# The modernization of commercial ports in the 19th century or the permanent adjustment process

by
**Pr. Bruno Marnot**,
University of La Rochelle

In the introduction to their article published in 1992, Yehuda Hayuth and David Hilling briefly describe the principles of sea port evolution, which are "determined largely by events and phenomena beyond their control"[1]. Consequently, ports, like any service provider, are obliged to adapt to the changes imposed by their clientele, namely transport operators, who are in a dominant position. Such a subordinate relationship, continue Hayuth and Hilling, implies that ports are equipped with the capacity to swiftly react to and anticipate the numerous problems of planning future facilities. Hayuth and Hilling's premise is based on the analysis of the evolution of the main European ports from 1965 to 1990; an evolution that was characterised by extremely rapid technological developments in maritime transport. A wealth of literature from historical, geographical and economic perspectives is dedicated to describing the transformation of the maritime and land transport economy, as well as its effect on the relationships between ports and cities during the second half of the 20th century.

Moreover, the work of many historians, in monographs and various thematic studies, has shown that the contemporary transformation processes of the port economy, as well as of city/port relations, appeared in the 19th century. They were established even after 1850, when, under the forward thrust of the northern hemisphere's new industrial powers, the planet underwent a process of globalisation that was then interrupted by the outbreak of the First World War. This analytical framework has guided our work on the transformation of the major French commercial ports during the century of the industrial revolution[2]. In particular, we have investigated the ways in which these changes occurred that completely caved to the new pressures of a global economic environment. Three sets of external pressures are clearly identifiable: the unprecedented growth of intercontinental trade, whether involving the transportation of passengers or goods, notably the explosion of transporting bulk cargo; the revolution of land and maritime transport characterized by considerable load capacities, increasingly faster and specialized (according to goods) modes of transport, all of which was increasingly controlled by powerful, profit-driven companies; lastly, new traffic organisation based on the workings of land transport networks and sea lines.

---

[1] Yehuda Hayuth and David Hilling, 'Technological Change and Seaport Development', in Brian S. Hoyle and David A. Pinder, eds., *European Port Cities in Transition* (London, 1992), 40.
[2] Bruno Marnot, *Les Grands Ports de Commerce Français et la Mondialisation au XIXe siècle* (Paris, 2011).

A port can be conceived of as a system: it carries out specific functions within a structure comprised of a series of inter-connected internal components, and links to the external environment. However, from the 19th century, port development, including both economic growth and physical development, was entirely determined by the requirements of the external environment[3]. Indeed, external pressures modified port structures and functions, and caused “clustering of innovations”, to use Schumpeter’s famous expression, within the port organism. These innovations, which came about in successive sequences of varied duration until the present day, all fit with what we have termed a “permanent adjustment process”[4]. Our study will comprise the analysis of the five distinguishing features of this process: technical adaptation of infrastructure and tools; spatial adaptation; adaptation of governance; selective nature of the adaptation process; non-reciprocal nature of the port modernization process. This article will concentrate on the evolution of the great Western maritime establishments, particularly those in France, which developed the most complex port systems of the 19th century, due to the leading role played by the industrialized countries of the northern hemisphere in globalisation between 1850 and 1914.

**Technical adaptation**

As Antoine Picon wrote, changes in the international economy had the knock-on effect of forcing the “technological paradigm” of port construction to change[5]. Additionally, the first half of the 19th century saw the journey from hydraulic architecture inherited from the Enlightenment, to the arrival of civil engineering specific to ports, which was able to respond to the challenges that arose[6]. The nature of construction changed in response to the new economic situation and through the development of innovative technology, which tended to be divided into increasingly specialized fields. One of the major consequences of the explosion of maritime trade and the nautical revolution was to conceive of port infrastructure on a new scale. Moreover, the constant renewal of naval equipment contributed to the accelerated rate at which the structures became economically outdated and thus decreased the depreciation period. This represented a new constraint which also resulted in technical problems. Changes to international trade had irreversible consequences on the port economy, resulting in, above

[3] David S. Hilling and Brian S. Hoyle, ‘Spatial Approaches to Port Development’, in David S. Hilling and Brian S. Hoyle, eds., *Seaport Systems and Spatial Change* (Chichester, 1984), 14. For a more general overview of the notion of systems, see Bernard Walliser, *Systèmes et Modèles. Introduction Critique à l’Analyse des Systèmes* (Paris, 1977).

[4] “logique d’adaptation permanente” Marnot, *Les Grands Ports de Commerce Français*, 63-69. Our ideas are more global than the model proposed by Loyen, which concerns the evolution of the structuring activities of the contemporary port. See Reginald Loyen, ‘Functional Shifts in the Port of Antwerp: A Throughput Model’, *International Journal of Maritime History*, 13, No. 2 (2001), 73-93.

[5] Antoine Picon, ‘Les Travaux Maritimes : de l’Architecture Hydraulique au Génie Civil’, in Jean-Louis Bonillo, ed., *Marseille, Ville et Port* (Marseille, 1992), 36.

[6] See, for example, Adrian Jarvis, ed. *Port and Harbour Engineering* (Liverpool, 1998).

all, major technological advances in several infrastructural domains, from the design stage to construction techniques and use of new materials. The science of maritime civil engineering had to make decisive progress to tackle the cluster of challenges it faced. In France, the higher education institution of engineering, *Ecole des Ponts et Chaussées*, ran a course dedicated to maritime civil engineering from 1828, which was taught by the institution's main specialists. The *Annales des Ponts et Chaussées*, a journal published yearly since 1830, allowed engineers to publish their theoretical work. Articles on port engineering became increasingly prominent over the decades: totalling less than seven per cent of articles in the 1830s, but twenty-seven per cent during the 1880s. This change reflected the increase in theoretical and experimental research undertaken during the 1860s-1900s. The thematic analysis of these studies (table 1), which was based on experiments carried out in ports in France and elsewhere, provides an indication of the engineers' main interests. The analyses dedicated to understanding tides and currents, as well as ways of protecting against them, made up the majority of the articles (fifty per cent), followed by the improvement of maritime channels and the related issue of dredging (thirty-four per cent).

**1. Distribution of thematic articles in the Annales between 1830 and 1947**[7]

| Theme of study | Number of articles |
|---|---|
| Rhythm and movement of the sea - wind - swells - tides - currents | 24 |
| Roads and outer harbours – dams and piers – breakwaters | 26 |
| Navigation locks – locks and scouring basin | 27 |
| Rivers and sea canals | 16[8] |
| Dredgers and dredging | 18 |
| Docks – quays – wharves | 19 |
| Port equipment | 13 |
| Dry dock machinery and shipbuilding sites | 16 |

Source: *Annales des Ponts et Chaussées*, table, 1934, p. 134-149.

The *Annales* quite accurately reflect the main concerns of maritime civil engineers. The most significant challenge the engineers faced was improving access for the largest ships by increasing the depth of channels and berths. The problems differed depending on whether the port concerned was on the sea front or a riverbank In the first case, the solution lay in replacing the natural riprap dams, significantly disadvantaged by their tendency to erode, with blocks of concrete, which guaranteed the stability of the structures against the power of the sea. In France, this new technique, tested by the

[7] Source: table, *Annales des Ponts et Chaussées* (1934), 134-149.
[8] For this theme, articles on interoceanic canals – 20 in total – were not taken into account.

engineer Poirel in the port of Algiers in 1833, was adopted for the construction of the large longitudinal pier of Marseille at the beginning of the 1840s. This daring solution, which made it possible to reach a depth greater than 10 metres, was the guiding principle for a succession of docks that were built according to need and, consequently, gave rise to the design of the new port built in front of the city[9]. The advent of concrete blocks freed up the design possibilities of structures built on the seabed, which increased in weight over the decades. At the dawn of the 20th century, they regularly reached between 100 and 120 tonnes per unit[10].

In river ports, the main challenge was to deepen the riverbed and modify its profile to allow the largest ships to come and go with optimum accessibility and safety. The construction of lower rivers was initially conceived in British ports. In France, the first structures on the lower Seine, the maritime Loire and the Gironde were completed from the 1840s. However, for a long time, the shoals that formed at river mouths and the silting of channels were major civil engineering difficulties faced with the absence of effective dredging technology. In fact, it was only after the boring of the Suez Canal, which required the development of powerful excavators, that this technology became available[11]. Indeed, since the 1830s, attempts had been made to improve access to the Lower Elbe, but decisive construction took place in the last third of the 19th century: in 1902, the channel was 10 metres deep at high tide for a 22-kilometre long section, which gave the largest vessels access to the port. Alongside empirical improvements, engineers specializing in hydraulics began theoretical research on the stabilization of watercourses.

