Intranet. Information standardisation.	Email, EDI, Internet, Intranet, phone (mobile), radio, post. Information standardisation.
<b>Work culture</b>  ✓ Labour resources ✓ Work organisation ✓ Work environment ✓ Employment conditions ✓ Work relations	Semi-bulk cargoes - highly labour-intensive operations (requiring physical labour), handling other cargoes (bulk), capital-intensive. Longshoremen labour protected by strong labour unions. Hierarchical organisational structure.	<b>Decreasing worker numbers</b>			
		Loading operations become capital-intensive and less labour-intensive			
		Unitisation of stevedoring of conventional cargo gave rise to replacing physical labour with that of mechanical devices. A decrease in worker numbers (despite the increase of the cargo volume).	Multi-skilling requirement. Organisational structure levelling. Increase of demand for IT skills  24-hour work time has become commonplace. Substituting contract workers with seasonal workers.	An increased emphasis on the quality of provided services.	Resignation from employing seasonal workers
		<b>Increasing diversity of port operations</b>			
<b>Port functions and port development processes</b>	The port as the point of changing the means of transport from land to sea and vice-versa.				
	Focusing on the cargo with supplementary activities conducted in a minor scope (within and without the seaport), e.g. crude oil refining.  Informal connections between the port and its users.	Increasing industrialisation via MIDAS (Maritime Industrial Development Area). Expanding the port area. Closer relations between the port and its users.	Diversification of port companies (towards logistics and services creating added value). Creation of duty-free zones and distribution centres. Unified port community.	Port community globalisation.	

1	2	3	4	5	6
<b>Work environment health and safety aspects</b>	Work in a port is dangerous due to the high share of physical labour. Improper legal regulations and insufficient training.	<b>Decreasing rate of work-related accidents and absences</b>			
		Decrease of the rate of accidents and a reduction of absences due to health issues.  Fewer work-related accidents. Worker health problems due to a reduction of simple physical labour (other accidents having much more severe results).	Port cranes become more ergonomic and adapted to the needs of the workers handling them.	An increase in the number of training sessions in the scope of occupational health and safety.  Formal policy in the scope of occupational health and safety.  EU directive on working time. Rigorous inspection of the workstation surroundings.	
<b>Natural environment</b>	Overall low level of awareness in the scope of the need to protect the environment.	<b>Increasing awareness of the surroundings</b>			
		Reactive answer to events	EU environmental assessment. Specific legislation. Local ad hoc initiatives.  An increasingly proactive system of environmental management.	Directive on bird breeding sites.  Ecological code of the ESPO (European Sea Ports Organization).	Quality of environmental protection ensured by the environmental management system. Conformance with environmental protection law and responsibility for the state of nature as an element of regular business planning
<b>Production means</b>	Intensive human labour	Human labour replaced with capital-intensive investments in devices used for port loading/unloading operations - introduction of new technologies.	Increasing technological advancement and basing port economy on knowledge (know-how).	Information and communication technologies.	Integration of economical interests of the entire port community

Source: Final Report, Workport WA-97-S.C.-2213, (in:) A. Naniopoulos, June 2000, <https://trimis.ec.europa.eu/sites/default/files/project/documents/workport.pdf> (last access: 9 December 2017).

In Polish literature on the subject, a new port classification was proposed by J. Semenov who in 2003 pointed out the problem of transforming ports from “a port as a cargo stevedoring system” to “a port as a logistic centre”<sup>29</sup>. He distinguished five categories of modern ports and their prehistory, which is shown in table 3.

Table 3. Port classification and basic characteristics according to J. Semenov

<b>Port generation</b>	<b>Characteristics</b>
Port prehistory	There was technically no such thing as a port. Boats carrying passengers and goods entered a gulf. These gulfs functioned as ports by connecting water and land routes.
1 <sup>st</sup> generation ports	Ports functioned as commercial centres.
2 <sup>nd</sup> generation ports	Points of ship handling within the bimodal transport system: e.g. maritime transport - rail transport; maritime transport - road transport etc.
3 <sup>rd</sup> generation ports	Port - industrial centre. Between 1940 and 1945, ports played a logistic function for the purposes of supplying the military.
4 <sup>th</sup> generation ports	Port - logistic centre as a node for handling multimodal transports.
5 <sup>th</sup> generation ports	An analysis of the 4.5 thousand years of port history leads to a conclusion that ports of this generation should combine the following functions: - wholesale centres which will cut the time of cargo delivery; - points of joining of water and land passenger streams; - industrial centres with comprehensive intermodal transport handling; - logistic centres as connecting points for multimodal cargo transport.

Source: J. Semenov, Kierunki strategiczne podwyższenia konkurencyjności polskich portów na tle wymogów UE, pr. zbior. pod red. K. Chwesiuk, Konkurencyjność polskich portów morskich w świetle integracji z Unią Europejską, III Konferencja Naukowa Porty Morskie, Szczecin, 2003, p. 6.

In the development of the fourth generation ports, J. Semenov saw the need to change the attitude of the port staff towards the scope of duties, from passively conducting stevedoring operations, to seeing them as a part of the global economic process. Raising the requirements for 4<sup>th</sup> generation ports also includes safety requirements in regards to the functioning of the ports and port logistic centres<sup>30</sup>. An important factor to raise the competitiveness of Polish

<sup>29</sup> J. Semenov, Kierunki strategiczne podwyższenia konkurencyjności polskich portów na tle wymogów UE, (in:). K. Chwesiuk, Konkurencyjność polskich portów morskich w świetle integracji z Unią Europejską, Szczecin, Wydawnictwo Kreos, Szczecin 2003, p. 6.

