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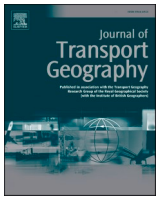

More claims than land: Multi-facetted land use challenges in the port-city interface

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ABSTRACT

Port areas in densely urbanized areas are locations where the lack of development space increasingly limits growth possibilities, and competition for space between stakeholders with diverging interests and land use claims intensifies. The aim of our paper is to enrich the scientific discourse on the port-city interface by arguing for a more multi-facetted understanding of the port-city interface beyond arguments of economic efficiency, and what this implies for how land use conflicts materialize and are dissolved. Based on quantitative data we have analyzed the characteristics of the land use conflicts in two case study areas (the ports of Rotterdam and Amsterdam in the Netherlands) in more detail. Furthermore, we developed a framework that could contribute to mitigating the effects of the land use conflicts, and have qualitatively explored this through an analysis of port visions and annual reports of the port authorities. The findings suggest that, even though the net claims do not yet outnumber the available land, the cumulative effects of these diverging interests do, which suggests that the battle for space is about to intensify as there are more claims than land.

1. Introduction

In the context of increasing urban populations, clustering economic activities in cities, and pressure on the urban landscape due to environmental pollution, the port-city is re-emerging as a relevant unit of study (Van den Berghe et al., 2023a). Port areas in or close to cities are locations where the lack of additional space increasingly limits growth possibilities, and competition for space between stakeholders with diverging interests and land use claims intensifies, especially for port areas where additional land is becoming increasingly scarce. This is especially true for the Netherlands, where the number of inhabitants per square kilometer and the density of urban planning activities are high (Witte and Hartmann, 2022). Environmental usage, pressure, and degradation are high, increasing competition for space in port areas. To some extent this is not surprising nor new (cf. Pellegram, 2001), as containerization has always put pressure on the spatial lay-out of port-city districts. However, increasingly, other land use claims resulting from underlying dynamics and trends such as energy transition and circular economy activities, climate adaptation and reducing urban heat stress, water quality and external safety, need to be equally considered.

From a vantage point of this increased diversity of land use claims, competition for space in the port city can be approached from either the urban (city-port) or the port (port-city) perspective (cf. Krośnicka et al., 2021; Monios et al., 2018). From the urban perspective, pressure on port sites might originate from increasing housing demand entering port areas and urban densification policies. For example, in the case of Amsterdam in the Netherlands, their newly planned 'Haven-Stad project' ('port-city district') is seeking large-scale residential development along the river embankment of the IJ-oever (Van den Berghe et al., 2023a). From the port perspective, pressure on adjacent urban space might originate from increasing demands on port functionality and innovation, energy transition, or climate adaptation (e.g., Dadashpoor and Taheri, 2023; Zheng et al., 2020).

Historically, the relationship between the port and the city has been close. Recently, the port-city interface has sparked renewed attention (Dadashpoor and Taheri, 2023; Fenton, 2020; Monios et al., 2018). This article focuses on this re-emergence of a close linkage between the port and the city, which, in our view, is becoming more tense as there is increasingly insufficient space. This might lead to a re-orientation, also in the academic debate, on the port-city interface, that traditionally has focused dominantly on arguments of economic efficiency. Land use conflicts could be 'avoided' by outsourcing industrial port activities

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towards peripheral port sites. This 'fleeing' of the port is no longer a viable option, since the entire port region is increasingly convoluted with port and urban land use activities in densely populated areas. We therefore argue for a broader, multi-facetted understanding of the port-city interface (based on Campbell's sustainability triangle) in which not just regional-economic development is considered, but also urban development and socio-ecological development (Campbell, 2016). This provides room to better acknowledge and incorporate the diversity of stakeholder interests in the port-city interface, including the local port community (cf. Moeremans and Dooms, 2024).

So, instead of outsourcing port activities to peripheral locations outside the port-city interface, the co-existence of port and city within the current space of the port-city interface increasingly becomes the norm in densely populated urban areas, leading to intensifying land-use conflicts. We apply this notion to two port cities cases in the Netherlands. This article aims to show how land use changes in port areas have developed over the past decades and what this implies for how current port-city challenges are addressed in the port's policies. This results in the following research question: How to identify and mitigate land-use conflicts in the port-city interface in densely populated areas? The added value of the paper is to enrich the scientific discourse on the port-city interface by arguing for a more multi-facetted understanding of the port-city interface beyond arguments of economic efficiency of the port, and what this implies for how new land use conflicts emerge and are dissolved. Based on quantitative data we have analyzed the characteristics of the land use conflicts in more detail. Furthermore, we developed a framework that could contribute to mitigating the effects of the land use conflicts, and have qualitatively explored this through an analysis of port visions and annual reports of the port authorities.

2. Renewed challenges in the port-city interface: A literature review

The relationship between port and city started with transport flows handled at quays, where cities began and grew and where maritime transport was facilitated (Ducruet, 2017; Ducruet, 2011). Various authors have analyzed this development of cities and maritime transport flows from a relational, or network, perspective (e.g., Van den Berghe et al., 2018; Jacobs et al., 2010). Over time, the relationship between port and city changed from maritime flows to facilitating port development and the port-city interface (Bird, 1963). This is well-captured in Bird's port development model, which consists of six phases, each involving an addition to or change in the physical layout of the port, which has been extensively discussed within the academic debate on port-city development.