The goal of meeting the new standards of maritime transport meant the internal development of ports demanded more and more of the engineers' time. Constantly adapting the docks to fit the size of craft, whose companies expected a greater turnaround speed in order to reduce operating costs, was another chronic problem of port engineering[12]. Invented in England in the 18th century[13], the dock-warehouse system which, with its dock impounded by a lock, guaranteed a constant water level, signalled a decisive solution. It was the forerunner of the wet dock that became widespread in the 19th century, in particular in ports with high tidal ranges. However, the concept became progressively controversial, due to the high cost of the locks and the fact that they became rapidly outdated faced with

---

[9] René Borruey, *Le Port Moderne de Marseille, du Dock au Conteneur, 1844-1974* (Marseille, 1994), 26.

[10] Emile-Théodore Quinette de Rochemont, *Des Changements Survenus dans les Conditions d'Etablissement et d'Exploitation des Ports Maritimes* (Evreux, 1908), 24. At the beginning of the 1930s, a concrete block could reach a weight of 450 tonnes.

[11] Dominique Barjot, *La Grande Entreprise Française de Travaux Publics, 1883-1974* (Paris, 2006), 82-84 ; Nathalie Montel, *Le Chantier du Canal de Suez, 1859-1869. Une histoire des Pratiques Techniques* (Paris, 1998), 554-565.

[12] In the context of a downward trend in freight rates, reducing the cost of transit through the port was one of the major concerns for shipping companies. This condition was, alongside the quality of services rendered, one of the essential components of competition between ports.

[13] Gordon Jackson, "The Ports", in Derek H. Aldcroft and Michael J. Freeman, eds., *Transport in Industrial Revolution* (Manchester, 1983), 177.

the ceaseless increase in craft capacity. Moreover, because of the time wasted in transit through the locks, wet docks were a growing handicap in the land-sea transport chain which continued to require increasing fluidity. This ultimately led to the Hamburg port authorities ceasing the construction of wet docks, after having consulted expert British engineers. Hamburg rejected the Liverpool model in favour of vast open docks. The first, Standhorhafen, was opened in 1866. At the beginning of the 20th century, the port comprised about fifteen such docks, covering approximately 500 hectares, which corresponded to roughly a third of the total surface area. In the 1870s, the new concept of the tidal dock, which was not separated from the sea by any barrier, thus became established in large commercial ports of the West. The main advantage of this new system was the consequent decrease in ship turnaround time, meaning vessels could now pass freely from the port to the sea at any time of the day or night. The major challenge for engineers was eliminating vertical tidal movements. The only requirement for building a tidal dock was a large draught, which could be obtained only by constructing high quay walls and carrying out deep dredgings. Thus, the dimensions of the Le Havre tidal dock, whose creation was sanctioned by the decree of 11 February 1909, was calculated to accommodate ships of more than 300 metres in length[14].

The creation of the "fast outer harbours", as some authors called them at the time, which were mainly dedicated to receiving large ocean liners, was just as remarkable. Sea lines were the ultimate innovative method of using the oceanic space in the 19th century[15]. Their creation caused an increase in layover sailing, insofar as the very principle of the regularity of departures prevented ships of increasingly large proportions from leaving fully loaded with goods or passengers. However, the new requirements for maritime transport to be cost-effective implied an optimal load factor on the part of the vessels. Consequently, layover sailing contributed to coastal construction because of the sharp increase in loading and discharging space required. Notably, the creation of outer harbours made it possible for river ports to reach the coast, at the cost of spatial duplication, thus regaining their competitive edge threatened by coastal ports. This is the logic that governed the creation of the docks of Hock (Rotterdam), Bremerhaven (Bremen), Cuxhaven (Hamburg) and Saint-Nazaire (Nantes). Even traditionally military ports, such as Brest and Cherbourg, created commercial ports from scratch on empty plots of land during the Second Empire (1852-1870) in the hope of attracting the clientele of transatlantic layovers. The advantage of these *ex nihilo* creations lay in the existence of land which could be easily divided into lots at little cost. This is also where the two generations of dock are found.

[14] Charles Laroche, 'L'Evolution des Travaux Maritimes de 1830 à 1930', *Annales des Ponts et Chaussées*, No. 9 (1931), 200.
[15] David M. Williams and John Armstrong, 'Technological Advances in the Maritime sector: Some Implications for Trade, Modernization and the Process of Globalization in the Nineteenth Century', *Research in Maritime History*, No. 43 (2010), 177-202.

The Saint-Nazaire outer harbour corresponds to the first era of modern ports, with the successive creation of two wet docks in 1857 and 1874. Whereas, the port of Abra, downstream from Bilbao, completed in 1902, consisted of a 200-hectare tidal dock, simply sheltered by the breakwaters of Santurce and the Algorta pier[16].

In connection with the increase in docks, the construction of built quay walls experienced rapid development from the 1840s and 1850s. In this area, there were multiple goals to work toward. The first objective was to deepen anchorage while gaining height, in order to facilitate the mooring of ships. Anchoring large ships outside of the port enclosure or in the river, loading and discharging with barges, was a form of time wasting that was increasingly incompatible with the new operating conditions that required faster and faster goods-handling. At the same time, engineers were obliged to reinforce the newly constructed vertical quay walls, as they now took on the function of supporting the wharf, which was invaded by increasingly imposing lifting machinery. Furthermore, the wharves had to be constantly widened to accommodate increasingly bulky storage areas and a growing number of railway tracks[17]. The engineers were thus charged with building quay walls capable of simultaneously bearing earth pressures, the traction produced by the mooring of large ships and the overuse of wharves. Their work was carried out in three dimensions: depth, width and length, as the 19th century ushered in the era of quays kilometres long to accommodate the maximum number of ships along the wharf. In France, the port of Rouen was used as full-scale laboratory for improving quay wall construction techniques. No fewer than 18 types of construction were used in the port in 1849, and such diversity of techniques notably complicated maintenance. The most used foundation technique of the time was the coffer dam, which consisted of draining the area where the work was to be carried out by means of a provisional dam. However, the limit of this technique came to light when it became necessary to deepen anchorage. The development of caissons, which were essential at the end of the 1870s in port engineering, solved this problem. In addition, the Rouen engineers chose the solution of building a wall on arcades supported by columns which had the benefit of not jutting out into the side of the river. This technical success led to the rebuilding of all the quays in the port from 1875. The work was completed five years later. Rouen now had the model example of a standardized quay, whose draught reached 7.50 metres

[16] Marthe Barbance, *Saint-Nazaire. Le Port, la Ville, le Travail* (Marseille, reprint 1979), 41,42, 64; Alexandre Fernandez, 'Bilbao, port industriel (1876-2006)', in Alexandre Fernandez and Bruno Marnot, eds., *Les Ports du Golfe de Gascogne. De Concarneau à La Corogne, XI^e^-XXI^e^ siècle* (Paris, 2013), 190.

[17] At the beginning of the 20th century, a well-equipped wharf had to contain 12 to 14 kilometres of tracks per kilometre of quay. See Marcel Hérubel, *Les Ports Maritimes* (Paris, 1943), 47.

in 1914[18]. At the beginning of the 1880s, the use of compressed air caissons was quickly extended to all types of port structure that required deep foundations, such as dams, tidal docks and dry docks[19].

The progress of the science of maritime construction thus generated a radically new design of the commercial port. The advent of the modern port was based on the guidelines of civil engineering now supported by theoretical principles and inspired by industrial techniques. The modern port was ultimately characterized by a physical change that did away with the partially "natural" character that could still be found in the ports of the first decades of the 19th century. In the space of a few decades, enormous rectilinear concrete blocks and more or less standardized structures on a huge scale became the norm. This gave ports the appearance of an immense facility, at once tertiary and industrial.