<sup>30</sup> Polish ports implemented the abovementioned assumptions by implementing the ISPS code in 2004. <http://www.portgdansk.pl/wydarzenia/isps-code> (last access: 9 December 2017). In December 2017, works were

ports is the port's perception as a uniform system, combining infrastructure, superstructure and information technologies in order to maximise convenience for port users. J. Semenov adds two criteria distinguishing a fourth generation port: adapting to new types of operations, including the creation of added value (which results in increasing the port's profitability) and playing the role of logistic hubs. A role model in this respect are container ports such as Hong Kong, Singapore, or Rotterdam.

J. Semenov's port classification does not include a criterion of port navigation capacity for handling the largest vessels, including container ships. Limitations of the depth of the port approach, turning basin, and quay basins in important European container ports such as Gothenburg and Hamburg<sup>31</sup> effectively prevent the possibility of handling the largest container ships. Such a seaport must account for being excluded from participating in the navigation services from Asia to Europe (e.g. Hamburg which has for years been fighting for the possibility to dredge the Elbe river from 14.5 m to 15.5 m) or the lack of possibility to fully load a ship (Gothenburg having quays where the maximum ship draught is 13.2 metres is unable to handle a fully loaded ship)<sup>32</sup>.

In 2012, A. Grzelakowski and M. Matczak proposed an original characteristic of the fourth generation port taking account of the following criteria<sup>33</sup>:

- containerization of the main cargo stream,
- port development strategy based on advanced automation and IT technologies,
- scope of services including full integration of the port with the transport, forwarding, and logistics industries, intermodal transport and information standardisation,
- the nature of the management system focusing on the globalisation of port operations and orientation towards SCM (supply chain management) and controlling the state of the natural environment,

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conducted in the Gdynia port consisting of building gates to detect radiation <http://www.gospodarkamorska.pl/Porty,Transport/terminale-portowe-lepiej-chronione-przed-materialami-nuklearnymi.html> (last access: 9 December 2017).

<sup>31</sup> M. Hollmann, Volume decline costs Hamburg No. 2 spot in Europe, JOC news, 10 February 2016, [https://www.joc.com/port-news/european-ports/port-hamburg/volume-decline-costs-hamburg-no-2-spot-europe\\_20160210.html](https://www.joc.com/port-news/european-ports/port-hamburg/volume-decline-costs-hamburg-no-2-spot-europe_20160210.html) (last access: 9 December 2017).

<sup>32</sup> The Impact of Mega-Ships: The Case of Gothenburg, Report of the International Transport Forum, OECD, 11 January 2017, <https://www.itf-oecd.org/impact-mega-ships-gothenburg> (last access: 9 December 2017).

<sup>33</sup> A. Grzelakowski, M. Matczak, Współczesne porty morskie, funkcjonowanie i rozwój, Wydawnictwo Akademii Morskiej w Gdyni, Gdynia 2012, p. 30-32.

- providing port services with the use of tools such as TQM (total quality management), HRM (human resources management) approach, process management and service process automation,
- basic development factors are innovation, technologies, and information.

According to A. Grzelakowski and M. Matczak, the distinguishing criteria of a fourth generation port correspond to the essence of a modern container port which is integrated with global supply chains via a computer network. However, similarly to the classification introduced by J. Semenov, they do not touch on the issue of the depth of port basins. Consequently, this classification cannot be used to explain the causes of the significant increase of container turnover in newly constructed ports (beginning of the 21<sup>st</sup> century) such as Wilhelms-haven in Germany, or the DCT in Gdańsk, Poland. They were constructed due to an insufficient depth of the other container ports in Hamburg, Gdynia, or Gothenburg.

## **2. Seaport classification in respect of creating added value**

The gradual increase of containerized cargo volume transported by sea in subsequent years of the 21<sup>st</sup> century contributed to the achievement of the highest level of port volumes in history – TEUs 699.7m in 2016<sup>34</sup>. The only year when maritime container transports were down being 2009, when the economic crisis was especially noticeable. Simultaneously, technical progress enabled construction of container ships of an increasingly larger capacity which in turn enable more cost-efficient cargo transports due the scale effect. In 2003, the 8063 TEU OOCL megaship was launched and in 2017, the largest container ship in the world was commissioned, also for the OOCL ship owner, having a capacity of 21 thousand TEU<sup>35</sup>. During its first voyage from Asia to Europe, the vessel, the only one to exceed 21 thousand TEU capacity, entered the DCT in Gdansk<sup>36</sup>. Along with an increase in the size of the constructed ships, this period saw significant developments in IT technologies which are not only applied by the

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<sup>34</sup> UNCTAD forecasts indicated a 3% increase of port volumes in comparison to 2016. Review of Maritime Transport, UNCTAD, 5 October 2017, [http://unctad.org/en/Publications\\_Library/rmt2017\\_en.pdf](http://unctad.org/en/Publications_Library/rmt2017_en.pdf) (last access: 9 December 2017).

<sup>35</sup> S. Saxon, M. Stone, Container shipping: the next 50 years, “Travel, Transport and Logistics” October 2017, McKinsey, <https://www.mckinsey.com/industries/travel-transport-and-logistics/our-insights/how-container-shipping-could-reinvent-itself-for-the-digital-age> (last access: 9 December 2017).

<sup>36</sup> Zawinięcie w dniu 28 czerwca 2017 roku, <http://www.portalmorski.pl/porty-logistyka/36100-najwiekszy-kontenerowiec-swiata-dzisiaj-w-gdansk> (last access: 9 December 2017).

largest container ports in the world such as Shanghai, Singapore, or Hong Kong, but are also implemented by an increasing number of ports of continental or regional importance.

M. Flynn, P. Lee and T. Notteboom proposed supplementing the port generation classification adopted by UNCTAD with a fifth level of seaport development. The most significant differences in functioning between fourth and fifth generation ports according to M. Flynn are shown in table 4.

In 2016, P. Lee and J. Lam ordered the stages of seaport development based on two criteria: creation of an economic added value, and the complexity of the port supply centre. They distinguished<sup>37</sup>:

- level one – simple loading/unloading operations ports,
- level two - logistic ports providing various services including warehousing,
- level three - ports being a part of the supply chain, making use of bilateral electronic data exchange, i.e. exchanging data with the customers,
- level four - global e-ports transferring information on a global scale, having global standards of cargo handling,
- level five - ports focused on customers and the local community offering deep IT integration with various stakeholders.

The fifth generation port is characterised with an increased complexity and better possibilities for creating added value than the ports of the previous generations which is shown in Fig. 1.

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<sup>37</sup> P. Lee, J. Lam, Developing the Fifth Generation Ports Model, (in:) Dynamic Shipping and Port Development in the Globalized Economy, ed. P. Lee, K. Cullinane, Palgrave Macmillan, London 2016, p. 188.

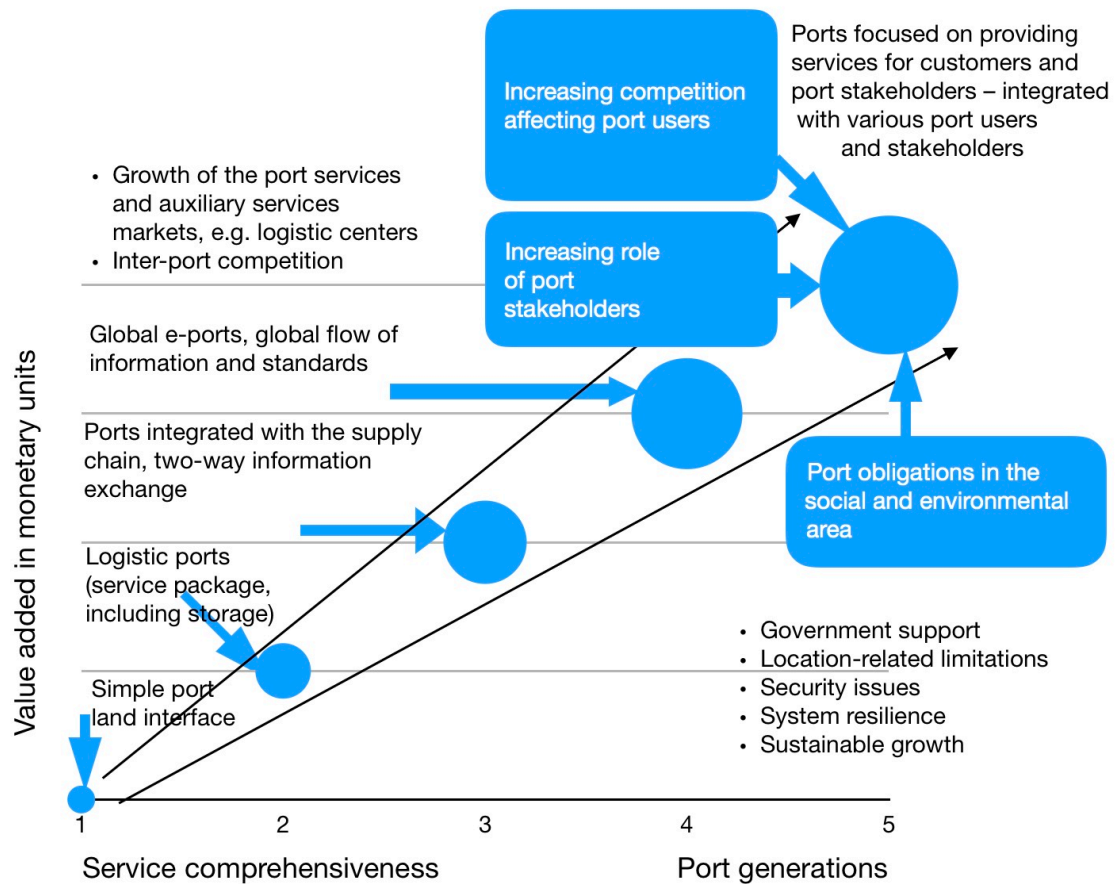


Figure 1. Evolution path of generation five ports according to P. Lee and J. Lam

Source: own elaboration based on P. Lee, J. Lam, *Developing the Fifth Generation Ports Model...*, p. 188.

Bearing in mind the increasing expectations of the main port stakeholders, i.e. ship owners, loaders, and local communities, it would seem that an unprecedented scale of coordination of activities at the mesoeconomic level. Generation five seaports must actively cooperate with municipal, regional, and national authorities in order to address conflicts and set priorities enabling an undisturbed exchange of cargo between the port and its hinterland, and ensure a high level of security, cost rationality, and generate progressively smaller external effects on the environment. It is important for a 5GP to shape its strategy and solve problems of the local community in a manner ensuring sustainable development.

Table 4. Comparison of UNCTAD fourth generation ports and M. Flynn, T. Notteboom and P. Lee generation five ports.