The transformations of port infrastructure were essential for the success of a second type of innovation that affected flow management and goods storage. This second form of technical innovation related to surface equipment that rapidly evolved to ensure faster transshipments. The modern port, whose aim was to meet the needs of industrial growth at the end of the 18th century, was born in England with the propagation of the "dock-warehouse" or the "English dock", as it was enthusiastically called by the first French engineers who had discovered the system at the beginning of the 19th century. It comprised a closed dock surrounded by a wall of multi-storey warehouses located at the edge of the quay. The dock became the instrument that allowed for the significant improvement of transshipment operations by shortening the distance between the ship and the warehouse, speeding up operations and the handling of large quantities of goods. As René Borruey summarizes perfectly, the English dock introduced "industrial precision to the port apparatus."[20] Furthermore, a second phase of constructing larger dock-warehouses began in England in the second quarter of the 19th century. New docks were thus built in Liverpool, a pioneer in this field, between 1824 and 1860 under the direction of the great engineer, Hartley. During those 36 years, more than half of the dock area of the port was constructed under his instruction[21]. In France, the construction of English docks came late and was limited: the first was built in Le Havre in 1854. The ports of Rouen, Marseille and Bordeaux followed the movement at the end of the 1860s. In contrast to England, the era of the dock-warehouse was thus short-lived in France. From the 1870s, a new rationale of pier construction tended to prevail, entirely subject to the urgent economic requirements of the transport chain. The shipping company, *Compagnie des Docks et Entrepôts* of Marseille, succinctly defined the principle in this 1871 text:

---

[18] Michel Croguennec, 'L'Aménagement du Port de Rouen de 1800 à 1940 : Contraintes, Techniques et Stratégies' (Unpublished PhD Thesis, Université de Rouen, 1999), 111-118.
[19] Barjot, *La Grande Entreprise Française*, 86.
[20] "la précision industrielle dans l'appareil portuaire" René Borruey, 'Le Port échappé, le Port Moderne et l'Espace de la Ville : l'Histoire de Marseille", in Michèle Collin, ed., *Ville et Port, XVIII^e-XX^e Siècles* (Paris, 1994), 86-87.
[21] Jackson, 'The Ports', 207; Hyde, *Liverpool and the Mersey. An Economic History of a Port, 1700-1970* (Newton Abbot, 1971), 82-83.

> the extension of the railway network and the almost equally considerable development of steam-powered navigation indeed make it possible for the largest shipments to pass from the ship's deck to the carriage and vice versa while hardly touching the quay, in such a way that the goods no longer need the warehouses, but instead great spaces, under the open sky or in a hangar, suitable for a short stay. Such are the new needs […].[22]

The "goods palaces" that were the dock-warehouses proved the structures increasingly unsuited to the growing coherence of the land-sea transport system, the explosion of transit traffic and the growing role of bulk cargo in port traffic. The falling demand for the services offered by the docks threatened the profits of the private companies that ran them, as seen in the docks of the port of London. Consequently, some of those private companies, such as the *Compagnie des Docks et Entrepôts* of Marseille, committed to modernising their equipment by increasing the mechanization of transshipment operations in order to increase productivity[23]. As a result, the function performed by warehouses in ports was no longer useful, whereas transit trade became increasingly important, because of the demand for regular and rapid supplies required by the continent's industries. A new storage concept, based on hangars and outdoor storage, was called for to replace the warehouse. The need to accelerate transshipment operations gave port constructions a fluidity that was missing from the dock system.

Cranes, essential components of docks and then hangars, became another norm of the 19th century modern port. As engineer Charles Viguerie reported to the national congress of public works in Paris:

> between the ships, on the one hand, and the dock warehouses, on the other, mechanical tools are the essential bridge […]. If we imagine the high operating costs of large ocean liners and high-tonnage cargo liners, we realize that the tools, such

[22] "l'extension du réseau de chemins de fer et le développement presque aussi considérable de la navigation à vapeur permettent en effet aux plus importantes cargaisons de passer du pont du navire sur le wagon et réciproquement en touchant à peine le quai, de sorte que la marchandise n'a plus besoin de magasins, mais de grands espaces, à ciel ouvert ou sous hangar, propres à un stationnement de peu de durée. Tels sont les besoins nouveaux […]" *Mémoire à l'appui de la demande en révision de la concession.* Cité par Borruey, *Le Port Moderne*, 195.

[23] Sarah Palmer, 'Port Economics in an Historical Context: The Nineteenth-Century Port of London', *International Journal of History*, 15, No. 1 (2003), 42; Borruey, *Le Port Moderne de Marseille*, 152-158.

> as the fixed structures of the port and the warehouses, must work towards the same goal: reducing the mooring time of the vessels to the bare minimum.[24]

Cranes went through a four-fold evolution involving their solidity, lifting capacity, mobility and the type of energy that powered them. Iron cranes made their first appearance circa 1850. At the end of the 19th century, the most widespread cranes supported loads ranging from 500 kilograms to 1.5 tonnes. To improve their performance, engineers integrated the various forms of energy developed during the 19th century, such as steam, of course, but also hydraulics, developed by two Liverpudlian engineers, Armstrong and Clarke. By 1850, this system already equipped the majority of English ports, but its propagation throughout the rest of Europe was rather slow. The appearance of electric cranes in the port landscape in the last decade of the century was the last stage of motorizing lifting operations. Thanks to the infinite divisibility of this form of energy, the electric motor had the unparalleled advantage of being able to support expansion of the site, which, moreover, offered better output. Furthermore, the major advantage of the electric crane lay in its automotive potential, since it could easily be fitted with an internal engine allowing it to move without capstans. Therefore, rail mounted cranes offered a new flexibility making it possible to position the machine in relation to the ship rather than the ship in relation to the machine, as was previously necessary. Finally, the handling of bulk cargo quickly forced the engineers to invent powerful and specialized tools. Consequently, tipping trucks, then wagon tipplers made it possible to accelerate the coal unloading process. Elevators and vacuums were developed for the transshipment of sugars and cereals. Successive innovations in transshipment and lifting devices accelerated in the last third of the 19th century and led to considerable productivity gains[25].

**Spatial adaptation**

The technical adaptation of the ports resulted in a considerable increase in their capacity to receive and process traffic, and a growing differentiation of the various zones of service and work. The second main feature of the permanent adjustment process was the change in scale of port sites. Several concomitant factors caused this double process of expanding and organizing port workspaces: infrastructure on a new scale, as mentioned above, the functionality of the port interface governed by new rules of intermodality, and, lastly, an increase in port activity. Thus, commercial ports grew in size in

---

[24] "entre les navires, d'une part, et les magasins des docks, d'autre part, l'outillage mécanique est le trait d'union indispensable […]. Si l'on imagine les frais énormes d'exploitation des grands paquebots et des cargos à fort tonnage, on se rendra compte que l'outillage, comme les ouvrages fixes du port et les magasins, doit concourir au même but : réduire au strict minimum la durée de stationnement des navires" Charles Viguerie, 'Note sur l'outillage des ports', *Actes du Quatrième Congrès National des Travaux Publics* (Paris, 1912), 9.

[25] While not the subject of our work, it is clear that the growing mechanisation of goods-handling operations had numerous, substantial, and indeed, permanent effects on the docker profession.

accordance with a twofold rationale: functionalist and cumulative. The functionalist element emerged from the necessity for each component to develop in harmony with the others so that the system could continue to provide services with optimal efficacy. Increasing the size of the docks to increase the port's reception capacity, meant, for example, considering new dimensions for wharves and warehouses, as well as improving access channels. It is no surprise that 19th century literature often considered ports, those permanent building sites, as "organisms", which could be described as tentacular, sprawling outwards as their various constituent parts expanded. The great French entrepreneur specialized in port construction, Georges Hersent, compared them "to a living being in the process of continual transformation."[26]

At the beginning of the 20th century, a French observer explained that "the constraint of the reduction of the duration of layovers [makes] it essential to adapt each port to the role it plays and even each part of the port to the function that it fulfills."[27] The functionality of modern ports was not only related to increasing goods-handling outputs and the speed of vessel manoeuvres. At the end of the 19th century, it was clear that an effective interface required the movement of goods from one surface to another be executed in the shortest possible time. Port developers had to increasingly take into account the new constraints of pre and post land-transport in the design of new port workspaces.