<b>Criteria</b>	<b>4<sup>th</sup> generation port</b>	<b>5<sup>th</sup> generation port</b>
<b>Quality of provided services</b>	compliance with regulatory requirements and general standards	exceeding the standard of services expected by port stakeholders
<b>Application of IT solutions</b>	limited to customs clearance and tracking the cargoes in the port	focusing on the level of quality of services, security, and increasingly better efficiency. Application of computer technology for the provision of port services and to predict events and measure results
<b>Influence on port stakeholders (environment)</b>	limited to compliance with planning procedures and environmental planning procedures	active approach towards stakeholders in order to coordinate planning and the process of mutual decision-making
<b>Port cluster</b>	operated under procedures of port area development	port services fully integrated with the port's mission and vision. The port authority plays the role of a "cluster leader", contributing to the increase of added value in the port
<b>Maritime cluster</b>	examined independently of port functions	functionally still outside the port cluster, however, by establishing creative financial incentives, it draws new ship owners and loaders, creating new jobs and added value
<b>Logistic hub</b>	development of the logistic function, as an expansion of port functions, as well as creating duty-free zones and logistic parks near the ports	logistics is a part of a maritime supply chain, air transport for valuable cargo and cargo requiring fast delivery. Advanced duty-free zones, as well as logistic parks near ports
<b>Land connection (hinterland)</b>	development of land connections in result of natural evolution	ports develop strategies of connections with the hinterland by their pricing policy and constructing a system of economical incentives aimed at securing loaders against such a development of the connection network which would harm the customers' interests

Source: M. Flynn, P. Lee, T. Notteboom, The next step on the port generations ladder: customer-centric and community ports, (in:) T. Notteboom, Current Issues in Shipping, Ports and Logistics, University Press Antwerp, Brussels 2011, p. 503.

In 2015, P. Lee and J. Lam developed the first adjustment of the criteria of recognising ports as category five. It was a result of a very general description of the indicators which

made it harder to empirically compare the largest container ports in the world such as Shanghai, Singapore, Hong Kong, or Busan, in regards to meeting 5GP requirements. For this reason, the need arose to increase the level of detail of the criteria<sup>38</sup>:

- the task of 5GP IT systems is efficient handling of port users via a “single window” system, as well as to inform the port stakeholders about technical-operational indicators which may be important thereto, as well as about environmental indicators concerning e.g. current level of emissions,
- the task of a constructive dialogue between 5GP with port stakeholders should be to plan terminal capacity including in particular, planning the development of port quays and making use of a financial incentive system for ship owners to operate ships in an ecological manner,
- the role of a 5GP within the port cluster should active enough, so that through the port activities (those of the port authorities) the quality of logistic services increases (so-called logistic hub) as does the added value generated in the port,
- the role of the port within the maritime cluster is to create financial incentives in order to draw ship owners, forwarders, and shipping agents,
- the role of the 5GP as a logistic hub is to improve relations with stakeholders from the port’s hinterland to create synergy,
- the task of the 5GP in the area of land connections is to apply a favourable pricing policy as well as a system of financial incentives for customers in order to improve cooperation, especially with intermodal operators and carriers in order to decrease the total costs of cargo transports,
- the task of a 5GP in the area of maritime connections is to take over containerized transit cargoes by participating in international supply chains in order to change the nature of the port from the port of destination (gateway), to a port which is competitive in the area of transit cargoes (transshipment centre).

Considering these modifiable criteria, according to P. Lee and J. Lam, the closest port to meet the conditions allowing it to be recognised as generation five is Singapore<sup>39</sup>. The con-

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<sup>38</sup> P. Lee, J. Lam, Developing the fifth generation ports model, (in:) P. Lee, Dynamic shipping and port development in the globalized economy, Palgrave Macmillan, London 2016, p. 191-192.

<sup>39</sup> P. Lee, J. Lam, Container Port Competition and Competitiveness Analysis: Asian Major Ports, (in:) C. Lee, Q. Meng, Handbook of Ocean Container Transport Logistics – Making Global Supply Chain Effective, “International Series in Operations Research & Management Science” 2015, Vol. 220, p. 97-136.

tainer terminals operating there provide maritime container stevedoring services of the highest quality in the world. The port has an efficient “single window” access to the system, also with the use of mobile devices (smartphones). The Singapore port plays an active role as a port cluster developer. The cluster includes bunkering services (the volume of fuel sold is one of the largest in the world), and the Singapore ship registry is in the top 10 largest in the world. The Singapore government promotes ecological solutions by lowering the initial registration fee by 50% and the annual fee by 20% for ships with less impact on the environment. In 2013, the Singapore government encouraged even more ecological (more costly for ship-owners) solutions for reducing emissions (installing so-called scrubbers), reducing the initial registration fee by 75% and the annual fee by 50%. The Singapore maritime cluster handles the port as a global container hub and a global hub for international traffic of all types of ships, not only container vessels. The Singapore port diverts special funds towards promoting ecological technical solutions (2011 investment programmes: Green Ship, Green Port and Green Technology cost SGD 100 million). A separate fund is intended to improve the productivity of the maritime cluster by targeted subsidies aimed at significantly improving the skills of workers in enterprises indirectly connected with the port (entities providing ship insurance, repairs, charters, or legal services)<sup>40</sup>. According to P. Lee and J. Lam, the active role of the port in Singapore makes it a fifth generation port. Additionally, the customs clearance procedures and short delivery times place it at the top spot according to 2012 World Bank estimates<sup>41</sup>. This has a favourable effect on attracting supranational corporations which establish their distribution centres at the port. The only important deviation from the 5GP requirements is the very limited hinterland comprised of the city of Singapore, a part of the Malaysian Johor-Mekka region and the Indonesian Riau Archipelago. Singapore’s access to the foreland through a network of 200 ship-owner companies which have ships entering 600 ports in 120 countries, as well through a network of container terminals (both dedicated and public) ensures its place as a fifth generation port. In 2016, P. Lee and J. Lam indicated new elements justifying placing the port of Singapore in the 5GP category. These included attracting an

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<sup>40</sup> Subsidies for short professional training are 90% and the subsidy for establishing a business connected with the widely understood maritime cluster is 70%. In 2016, the Singapore port dedicated a grant of SGD 12 million for recruiting new workers into maritime economy (from amongst the population of the Republic of Singapore and persons with a permanent right of residence). <http://www.mpa.gov.sg/web/portal/home/maritime-companies/setting-up-in-singapore/developing-manpower/maritime-cluster-fund-mcf> (last access: 9 December 2017).

<sup>41</sup> Ibidem.

international community of maritime ship-owners by way of tax cuts and exemptions<sup>42</sup>. The distinguishing factors of a fifth generation port have not been sufficiently specified in earlier publications, therefore, in 2016, P. Lee and J. Lam proposed measurable distinguishing features which are shown in table 5<sup>43</sup>.

Table 5. Criteria for defining a fifth generation port in accordance with the second amendment to the model by P. Lee and J. Lam of 2016

<b>Area</b>	<b>Feature</b>	<b>Criteria</b>	<b>Criteria explanation</b>
1	2	3	4
Port service	Service quality	(A1) Reliability	Port services provided to the port's customers are efficient, reliable, and high quality. These services minimise the level of customer uncertainty in regards to the services package provided at the seaport
Port service	Service quality	(A2) Port system flexibility	Port operators have at their disposal not only a flexible system (i.e. port supply centre) reacting to risks and accidents (including natural disasters), but also showing activity towards improving customer service standards
Application of IT solutions	Communications system	(B1) Single window system	Development of the single window system which integrates the port's IT systems and the logistic EDI system, with the use of IT tools, nanotechnology, and biotechnology

<sup>42</sup> P. Lee, J. Lam, Developing the Fifth Generation Ports Model, (in:) P. Lee, Dynamic Shipping and Port Development in the Globalized Economy, Palgrave Macmillan, London, 2016, p. 197.

<sup>43</sup> Ibidem.

1	2	3	4
Application of IT solutions	IT	(B2) RFID system or similar IT solutions	The use of RFID or other systems such as SWS (smart wearable systems) for container management at the port
Sustainable development	Port and city symbiosis	(C1) Port and city development coordination	Port and city authorities coordinate spatial plans in order to achieve sustainable development
Sustainable development	Ecological development	(C2) Integrated development	Integrated development of technical systems in order to decrease emissions and air pollution through financial incentives
Sustainable development	Ecological development	(C3) Developing an ecological (green) port	A friendly environment which means that sustainable development measures will benefit the port city
Cluster	Cluster creation	(D1) Port cluster management	Port cluster supported by both port and government policies
Cluster	Cluster creation	(D2) Maritime cluster management	Creative financial incentives and social infrastructure in order to draw owners of ships and cargoes by creating jobs and added value within the port and the cities clustered around it
Hub port	Global hub connections	(E1) Port infrastructure and superstructure	Capacity to handle megaships without technical restrictions in order to improve port service production efficiency
Hub port	Global hub connections	(E2) Maritime connections	Connections with other ports along with feeder connections for the largest ship-owner companies
Hub port	Logistic hub	(E3) Land connections and added value function	Logistic chain for creating high added value in connection with free trade areas and logistic parks

Source: own elaboration based on P. Lee, J. Lam, Developing the Fifth Generation Ports Model, (in:) P. Lee, Dynamic Shipping and Port Development in the Globalized Economy, Palgrave Macmillan, London 2016, p. 200-201.

### 3. New 6GP concept

The current classification of seaports explains the changes which have already occurred in ports around the world. Literature lacks results of predictive research which would allow to anticipate the classification of future seaports based on current criteria for a fourth or

fifth generation port. Quick changes in the vicinity of seaports, such as implementing new IT technologies, social network development, new methods of team and company management, are ahead of the development of the port supply centre. In result, seaport generation models are created as a reaction to changes in the global economy. Therefore, there is a need for updating the criteria of port assessment under the INCTAD or WORKPORT projects of the EU. While comparing WORKPORT and UNCTAD, A. Beresford drew attention to the fact that certain criteria could not have been taken into account (they were never before present in the port's reality). The current criteria of classifying ports into generations are not stable which makes both comparisons between ports and comparisons over time quite difficult. It would seem that criteria should be developed, of yet another port generation which will be connected with their functioning in the next 50 years.

T. Notteboom and J. Rodrigue propose a look on the current and future port development tendencies. They take account of the trends on the containerized cargo transport market on land on sea, limitations of logistic system effectiveness as well as that of the global supply chains<sup>44</sup>. A key issue is the conflict between the evermore effective container transport by sea using megaships and the atomised land transport which in many cases is not capable of handling the cargo volume without external costs such as congestions in ports, on roads leading thereto, and an inefficient rail transport. T. Notteboom and J. Rodrigue claim that subsequent seaports will be limited by the scale of development of the land transport system. It would seem that this criterion may be helpful with specifying the determinants of a sixth generation port. T. Notteboom poses a question about the nature of containerized cargo transports in 2056 (the hundredth anniversary of containerization) and proceeds to analyse the influence of the bargaining power of three groups of factors: economic, technological, and logistic. A possibility is also envisaged, of shortening supply chains in the event the economic powers decided on a regional nature of production<sup>45</sup>.

The future of seaports is also the object of interests of economic practitioners for whom in 1967 in the UK, the McKinsey company prepared a report on the future of containerization. It correctly predicted the popularisation of container transports, container standardisation, the creation of a hub and feeder port system, ship-owner company expansion causing an oversup-

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<sup>44</sup> T. Notteboom, J. Rodrigue, The future of containerization: perspectives from maritime and inland freight distribution, „GeoJournal” 2009, vol. 74, No. 1, p. 7-22.