Transportation geography indeed showed that the node is the most delicate link in the transport chain because it is a point of discontinuity. This is particularly true of ports because this component is characterized by a threefold break in the chain: surface, mode and packaging. The designers of modern ports thus concentrated their efforts on improving the techniques that allowed for the enhancement of the "nodal sequence"[28], which was guided by the three principles of fluidity, speed and interconnection. The issue of port interconnection became more acute with the improvement of the transport chain which exerted considerable pressure on reducing the transshipment sequence. Ports were not only subject to the law of the ship, but also to that of land transport, in particular to the authority of the railways, whose right of way on the ground took up significant amounts of space. This explains the problems linked to the spatial restriction of sites that quickly arose from the installation of railways along the historical quays located near the urban environment. Confronted with this challenge, the ports of Bordeaux and Rouen, for example, were obliged to consider the plot of land on the opposite bank which was,

[26] "à un être vivant en voie de continuelle transformation" G. Hersant, *L'Outillage Economique de la France* (Paris, 1921), 8. Initially associated with his father, Hildevert Hersent, with whom he won fame with the modernization of the port of Antwerp between 1877 and 1902, Georges took over the company and built many ports in France and abroad. One of his largest creations was the construction of the new port of Rosario, in Argentina, between 1902 and 1913.

[27] "La contrainte de la réduction du temps d'escale [rend] indispensable d'approprier chaque port au rôle qu'il joue et même chaque partie du port à la fonction qu'elle remplit" Emile Manjot, *De l'Evolution des Transports Maritimes et de ses Conséquences sur les Aménagements et l'Outillage de nos Ports de Commerce* (Nantes, 1911), 41.

[28] "séquence nodale" Jean-Jacques Bavoux, Francis Beaucire, Laurent Chapelon, Pierre Zembri, *Géographie des transports* (Paris, 2005), 32-33.

fortunately, still undeveloped. Consequently, from the 1880s, a veritable rail-port complex emerged on the right bank of the port of Bordeaux under the guidance of the railway company, *Compagnie des chemins de fer de Paris-Orléans*. The construction and the rational organization of railway tracks proved even easier in zones on the site proper, as in the outer harbours built from scratch, which, by definition, avoided various socio-economic pressures and the constraints of old urbanization. Moreover, the installation of rail and river links in these *ex nihilo* sites was planned from the beginning.

Port interface equipment now constituted the structural elements of port architecture. The various systems for modern goods-handling required the quays to be rigorously organized to ensure optimal freight transshipment. Throughout the world, the construction of wharves took the form of a linear structure, with gantry cranes on the quay edge, linked to an initial railway, and behind that, hangars, covering a large surface area, as well as other railways and canals. The pursuit of maximum functionality demanded a certain standardization of equipment in large commercial ports. On the eve of the Great War, these ports, with their various shipping lanes and land transport networks, increasingly resembled veritable hubs of communication. Beyond the various individual cases which showed clear disparities in terms of equipment and functionality, ports formed the first platforms in the history of transport, the definition of which they fit perfectly: they allowed “not only the passage of goods from one means of transport to another, but also a true organization of cargo, flows, and trade.”[29] The issue of logistics thus became an essential new dimension in port organisation.

Ports also grew by accumulating functions, as it became vital for the local business environment to expand its range of services and activities in order to ensure that the port remained commercially attractive. This explains the growing space, in a literal and figurative sense, occupied by industrial functions in the reconfiguration of port sites in the 19th century. Consequently, various areas of the port tended to specialize according to the diversification of goods and the increase in functions. “A large port,” wrote Hersent in 1921, “is, so to speak, the collection of several specialized ports, with suitable architecture and tools.”[30] This vision already contained the seeds of the concept of the “port terminal”. It was not rare to find, for example, that each bank in large river ports had a specific economic vocation. In Rouen, the commercial port remained essentially the privilege of the right bank, the oldest one, while the new industrial and bulk cargo port developed on the left bank, at the beginning of the 1880s. Discharging bulk cargo and processing units also became essential structural elements in the spatial organisation of ports, which evolved into an increasing division of functions. The growing presence of heavy industry (iron and steel, mechanic, chemical, oil refineries), which preceded the industrial port

[29] Roger Brunet, ed., *Les Mots de la Géographie. Dictionnaire Critique* (Paris, 1993), 340.
[30] “Un grand port, c’est pour ainsi dire la réunion de plusieurs ports spéciaux, à l’architecture et à l’outillage appropriés” Hersent, *L’Outillage Economique*, 41.

zones of the 1950s, imposed new positional constraints because these large, polluting manufacturing units needed to be located near the raw materials and fuel, the storage of which required vast surface areas.

From the 1870s, this issue of space was accompanied by the issue of safety, due to increasing imports of oil. Ships going up in flames grabbed people's attention and made them aware of the dangers of the new product. At the beginning of the 1870s, the combustible and explosive nature of the product led to the development of regulations, which were most rigorous in France[31]. In Le Havre, for example, the precautionary measures meant the sites reserved for discharging oil were constantly moved away, until the construction of a site exclusively intended for mooring oil tankers to the east of the Bellot dock, between 1891 and 1897. From the 1890s, transport of bulk cargo and oil stores in the form of tanks appeared in ports, driven by new importation and refinery companies. All importation ports adopted these measures. The turn of the 19th century thus saw, within commercial ports, both the birth of the oil terminal, equipped with docks and specialized equipment having to fulfil new transport and safety requirements, and the appearance of the first tanksteamers.

Nevertheless, the process of spatial organisation in French ports did not improve to the extent seen in certain foreign establishments, such as Antwerp and especially Hamburg, which was a model example. In addition to the outer harbour of Cuxhaven, comprised of two deep docks capable of accommodating the largest ocean liners, the primary German port covered a surface area of 1,500 hectares with zonal specialization that was admired by foreign engineers. The port drew a particular advantage from the quality of the transportation and outflow of goods. The overall length of the quays was 64 kilometres, served by some 180 kilometres of railway tracks, the length of which was equipped with 80 hangars covering an overall length of 12.5 kilometres and offering 368,500 m² of storage. Transshipment operations were carried out by 750 gantry cranes of all types (fixed and mobile, steam, hydraulic and electric).

On the whole, the ceaseless search for space forced the authorities responsible for running the port to anticipate future requirements by implementing a land acquisition policy. Hersent was insistent on this aspect: "a port is never complete. Consequently, alongside its current plan, an *expansion plan must always be ready*: substantial surface areas must be reserved to this end […]. The port must be outside the city, as much as possible on flat land, in the middle of large available surface areas […] and easily accessible to the railways."[32] Thus, the Rouen chamber of commerce embarked on a land

[31] In Britain, the Petroleum Act was adopted in 1871. Regarding its concrete application in ports, see, for example, David Large, *The Port of Bristol, 1848-1884. Docks Committee Minutes* (Bristol, 1984), 102.

[32] "un port n'est jamais définitif. Par conséquent, à côté de son plan actuel, doit *toujours être tenu prêt un plan d'extension* : d'importantes superficies doivent être réservées dans ce but […]. Le port doit être extérieur à la ville, autant que possible en

acquisition policy from 1891. In 1914, 180 hectares were bought in total and put in reserve for future construction. The port development policy over the following 25 years relied on these undeveloped plots of land[33]. In his study on the Liverpool land acquisition policy, notably under the leadership of the Mersey Docks and Harbour Board from 1857, Adrian Jarvis has shown that this endeavour was age-old and, indeed, that it was an essential precondition for anticipating future technical and economic port developments[34].

Moreover, in the name of preserving unity, port expansion required the annexing of multiple suburban municipalities onto which the new equipment extended. In New York, it was not until the last decade of the 19th century that eminent domain legislation came into force. The municipality now had the means of repurchasing entire blocks between the 11th and 13th avenues to carry out the expansion project devised in 1880: of the 40 million dollars spent between 1870 and 1900 to equip the port with a system of modern quays, a quarter was allocated to the acquisition of private property[35]. Ports entered what the authorities of Rotterdam termed “the era of the land-hungers”: indeed, the great Dutch port increased in size by almost 6,000 hectares between 1869 and 1909, which corresponded to an increase of 862% of the initial surface area of the city[36]. The ultimate consequence of the spatial expansion of ports was the beginning, in several cases, of a separation from the original urban site. This territorial independence was the result of the new technical and economic vocation of ports in the industrial era, increasingly controlled by a site specific rationale.

**Adaptation of port governance**

The port technical and spatial modifications required new operating methods to be established, capable of reacting as quickly as possible to the new needs of the clientele[37]. In Europe and North America, various models of governance coexisted, from the most liberal, where the port was run like a

---

plaine, au milieu de larges superficies libres […] et facilement accessibles aux voies ferrées” Hersent, *L’Outillage Economique*, 47-48. The words are emphasized by the author.

33 Croguennec, *L’Aménagement du Port de Rouen*, 215-216. A study carried out in 1979-1980 by 40 port authorities demonstrated that the property issue was their principal concern for the future development of the port. See James Bird, ‘Seaport Development: Some Questions of Scale’, in Hilling and Hoyle, eds., *Seaport Systems*, 28-29.

34 Adrian Jarvis, ‘Land Policies in the Port of Liverpool, 1709-1857’, *International Journal of Maritime History*, 12, No. 2 (2000), 69-84; ‘Land Policies in the Port of Liverpool, 1857-1930’, *International Journal of Maritime History*, 14, No. 1 (2002), 115-133.

35 Heffer, *Le Port de New York et le Commerce Extérieur Américain* (Paris, 1986), 433-434.

36 André Vigarié, *Les Grands Ports de Commerce de la Seine au Rhin, leur Evolution devant l’Industrialisation des Arrière-Pays* (Paris, 1964), 357.

37 This issue remains pertinent. See, for example, Jacques Guillaume, ‘Les Mutations récentes de la Gouvernance des Ports Français sous la Pression des Contraintes internationales’, *L’Espace politique* [En ligne], 16, No. 1 (2012); Fernando González Laxe, ‘Gouvernance Portuaire : Principales Trajectoires dans les Ports Européens et Latino-Américains’, *Méditerranée*, N° 111 (2008), 53-59.

private company, to the state controlled model[38]. Between these two extremes, various mixed formulas were tested. In France, the operating method of the ports was increasingly believed to be inadequate regarding the new commercial realities and considered a major cause of the French establishments' inferiority in comparison with their European rivals. However, it has been noted that the higher dynamism seen in the last third of the 19th century in the great port systems of the European continent, such as Antwerp, Rotterdam, Hamburg and Genoa, relied on a form of understanding between the state, which considered the ports a great national interest, and local management, which was in line with commercial realities. In Belgian and Dutch ports, management came under the jurisdiction of, and was owned by, the city. The first mission of the state, which had renounced direct tax levies on port visits, was to build, improve and maintain the access channels to the sea (the Scheldt, Nieuwe Waterweg, the North Sea Canal). In the case of Belgium, the state also instated a railway policy entirely dedicated to the development of its ports, in particular, Antwerp. In addition to the capital injected by the municipal budget, the state granted loans and additional subsidies for infrastructural expenditure. It was particularly thanks to the support from its government that the city of Antwerp was in a position to complete quite impressive infrastructural works between 1860 and 1880 and to replace Le Havre as the continent's principal entry and exit point. The main advantage of this system, in which a large proportion of investment was borne by the urban and national population, was limiting the local tolls and, consequently, the price of services. The development of the port of Hamburg from the middle of the 19th century was also planned and financed by local government. To avoid interrupting this process following the unification of Germany, the port benefited from an anomaly. It could retain a considerable amount of autonomy thanks to the introduction of a tax-free zone intended to compensate for the city's incorporation into the Zollverein in 1888. Freihafen, whose surface area covered approximately two thirds of the 1,500-hectare port, was able to continue performing its function as a centre of reshipment, on which part of its prosperity relied[39].

In France, all the ports were state-owned. However, the state only considered them as a source of taxes, which made the cost of port transit particularly high compared with the ports of northern Europe[40]. The relative disinterest of the state explains why it was never able to instate a global policy for its ports, in contrast to what was done for the canals and railways. The role of centralised power mostly came down to approving loans in accordance with requests from municipalities and local chambers of

---

[38] A good overview of this issue is presented by Miguel Suárez Bosa, 'Introduction', in Miguel Suárez Bosa, ed., *Atlantic Ports and the First Globalisation, c. 1850-1930* (Basingstoke, 2014), 33-42.

[39] Vigarié, *Les Grands Ports*, 366-367; Veraghtert, 'The Growth of the Antwerp Port Traffic', 585. Different case studies are approached in Leo M. Akveld and Jacobus R. Brujin, eds., *Shipping Companies and Authorities in the 19th and 20th Centuries: Their Common Interests in the Development of Port Facilities* (The Hague, 1989).

[40] Shown notably in the survey by Théodore Laroche and Alexandre Plocq, *Etude sur les Principaux Ports de Commerce de l'Europe Septentrionale* (Paris, 1882), 2 vol.

commerce. In fact, the municipalities had to ensure the financing of initial construction works by advances made to the government. According to our calculations, local publicly-owned establishments invested forty per cent of the total amount allocated to non-recurring works over the period 1814-1910[41]. On the other hand, the centralized nature of the French system necessitated a lengthy approval procedure, which could last several months, if not several years, from the realization of the preliminary draft of a project to its approval by parliament. While the construction of new structures was accelerated by the pressure of competition, approval procedures tended, on the contrary, to be weighed down by the increasing size of the projects. The nation's lack of interest in its ports also explains why the chambers of commerce in port cities took the initiative to purchase and manage the superstructures. By a series of decrees and ordinances (1832, 1853, 1883), the state gradually extended its prerogatives in this field until the law of 9 April 1898, which formalised the new status of the chambers of commerce: article 15 specified that they could "be declared concessionaries of public structures and responsible for public services, in particular those which involve sea ports or the inland waterways of their district". The chambers of commerce, including the 16 of the largest French ports, numbered 27 at the beginning of the 20th century.

Consequently, the central role of the local chambers of commerce in the implementation and financing of modernization projects and the management of equipment led to them demanding more autonomy from the 1870s. A decentralized port management system would make it possible, according to its supporters, to put an end to financial waste and to complete alteration works with continuity, which would considerably accelerate their completion. A long power struggle subsequently began between the chambers of commerce and the state, which did not intend to lose control of port development. Until the First World War, proposals and counter-proposals followed one after the other without either side backing down. Finally, a compromise took shape between 1906 and 1912 around the idea of a syndicate managing the port, inspired by the Consorzio of Genoa set up in 1903: the administration and running of the port were handed over to a syndicate comprised of local representatives and the state, which appointed the president of the consortium, audited the accounts and held decision-making power regarding works of over 100,000 francs[42]. The broad outlines were included in the first law of port autonomy approved in 1912. However, its coming into force was deferred when the war broke out. A new law, adopted in 1920, entrusted the running of the port to a local organization. The autonomous port became a publicly-owned establishment with a legal personality and which, for this reason, was in control of its budget. The management of the port was provided by an administrative council and a

---

[41] Marnot, *Les Grands Ports de Commerce Français*, 187.

[42] Assemblée Nationale archives: report by Léon Janet, session of 13 July 1906, in *Annales de l'Assemblée nationale, de la Chambre des députés et du Sénat*.

director appointed by the state. The remit of the council was widened, since it was "called upon to deliver its opinion on all the issues concerning public services and involving the port". However, nothing stipulated that its directorship would be automatically assured by the president of the chamber of commerce. Within the council, the representatives of the local chamber of commerce were no longer in the majority. Works were authorized by simple decree when the share of the expenditure borne by the state was to be less than 10 million francs. On the other hand, works likely to involve major modifications to structures and access channels to the port would have to receive the approval of the public works administration. The law of 1920 thus gave the state primacy. With the exception of Bordeaux and Le Havre, the chambers of commerce of the principal ports refused to enter into this regime of autonomy, the adoption of which was optional, because they regarded it as largely false.

Furthermore, it is interesting to note that the extreme decentralization of the British system also had negative results. From the end of the 18th century to the middle of the 20th century, the only goal of the various governments' decisions was to encourage competing investments between the various ports with the aim of reducing running costs and ultimately improving their competitive edge, which was perfectly aligned with the theories of free trade and competition[43]. Consequently, parliament was assailed by constant requests for works on behalf of the various port authorities but, as in France, it did not seek to instate a policy aimed at creating an effective and coherent port system. From the 1850s, its only ambition was to reduce the port operating costs by limiting the rights of the docks. In actual fact, this form of short-term governance had harmful effects on port facilities. Paradoxically, many port authorities were low in capital, while competition forced them to invest. Consequently, many authorities called for a large-scale development policy when manufacturers, in particular from the cotton sector, waited for the government to provide the least expensive system of transport possible. Governmental negligence was clear at the end of the 19th century, when the digging of deep water docks required substantial investment. In fact, only the rapid expansion of maritime trade and the long-held dominant position of British commerce masked the failure of the state to coordinate port development. However, for Gordon Jackson, the situation is clear and echoes what was established in the French case, but for different reasons: the British government did not have the concept of a national port system because the ports were not one of the state's main interests[44].