<sup>45</sup> Ibidem, p. 18.

ply of transport services and even handling ships of over 10 thousand TEU capacity<sup>46</sup>. S. Saxon and M. Stone make the global containerization development conditional on macro-economic indicators such as GDP increase. By 2066, they predict (at minimum) an annual increase of the volume of containers transported by sea by ca. 1.9% (at maximum, by 3.2% annually). Unlike T. Notteboom and J. Rodrigue, they do not assume the risk of saturating the market with containers in this period (the peak of demand for containerized transport). S. Saxon refers to the market of crude oil transports by sea as a reference level for the size of container ships. He notes that despite the lower unit cost for container transports with a large container ship, ship-owners can simultaneously order an excessive number of vessels and once again lead to a significant oversupply of tonnage. This causes economic pressure on lowering the prices of transport and deepens the business cycle in this industry. S. Saxon warns that economic advantages of the scale resulting from an increase of a ship's capacity from 20 thousand TEU to 40 thousand TEU are significantly lower than those connected with increasing a ship's capacity from 10 thousand TEU to 20 thousand TEU. When increasing the ship's capacity, it can be lengthened, widened, or deepened which causes specific technical and economic effects. In 2017, megaships operated by container ship-owners did not exceed 400 metres in length due the size of port quays, difficulties in manoeuvring such a vessel, and the ports' custom to charge fees per every 100 metres of a ship's length. It would seem that in the future, only the simultaneous widening and increasing draught will allow to increase a ship's capacity. However, S. Saxon notes that a natural limitation of a ship's draught will be the depth of the Sues Canal which, after the recent modernisation, reached 24 metres. The depth of the Strait of Malacca is 25 metres which currently limits the size of the vessels sailing on that route, transporting crude oil (VLCC - very large crude carriers). The draught of Malaccamax type of vessels is 20 metres<sup>47</sup>. An alternative for megaships is to cross the Lombok Strait (near the Indonesian island of Java) located 1734 km south-east of Singapore which is 250 metres deep<sup>48</sup>. Container ships built in the future (post-Malaccamax) would have to significantly alter their routes, adding thousands of kilometres and thereby, by-pass certain seaports. The maximum depth of the Panama Canal, after dredging in June 2016, is only

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<sup>46</sup> S. Saxon, M. Stone, Container shipping: the next 50 years, "Travel, Transport and Logistics" October 2017, McKinsey, <https://www.mckinsey.com/industries/travel-transport-and-logistics/our-insights/how-container-shipping-could-reinvent-itself-for-the-digital-age> (last access: 9 December 2017).

<sup>47</sup> What are Malaccamax Vessels?, Marine Insight, 22 lipca 2016, <https://www.marineinsight.com/types-of-ships/what-are-malaccamax-vessels/> (last access: 10 December 2017).

<sup>48</sup> Own calculations on the basis of data taken from the wolframapha website, <https://www.wolframalpha.com/input/?i=distance+from+Lombok+Strait+to+singapore> (last access: 10 December 2017).

13.11 metres which allows passage of vessels up to the Neopanamax type, of a capacity of 13 thousand TEU, thus limiting the possibility of operating the newly designed megaships<sup>49</sup>.

Bearing in mind the limitations concerning the maximum ship draught, recorded in the McKinsey report and the remarks of T. Notteboom and J. Rodrigue concerning land connections with the hinterland, it would seem that the new, sixth generation ports (6GP) should have the three following characteristics:

1. ability to handle container ships of a 50 thousand TEU capacity, with a maximum draught of 20 metres,
2. full automation of the container terminal due to the significant volume of loading/unloading operations in a short time as well as significant progress of information technology over the last 50 years. The constant pace of development of new technologies such as the Internet of Things, or big data analysis, form a basis for maintaining the rate of IT and information technology development over the next 50 years,
3. handling intermodal connections with the hinterland which allow the transport of containerized cargoes with low external costs (e.g. connected without congestion).

Assuming a small number of high-level criteria seems to be a chance to make the criteria for a sixth generation port stable over time and simultaneously will allow a delimitation of the largest ports of the world over the next 50 years. In order to achieve the level of development characteristic for the 6GP, a port needs first to become a fifth generation supply centre. This will allow the sixth generation port classification to omit the four criteria for fifth generation ports proposed by P. Lee and J. Lam in 2016 concerning: information technologies, substantial development, the port cluster, and the hub port. As of 2017, no port in the world meets the 6GP criteria.

Seaports which meet the criteria of the fourth or fifth generation have a container stevedoring capacity allowing them to handle 22 thousand TEU ships (working with 22 - 24 rows gantry cranes). Ships of this size were already ordered by CMA/CGM and MSC and are scheduled for delivery in 2019. This means it would be necessary to withdraw a certain number of MSC ships of a capacity of 13 and 14 thousand TEU<sup>50</sup>. The ratio of ship size increase, calculated as a fraction of 50/22 (2.27 times) is much smaller than its equivalent from 2000 to

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<sup>49</sup> Data on the basis of the P&I Club, Great Britain, Bulletin 1102, 2 June 2016, <https://www.ukpandi.com/knowledge-publications/article/1102-06-16-update-panama-canal-draft-restrictions-panama-135271/> (last access: 10 December 2017).

<sup>50</sup> G. Knowler, MSC latest carrier to order 22,000-TEU vessels, [https://www.joc.com/maritime-news/second-carrier-places-order-giant-22000-teu-vessels\\_20170921.html](https://www.joc.com/maritime-news/second-carrier-places-order-giant-22000-teu-vessels_20170921.html) (last access: 10 December 2017).

2017 (2.6 times). Handling 50 thousand TEU ships would require a larger water overreach of the gantry cranes which poses a challenge for port engineers and designers due to the increasing dimensions of such a ship, which is shown in fig. 2.