**Adaptation and selection**

---

[43] Gordon Jackson, 'Ports, Ships and Government in the nineteenth and twentieth Centuries', in Paul C. Van Royen, Lewis R. Fischer, David M. Williams, eds., *Frutta di Mare. Evolution and Revolution in the Maritime World in the 19th and 20th Centuries* (Amsterdam, 1998), 169. Also to see in the same volume, Adrian Jarvis' article, 'Attempts at Reducing the Expenditure of the Port of Liverpool, 1836-1913', 177-193.

[44] Jackson, 'Ports, Ships and Government', 170.

Overall, the multiform changes confronted by the ports required the use of colossal and ever-increasing financial resources over the long term. The permanent adjustment process was, consequently, a selective process which came about to the benefit of the largest establishments: due to the substantial investments and importance of fixed costs, port facilities obeyed the rules of economies of scale, playing the numbers game in terms of the concentration of traffic. Table 2 shows, in the French case, the exceptional push of non-recurring funds, that is, expenditure devoted to new structures, between 1879 and 1900, the period that corresponds to the great public works program launched by the French minster of public works, Charles de Freycinet. This table also shows that the share of the efforts devoted to the 16 largest French ports[45] gradually increased from the beginning of the 1830s, until the pooling of more than three quarters of investments between 1879 and 1900.

**2. Evolution of non-recurring funds by category of ports under the various political regimes from 1814 to 1900 (in francs)[46]**

| **Political regime** | **Bourbon Restoration 1814-1830** | **July Monarchy 1831-1847** | **Second Republic 1848-1851** | **Second Empire 1852-1870** | **Third Republic 1871-1878** | **Third Republic (Freycinet Programme) 1879-1900** | **Total 1814-1900** |
|---|---|---|---|---|---|---|---|
| Total non-recurring expenses for the whole of the ports (1) | 23,558,286 | 122,498,933 | 28,990,094 | 228,882,341 | 114,004,715 | 557,741,165 | **1,075,675,534** |
| Total non-recurring expenses for the 16 ports **(2)** | 17,743,199 | 77,879,371 | 18,503,892 | 152,591,275 | 86,218,228 | 430,205,989 | **783,141,954** |
| Ratio (2) / (1) | 75.3 | 63.6 | 63.8 | 66.6 | 75.6 | 77.1 | **72.8** |

However, this result is misleading, since the intensity of the budgetary input is meaningful only when compared to the evolution of the ever-increasing needs of the port systems. The true measurement of public investment must thus be appreciated in light of the evolution of ports' commercial activities. Additionally, the annual average of non-recurring expenses should be related to the average foreign trade, that is, the category of port traffic requiring the development of new infrastructure. The calculation of the average rate of annual investment for the 16 large ports shows that this sharply declined under the Third Republic (table 3). The budgetary input which made it possible to keep up with the changes in traffic was not continued beyond 1870[47]. These 16 large ports, which handled eighty-one per cent of the total foreign trade in French ports in 1850 and ninety-two per cent in

[45] At the end of the 19th century, the French administration divided commercial ports into three categories, depending on the amount of traffic: 7 category I ports, 9 category II and the rest category III.
[46] Source: Ministère des Travaux Publics [Ministry for Public Works] (MTP), *Actes législatifs et dépenses concernant les travaux de navigation intérieure et maritime de 1814 à 1900* (Paris 1902).
[47] The good ratio obtained in the period 1848-1851 was not down to a supplementary investment effort, but by default, due to the stagnation of traffic following the economic crisis of the middle of the century.

1913, received only 69.1% of the funds intended for the modernization of infrastructure over the period 1814-1910. It seems, therefore, that the funds assigned to the various categories of port were not proportional to their commercial activity, even if the value criterion of foreign trade to establish their real economic weight is missing. The new capital investment program put forward in 1901 by the minister for public works, Pierre Baudin, tried to change this tendency by proposing to focus financial input on the elite French ports: on the Atlantic coast, Dunkirk, Le Havre, Saint-Nazaire and Nantes were to receive the highest financial input, because they possessed the best assets in the field of international competition. On the Mediterranean coast, Sète was supported because of its recent modifications, and a vigorous budgetary input was to be made for Marseille, increasingly threatened by the growing dynamism of the port of Genoa. This selective policy was to be supplemented by a rapid improvement of the connections between neighbouring ports and the land borders of France. Indeed, Baudin had correctly grasped that, at the turn of the century, the explosion of transit trade had become a major aspect of port competition, as was shown by Antwerp's superiority in this area over Le Havre[48]. However, his capital investment programme was distorted by the Senate, which decreed that public funds were to be redistributed.

**3. Average rate of annual investment in the 16 large French ports by political regimes[49]**

| | Bourbon Restoration 1814-1830 | July Monarchy 1831-1847 | Second Republic 1848-1851 | Second Empire 1852-1870 | Third Republic 1871-1878 | Third Republic (Freycinet Programme) 1879-1900 | Third Republic (Baudin Programme) 1901-1910 |
|---|---|---|---|---|---|---|---|
| **Annual average of non-recurring expenses** | 1,043,717.6 | 4,581,139.5 | 4,625,973 | 8,031,119.8 | 10,777,278.5 | 19,554,817. 7 | 18,847,225.1 |
| **Annual average of foreign trade (t)** | - | 5,007,081.8 | 3,578,976 | 8,050,478.8 | 14,455,044.3 | 25,494,441.8 | 43,544,536.3 |
| **Annual average rate of investment** | - | 0.91 | 1.29 | 0.99 | 0.74 | 0.77 | 0.43 |

This first approach tends to conclude that from the 1870s, that is, at the time when competition between large European maritime establishments intensified, France did not provide its large

48 Karel Veraghtert, 'Anvers et les ports français durant la seconde moitié du XIXe siècle', in *Les Relations Franco-Belges de 1830 à 1934*, (Metz, 1975), 114-119.

49 Sources: MTP, *Actes législatifs et dépenses* ; Administration des Douanes, *Tableau général du commerce de la France avec ses colonies et les puissances étrangères,* 1831 - 1910.

commercial ports with the means necessary to fight. Their development took place in a context of increasing underinvestment, which resulted in chronically undersized infrastructure. None of the bills relating to the situation of the French ports at the turn of the century mentioned the large European ports, which appeared to be constantly at an advantage compared to the French establishments. Observers enviously noted the incomparable levels of investment that were authorized in other European ports. The best equipped French port, Le Havre, received 225 million francs between 1814 and 1913, whereas its direct foreign competitor, Antwerp, received 250 million francs over the 35 year period that preceded the First World War and Hamburg received approximately 400 million. Between 1870 and 1890, investments in Liverpool rose to nearly 260 million francs, accounting for twenty-two per cent of the 1.175 billion francs spent by English ports during this period. This sum, spent over one 20-year period, was equivalent to the total of the non-recurring expenses allocated to all French ports for the whole of the 19th century[50]. In contrast to Belgium, the Netherlands and Germany, whose establishments were direct rivals as entry and exit points for traffic to Europe, the insufficient concentration of financial input in the largest French ports caused waste, an increase in the cost of services and a general loss of competitive edge for the French port economy.

A significant number of comparative investigations were launched from the 1880s as a result of French ports dropping out of the European hierarchy. A number of these studies revealed that the amount and quality of port facilities in the principal national establishments were disadvantageous. These criteria ultimately proved to be the most revealing as regards the insufficiency of the financial commitments to the modernization of commercial ports. The most significant report, by engineers Laroche and Pobeguin, was submitted to the fourth national congress of public works held in Paris in 1912. It was highly commented upon, including after the War. This first systematic study made it possible to evaluate the standard of facilities in the seven largest French ports (Dunkirk, Le Havre, Rouen, Nantes, Saint-Nazaire, Bordeaux, Marseille) compared to a sample of European competitors (Cardiff, Bristol, Liverpool, Genoa, Antwerp, Rotterdam). The authors, who insisted on the empiricism of their investigations[51], presented their results in nine synoptic tables. The first three tables, regardless of

---

[50] Hersent, *L'Outillage Economique*, 29 ; Hyde, *Liverpool*, 116. The par value of the pound sterling at the beginning of the 20th century approximately corresponded to 25 francs.

[51] The authors specify in the introduction that "les statistiques sont acceptées et employées telles que les ont fournies les ports qui ont bien voulu répondre au questionnaire posé. On n'y a apporté d'autres correctifs que ceux qu'imposait le sujet même de l'enquête, par exemple en éliminant des quais ou bassins manifestement inutilisables par les *cargo-boats* modernes" [the statistics are accepted and used as they were provided by the ports who wanted to participate in the questionnaire. We made other corrections to the questionnaire imposed by the subject of the study itself, by, for example, removing quays or docks evidently unusable for modern cargo-boats]. See Charles Laroche and Emile Pobeguin, 'Etude Comparée de l'Outillage des Ports Français et Etrangers', *Actes du quatrième Congrès National des Travaux Publics* (Paris, 1912), 1.

maritime and commercial activity, compared the fixed components of the ports[52]. Whereas the other six, in which one of the terms of the report was the total annual traffic, concerned commercial load factors, indicating to what extent the existing structures fulfilled their purpose[53]. The conclusions of this study clearly showed that the French establishments were not at an advantage. Indeed, in particular, the French ports were shown to have smaller wharves and lower mileage of railway tracks on the quays, as well as less sophisticated goods-handling machinery. It was not the number of lifting devices per se that was lacking, but the number of powerful machines with which foreign ports were better equipped, in particular transporter bridges for discharging coal. These shortcomings, in particular, meant that the quays were significantly more obstructed to the extent that the French ports had “to ensure a more intense unit traffic” but did not have “as many means of evacuating it.” The coefficient of capacity for goods evacuation in particular revealed the clear inferiority of French ports compared to foreign establishments, such as Bristol, Antwerp and Genoa. The quay railway tracks seemed to be the weak link in the French port interface. This conclusion should nonetheless be qualified, as the two experts only took into account the railway as the criterion for evacuating goods, whereas waterways were primarily used to this end in ports such as Le Havre, Rouen, Nantes and Bordeaux. The French ports fared better, on the other hand, regarding the obstruction of docks, which led to the two engineers stating that “in French ports, the ship is more at ease than the goods.”[54] In the conclusion of their report, the authors made the case for the budgetary input to be given to four or five ports “appointed according to their traffic, in order to put them at the height of the modern requirements for sailing and maritime trade.” Yet, they went on to state in a moment of clarity that “there is still much to do in this regard.”

**Single-minded adaptation**

The multiform process of the innovations introduced to commercial ports at an accelerated pace from the middle of the 19th century did not exert influence or have any repercussions on the functioning of maritime and land modes of transport, which constantly imposed their technical, pricing and commercial will. The fifth aspect of this logic lies in the non-reciprocal nature of principally adaptive innovations, insofar as the process of port modernization was carried out single-mindedly. The permanent adjustment process supports the idea that ports were put into a subordinate position, making engineers aware of a temporal disparity that was impossible to bridge between the rapid evolution of the

[52] Tables 1 to 3: coefficient of ability to evacuate goods, coefficient of lifting equipment, coefficient of fixing ability.
[53] Tables 4 to 6: coefficient of commercial use of docks, quays and wharves. Tables 7 to 9: coefficient of goods storage, coefficient of handling ability, coefficient of availability of forms of dry dock.
[54] “le navire est, dans les ports français, plus à l’aise que la marchandise” ; “tout désignés par leur trafic, afin de les mettre à la hauteur des besoins modernes de la navigation et du commerce maritime” ; “il reste beaucoup à faire dans cet ordre d’idées…” Laroche and Pobeguin, ‘Etude Comparée’, 2.

global economy during the second half of the 19th century and the significantly longer response time required to build new infrastructure. The disparity between the facilities on offer and demand from transport operators was a continual source of tension in traffic management. Indeed, at the end of the 1880s, the cargo liners of the *Messageries Maritimes* encountered insufficient facilities in almost all the ports around the world that they frequented. In the establishments where modern infrastructure was found, such as Yokohama or Alexandria, the company's agents stationed in the ports endeavoured to rent or reserve the berths that best facilitated mooring and were closest to the warehouses, but in the majority of cases, the ships had to moor to a buoy fixed to the roads[55].

The transport revolution and the globalisation process, which became established in second half of the 19th century, plunged the engineers, as well as the maritime business community, into unchartered waters. This uncertainty affected all sectors of the port economy. The engineers' task was now all the more complicated, as uncertainty factors accumulated over time. This succession of sources of uncertainty, which determined the new infra and superstructural norms, can be summarized by the following outline (table 4). The breadth and diversity of the technical challenges, mentioned above, take on their full meaning in relation to the concept of adaptation, which refers to both the issues of uncertainty and anticipation.

**4. Uncertainty factors and solutions provided**

| Sources of uncertainty | Solutions |
|---|---|
| 1° evolution of traffic in quantity and in kind | → increase in storage surface area<br>→ specialization of storage zones |
| 2° evolution of the size of vessels and their load capacity | → improvement of port access<br>→ deepening draughts |
| 3° decreased turnaround time of vessels due to new requirements of profitability imposed on ships | → adaptation of shape and size of docks<br>→lengthening quays to increase mooring zones |
| 4° Acceleration of land-sea transshipments | →increased mechanization of lifting operations<br>→ improvement of interconnecting structures |

Uncertainty was one of the major causes of the proliferation of technical expertise, which could also reflect, in certain cases, the differences in judgement between the various decision-makers, sometimes transformed into rival factions. Indeed, the choices made had serious consequences since they were not only supposed to respond to the pressures of the present, but also of those yet to come. Therefore, the technical solutions which were proposed largely relied on calculations which looked to

55 Marie-Françoise Berneron-Couvenhes, *Les Messageries Maritimes. L'Essor d'une Grande Compagnie de Navigation Française, 1851-1894* (Paris, 2007), 548.

the future of the port system over the long, indeed, very long, term. This accounts for the obsession in the field of port engineering in the 19th century with anticipating changes in the economic environment. A culture of anticipation within the community of engineers gradually emerged and ultimately drew on a large amount of their knowledge. The port entities' capacity to react ultimately accounts for the pursuit of the mode of governance best adapted to providing solutions as quickly as possible. The obsession with flexibility accounts for the repeated requests to shorten proposal approval procedures. In France, this was one of the major concerns in the debate on port autonomy. In addition, it is important to remember that, in all ports, capital investment programs were the subject of numerous and long debates between stakeholders (port users, technical experts, senior officials, political leaders) during which they each defended their own vision of the future "growth path" of the port system. The general process of permanent adjustment should not overshadow the fact that the evolution of port systems also followed local developments, which were not only of a technical and economic nature, but also conflictual, insofar as port construction was the cause of constant tension between sometimes antagonistic lobbies.

The concepts of port growth and anticipation of major changes in the maritime economy were, and remain, complex data to master that had to be integrated into the basic knowledge of the engineers assigned to port construction. That is, these engineers had to justify the utility of future work based on economic judgements which had to, in turn, determine an optimal combination of technical options. In France, the civil engineers from the *Ponts et Chaussées* corps had developed from the first half of the 19th century a "very elaborate thought in analytical economics"[56] in the wake of traditional economic policy. Furthermore, it is no mere coincidence that the 1830s-40s, when the great communication networks were developed, saw a debate on the public utility of transport infrastructure emerge within the corps. However, the projects for the creation and development of port facilities were elaborated outside of this theoretical framework. Indeed, the conceptual and economic tools at the disposal of the engineers in connection with channelling or railway line projects proved to be useless for the designers of modern ports. Consequently, empiricism reigned in their projections. Indeed, in Rouen, the engineers calculated the shortfall in quay length according to the excessive rate of obstruction at the time and, above all, according to what was to come. But "reality [has shown] that the planning done by the engineers [was] difficult to implement precisely". It was consequently almost impossible to agree the quay length on offer with the demand from trade[57].

---

[56] "riche pensée gestionnaire" Bernard Grall's expression, *Economie de Forces et Production d'Utilité. L'Emergence du Calcul Economique chez les Ingénieurs des Ponts et Chaussées, 1831-1891* (Rennes, 2004), 4.

[57] "la réalité montr[ait] que la planification faite par les ingénieurs [était] difficile à établir avec précision" Croguennec, *L'Aménagement du Port de Rouen*, 167-168.