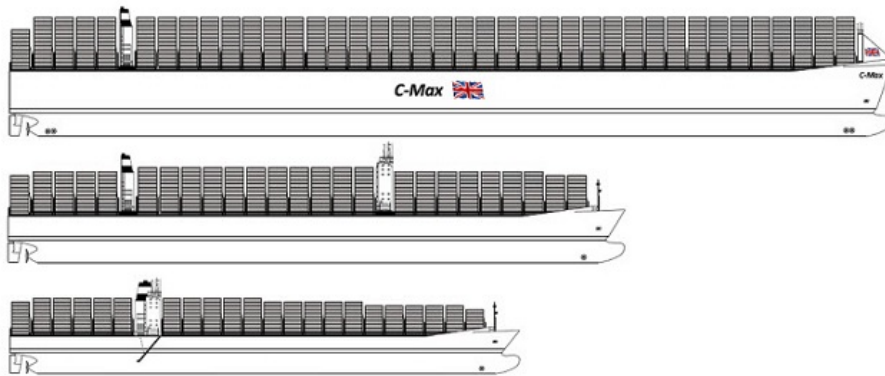


Figure 2. Size comparison of 10, 18, and 50 thousand TEU ships according to T. Bebbington.

Source: T. Bebbington, 50,000 TEU... the Future or Not?, Maritime Executive, 9 November 2017, <https://maritime-executive.com/editorials/50000-teu-the-future-or-not> (last access: 15 December 2017).

Megaship handling at a quay requires the latter to be of appropriate length and spacious storage yards. T. Bebbington calculates that a 50 thousand TEU ship will be ca. 470-500 metres long, wide enough to accommodate 32 container rows (ca. 93 metres), and with a draught of 20 metres. Such parameters require the ports to ensure sufficiently long quays which is shown in fig. 3. The sixth generation port would require an even larger storage yard area than those of the fifth generation which could be achieved with the use of innovative container storage and management at port yards.

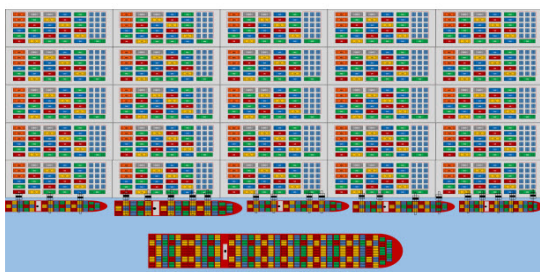


Figure 3. The visualisation of a call of a 50 thousand TEU vessel at a quay handling 18 thousand TEU ships according to T. Bebbington

Source: T. Bebbington, 50,000 TEU... the Future or Not?, Maritime Executive, 9 November 2017, <https://maritime-executive.com/editorials/50000-teu-the-future-or-not> (last access: 15 December 2017).

Stevedoring containers will be a technical challenge for ports which would be handling 50 thousand TEU ships, as the current largest quay gantry cranes (24-row) are unable to handle even half the containers transported thereby (fig. 4). The laws of physics dictate that the longer the overreach of the gantry arm towards the sea, the smaller the mass it can lift. The required length of nearly a hundred metres means that the crane structure would have to be stronger which in turn would entail making it wider, adding additional wheels and constructing crane rails which would transfer a significantly larger pressure to the quay structure than is presently the case. Widening the gantry crane has a negative impact on its operational parameters including the ability of accessing adjacent holds on the ships. T. Bebbington states that the current quay gantry crane construction technology does not allow for such a long arm over the sea, because then the entire crane would collapse under its own weight.

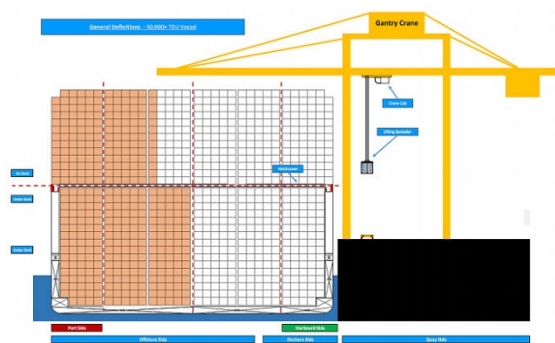


Figure 4. Limited capacity of 23/24 row cranes to handle a 50 thousand TEU ship according to T. Bebbington

Source: T. Bebbington, 50,000 TEU... the Future or Not?, *Maritime Executive*, 9 November 2017, <https://maritime-executive.com/editorials/50000-teu-the-future-or-not> (last access: 15 December 2017).

Considering the technical limitations of quay gantry cranes, T. Bebbington proposes placing one on each side of the ship which would require the terminal to be configured along the lines of the Ceres Container Terminal in Amsterdam. However, the abovementioned port was unable to cope with the increasing ship size, having a “U” shaped quay with 23-row cranes on each side<sup>51</sup>. The visualisation of handling a megaship from both sides is shown in

<sup>51</sup> The Ceres Terminal has been purchased by Hutchinson Port Holding (HPH) in 2008. Due to declining competitiveness, HPH decided to close the terminal in 2012. The Amsterdam port is difficult to access via channels from the seaside and limited in regards to the size of the ships it can handle. The two gantry cranes which were

fig. 5. Placing quay gantry cranes on both sides of a ship would require building two container terminals next to each other and their effective connection. T. Bebbington suggests that such a terminal can be constructed as a floating island, which may prove to be costly with the current level of technology, both in construction and in operation. The possible increase of ship capacity beyond 50 thousand TEU may cause the terminal area to be widened which is not possible in the case of a two side Ceres-type terminal. The floating island seems to be a feasible alternative only after mastering low-cost large space storage yards, their stabilising in space (by way of GPS, Baidou, or Galileo satellite positioning with high accuracy in relation to the ship), as well as accounting for the tides. Another issue is considering the mode of operations for such a terminal - fully or semi-automatic. Gantry cranes in automatic 4GP which are currently under construction perform ca. 26 movements per hour, while traditional ports, based on human labour at container terminals, reach an effectiveness of 30 movements per hour. The cost of automating the Middle Harbour in Long Beach, California, which has a capacity of 3 million TEU, is USD 1.5 billion which will offset in 40 years (the problem is the short term of licenses which is only 20 years)<sup>52</sup>.

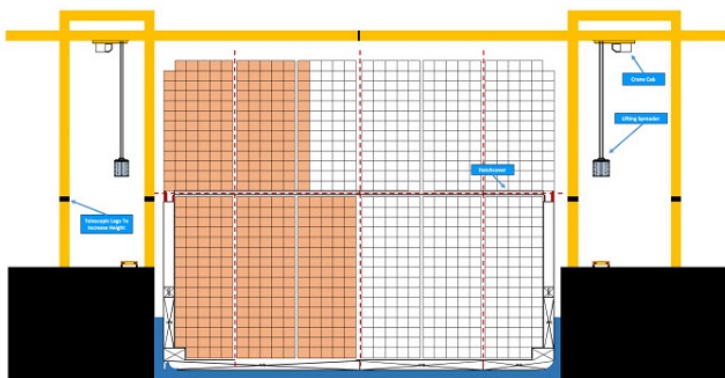


Figure 5. The visualisation of handling a 50 thousand TEU ship with the use of 23/24 row cranes according to T. Bebbington

Source: T. Bebbington, 50,000 TEU... the Future or Not?, Maritime Executive, 9 November 2017, <https://maritime-executive.com/editorials/50000-teu-the-future-or-not> (last access 15 December 2017).

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originally used therein, have been displaced to a sister container terminal within the HPH group - the GCT in Gdynia. <https://theloadstar.co.uk/amsterdams-white-elephant-is-put-out-of-its-misery/> (dostęp: 15 grudnia 2017 r.).

<sup>52</sup> US ports in no rush to follow Shanghai on automation path, JOC News, 11 December 2017, [https://www.joc.com/port-news/terminal-operators/shanghai-international-port-group/us-ports-no-rush-follow-shanghai-automation-path\\_20171211.html](https://www.joc.com/port-news/terminal-operators/shanghai-international-port-group/us-ports-no-rush-follow-shanghai-automation-path_20171211.html) (last access: 15 December 2017).

Sixth generation ports may be criticised due to the significant asymmetry between the costs and benefits arising from their impact on port stakeholders. Ship owner companies would achieve a lower level of unit costs thanks to distributing the costs of maritime transport among a larger number of containers. T. Bebbington notes the increasing demands of ship owners with regards to infrastructure and superstructure of container terminals able to handle 50 thousand TEU megaships. With current technology this is extremely costly. Container terminal operators (both public and private) would have to incur significant costs of port modernisation or constructing a floating port and bridges connecting it to the mainland. Ship owner companies often change navigation alliances as well as the ports on which their ships call. A loss of such an alliance would cause the port to quickly lose all its cargoes which increases the investment risk. Because of that, the need arises to change the model of contracting services between ports and ship owners, in order to ensure long-term financing for such a large investment. External costs may also be generated by limitations resulting from the atomisation of land transport which is mentioned by T. Notteboom and J. Rodrigue and includes pollution, congestion in result of the megaship call cycle on ports, as well as congestion on road and railroad routes in the region. The need arises for technical and organisational innovations which will make the sixth generation port a reality not only in technical terms, but also in the scope of economic and social feasibility and taking account of environmental requirements.

## **Conclusion**

Between the 1960s and early 2000s, seaports went through four generations in their development (according to the UNCTAD model). Due to the evolutionary (and not abrupt) process of developing these transport points, the WORKPORT model (financed by the EU) assumes the co-existence of ports and terminals of varying generations (even within a single port supply centre). Technical, organisational, and IT innovations allowed to broaden the package of services provided by fifth generation seaports as well as the scope and degree of cooperation between the ports and the stakeholder group. A 5GP is not only the main point of global sea transport connections, but also has a positive impact on the social environment and plays a role in nature protection. The rate of IT system and innovative transport technology development in regards to 50 thousand TEU megaships which will be maintained in the future, will probably cause a shift of cargoes between ports towards those able to handle large vessels, and a significantly larger cargo traffic on the landside. The article proposes to distin-

guish (by way of the indicated criteria) sixth generation ports (6GP) which will be able to efficiently handle vessels more than twice as large as those operated currently.

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## **FIFTH AND SIXTH GENERATION PORTS (5GP, 6GP) – EVOLUTION OF ECONOMIC AND SOCIAL ROLES OF PORTS**

**(Abstract)**

**Keywords:** maritime ports, port generations, fifth generation port, 5GP, sixth generation port 6GP, 50,000 TEU vessel

This paper examines the way that maritime ports have evolved since 1960s, reaching conceptual port development stages (generations) from the first to the fifth generation (P. Lee and J. Lam, 5GP 2016). Based on 5GP criteria an example of Singapore port has been critically discussed. This method is applied to the situation in Poland, as the country has overpassed Singapore in one category (24 hrs customs and admin clearance), yet needs further improvements in others. This article is of value to port managers in view of measures that can contribute towards closing the above gap (leading towards 5GP). Also, this paper addresses an under-researched theme in the extant literature on predictive ability of port generations. Future container vessel growth predictions, proposed by T. Notteboom and J. Rodrigue 2009 as well as 2017 McKinsey container industry research, require a matching port generation concept. Thus, a new sixth generation port (6GP) conceptual framework has been proposed. The criteria for 6GP include: port's ability to serve 50,000 TEU vessels of 20 meters depth; semi or full automation of a container terminal and strong hinterland transport links minimising negative externalities. As in 2017 none of existing ports fulfils criteria for 6GP, T. Bebbington's working paper has been critically analysed to elaborate on both technical and economic challenges to port strategy, planning decisions, as well as construction and operation of such a port in future.

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