Additionally, as the great engineer Voisin-Bey wrote, the only rule to be followed was that of "réserver l'avenir" [ensuring the future]. Debates in the sections of sailing congresses devoted to port works were haunted by the issue of anticipation. Indeed, at the eighth International Sailing Congress, held in Paris in 1900, the American civil engineer, Corthell, presented a report that had considerable repercussions: it projected that, in 1923, the 20 largest ships would reach an average length of 233.2 metres with a width of 24.4 metres and an average draught of 9.4 metres. These assumptions relied on generous data acquisition relating to the characteristics of the major ports in the world, compared to shipbuilding statistics during the preceding 50 years (1848-1898)[58]. Despite this, technicians were constantly surprised by the predicted dimensions of their work. Almost every time, traffic growth forecasts and predictions of the evolution of the merchant navy's capacities were contradicted by the facts; hypotheses on the adequate size of port structures for the predicted traffic could only provide transient information at best. This culture of nascent anticipation resulted in a strategy of "open-ended flexible planning", as termed by James Bird, borrowing the expression from the engineer, Walker, who worked on the construction of the port of Belfast in 1830: "In Practice […] port planning is conceived to provide for a period of five years, the choices being operated in such a way that subsequently we keep open as many possibilities as possible […]"[59]. However, a century later, it was necessary to design constructions bearing in mind a longer time scale. Thus, on the eve of the Great War, the civil engineer from the *Ponts et Chaussées* corps, Yves Trocquer, protested against the restricted design of new infrastructure in favour of, on the contrary, planning big from the start. "What it is essential […] is to adopt a program of the future, to construct, from today, the new structures in such a way that, without having to demolish them, we can, when needed, realize the necessary depths and satisfy the requirements of craft." According to the engineer, this method had the twofold advantage of avoiding tying up large amounts of capital "in structures needed to provide current services than in the remote future" and "expensive wrong manoeuvres which the implementation of short-term projects involves," which could also lead to costly demolitions[60].

Le Trocquer's idea was also a way of highlighting the issue of the possible reversibility of facilities, which was the ultimate consequence of the permanent adjustment process. The reversibility issue was notably set out in the "port life cycle" concept proposed by Jacques Charlier, in response to

---

[58] Corthell's memoir was published in the *Annales des Ponts et Chaussées*, No. 1 (1907) I, 77.
[59] Cited by Bird, 'Seaport Development', 38-39.
[60] "Ce qu'il importe […] c'est d'adopter un programme d'avenir, d'exécuter dès aujourd'hui les nouveaux ouvrages de telle sorte que, sans les avoir à démolir, on puisse, le jour où il sera utile, réaliser les profondeurs nécessaires et satisfaire aux exigences de la navigation" ; "dans des ouvrages appelés à rendre des services effectifs que dans un avenir assez lointain" ; "les fausses manœuvres coûteuses qu'entraîne l'exécution de projets à courte vue" Yves Le Trocquer , *De la Politique Economique, Administrative et Financière à suivre en Matière de Travaux Publics. Ports Maritimes et Canaux* (Paris, 1914), 79.

James Bird's "Anyport" model[61]. Yet, since the 19th century, the issue arose of how to apprehend the effects of the reversibility, or not, of facilities in relation to the rapid changes of the economic environment. This matter became another constant of the morphological and technical evolution of port systems[62]. The issue of obsolete facilities was more acute in terms of infrastructure, whose permanent and massive character posed different, more complicated reversibility problems compared to superstructure. For example, when the new outer harbour of Saint-Nazaire was designed, the first proposal in 1837 included the construction of a 500- by 100-metre wet dock, equipped with a 5.7-metre draught. The dimensions of the dock were calculated in accordance with the largest steamers known at the time, which could load and unload there without difficulty. However, further enquiries proved controversial and the initial preliminary draft was quickly nullified. The unending debates between the opposing parties, with the aim of finding the best solution, contained their own trap. Indeed, the time factor forced the developers to constantly modify their proposals. It ultimately and unavoidably came down to a form of managing irreversibility, since this deferred important decisions and those likely to be detrimental to the growth of the port in the long term. Additionally, 11 years later, when the new project was definitively approved, the dimensions of the dock had to be increased. The outer harbour now comprised a large rectangle of 580 by 160 metres, flanked on the western side by a rectangle of 140 by 90 metres. Yet, even before the work was completed in 1856, the Nantes chamber of commerce noted with some resentment that "the dock of Saint-Nazaire has not yet been made available for business and already its insufficiency is clear for all to see." The rapid growth of the outer harbour's traffic was quick to confirm this prediction: the number of ships increased from 467 in 1857 to 1,541 in 1860 and the tonnage of the craft more than doubled in that time[63]. The issues of anticipation and reversibility are closely interwoven in this case: the dock, which would be unable to accommodate the largest ships in the near future, forced the local authorities to come up with another use for it and, consequently, to consider the construction of a larger dock so that the port was able to maintain its status as a transatlantic layover. Additionally, the municipality of Saint-Nazaire started a second and long-drawn-out battle for the construction of a second dock in 1857, the future dock of Penhoët, which came into existence in 1874. This time, the possibility for enlargement had been kept for the remote future.

## Conclusion

---

61 Jacques Charlier, 'The Regeneration of Old Port Areas for new Port Uses', in Hoyle and Pinder, eds., *European Port Cities*, 137-140.

62 Bruno Marnot, 'L'Irréversibilité dans l'Equipement des Grands Ports de Commerce Occidentaux au xixe Siècle : les Bifurcations d'une Trajectoire d'Innovation", Transportes, Servicios y Telecommunicaciones, No. 23 (2012), 20-33.

63 "le bassin de Saint-Nazaire n'est pas encore mis à la disposition du commerce et déjà son insuffisance est patente pour tous les yeux" Barbance, *Saint-Nazaire*, 41-49.

From the 19th century, which inaugurated, to use Charlier's expression, a new "long port life cycle", the permanent adjustment process became a stable feature of the construction of ports. These ports, centres of conflict in a system of intercontinental transport undergoing rapid change, became, in their turn, domains of continuous and multiform innovation. The concept of the "perpetual port" conceptualized by the engineer Pascal, where "works follow one another constantly,"[64] perfectly illustrates the idea that, from the 19th century, the static and immutable vision of the port was definitively broken, in favour of a dynamic, evolutionary and almost biological concept of the entity. However, this Schumpeterian dimension of constant "creative destruction" should be qualified because, in fact, two chronological sequences follow one another in the port design of the 19th century. The first corresponds to the era of crane mechanization (steam and hydraulics), wet docks and the dock-warehouses, due to the ever-important role of storage. This phase, covering the period 1820-1870, features the improvements brought to steam-powered navigation, the rise of sea lines and railway networks. However, this first technical port system of the late modern period was increasingly unable to meet the new requirements resulting from the improved intercontinental transport chain, the salience of the transportation of bulk cargo and the rise of transit trade. The solutions provided by civil engineering, from the 1870s-1880s, lay in the construction of tidal docks, lighter storage structures, faster transshipment machinery, increasingly rational and standardized organization of quayside equipment, as well as an increasing specialization of the various workspaces within the port. This new phase of adaptation corresponds to globalisation's rise to power and the beginning of the second industrial revolution. Consequently, the structuring principles of commercial ports remained more or less unchanged until the 1960s, when new pressures from the global environment moved the goalposts again. Nevertheless, the global trajectory of the technical innovation of commercial ports over the last two centuries resulted in the gradual disappearance of buildings and a growing presence of goods-handling equipment, physical proof of the increasing fluidity of transshipment operations and the gradual victory of logistics over the long-winded loading process. Of course, adaptation was necessary but not the only logic in the commercial development of ports: other factors came into play, on macro- (state business policy) and micro-economic levels (growth strategies devised by various local businesses). Lastly, it must be noted that while this permanent adjustment process began in the developed countries of the northern hemisphere, it reached, by its own rhythms and devices, the other ports of the world,

[64] "port perpétuel" ; "les travaux se succèdent constamment" Speech given at the Académie de Marseille by engineer Pascal, 21 May 1865. Cited by Marcel Roncayolo, *L'Imaginaire de Marseille, Port, Ville, Pôle* (Marseille, 1991), 307.

those on the periphery, whether under colonial influence or not, which also had to keep step with globalisation[65].

[65] See, for example, the collection of different case studies dedicated to the ports of the South Atlantic in Suárez Bosa, ed., *Atlantic Ports*.