In the last decade, attention shifted to the planning and governance of ports and the behavioral analysis of actors (e.g., Hesse, 2018; Daamen and Louw, 2016), which brings the port-city interface to the center of attention. It should be stressed that the above-mentioned port-city development models mostly originate from studies on Western port-cities. With the 're-emergence' of the port-city as a relevant unit of study, we come closer to port development models that are based on studying Middle-Eastern and Asian ports (e.g. Lee et al., 2008; Akhavan, 2017). In these contexts, the relations between port and city have remained closer, due to lessened hinterland penetration, and therefore, over time, far more reciprocal relationships between port and city have been consolidated.

Based on the combination of these scientific insights, we observe that – implicitly – different levels characterize the contemporary port-city interface literature: 1. the port region, 2. the port-city level, 3. the waterfront level. We incorporate these levels as important input into our theoretical framework. Besides the 'traditional' focus on the port's economic development also 'planet' and 'people' become much more important in port-city developments. By addressing different levels and dimensions of port-city development, the stakeholder spectrum is becoming more diversified, leading us to propose a multi-facetted port-city framework.

2.1. A multi-level perspective on the port-city interface

The scientific literature on the port-city interface has evolved over the years. Initially, it started as a theoretical concept especially focusing on the port and the city. In the last decade(s), however, the port-city interface broadened towards – on the one hand – a larger entity namely the port region and – on the other hand – to a smaller entity namely the waterfront. Increasingly, the port-city interface develops towards a larger region often constituting more ports and cities. On the lowest level, the waterfront especially focuses on housing entering port areas often together with creative and innovative industries. These three levels are integrated into our proposed framework and discussed below.

2.1.1. Highest level: Port region

Different recent studies have addressed the port regional level. Looking at the physical environment, Van den Berghe et al. (2023b) combined planning literature on polycentric urban regions with port geography literature on multi-port gateways to propose the emergence of polycentric port regions. Ducruet et al., 2020; Ducruet et al., 2018 state that vessel tonnage in ports coincides with the demographic size of the world's largest coastal and inland city regions and suggests that physical connectivity is important for port city regions and their spatial development paths. Regarding sustainability, Zheng et al. (2020) review research trends in port-city sustainability, but their geographical analysis does not distinguish different levels of port-city development. Finally, from a social change perspective, Witte et al.'s (2018) study regional dynamics in terms of entrepreneurship in the cases of the ports of Rotterdam and Montréal. Krośnicka et al. (2021) state that complex urban environments result at the port regional level because of all these diverging land uses in port areas. All in all, we observe in studies focusing at the port regional level an increasing awareness of competing and partially overlapping ambitions and land uses. This leads us to consider the next level, the port-city, where many of these competing claims materialize.

2.1.2. Middle level: Port-city interface

In Bird's port model, new port facilities were built further downstream in each phase than in the former. This resulted in a growing geographical separation of port and city and could be seen as the start of the port-city interface literature stream. It signaled the separation of port and city as both grew and needed more space, which – at that time – was abundantly available. Both Hoyle (1989) and Norcliffe et al. (1996) present an evolution of the port–city interface, in which the spatial separation between the port and the city is emphasized in terms of changes in land use without actually discussing the links between the city and the port: the port is geographically moving away from the city while at the same time the geographical overlap between the port and the city in terms of land use diminishes. At that time, the lack of discussion of the link between the port and the city was logical, as additional space for expansion of both port and city was available. Currently, this space availability for expansion has decreased, meaning ports and cities increasingly compete for the same space.

Wiegmans and Louw (2011) added port regulations to the basic Bird (1963) because these are also important for companies that settle in port areas. Port regulation refers to all sorts of regulation concerning port activities, such as environmental regulations (concerned with noise, fine dust, CO2, water quality, odor), transport (modal shift, tons handled per quay), spatial planning (land use), labor, safety and security. Adding these regulations indicates the widening scope from solely economics to economics and the wider environment in the port-city concept. Like Wiegmans and Louw (2011), Yu et al. (2020) emphasize the ecological perspective of spatial port-city relations. Furthermore, Liu et al. (2019) stress the mismatch and lack of coordination between port actors,

leading to lessened degrees of sustainability of port-city systems. Sustainability is also emphasized by Fenton (2020). The port-city interface is not just studied in terms of port operations and sustainability, but also urban transformation, planning and transition management perspectives receive increasing attention (e.g. Abaza et al., 2022; Jugović et al., 2021; Pugliano et al., 2018). Finally, various authors draw attention to spatial claims for new or innovative land (re-)use in the port-city interface, including technological developments, critical infrastructure development and circular economy (e.g. Dadashpoor and Taheri, 2023; Van den Berghe and Verhagen, 2021; Karimpour et al., 2020; Van den Berghe et al., 2020). All these studies signal the broadening and deepening of the port-city concept.

2.1.3. Lowest level: Waterfront

The final level of the port-city interface is the urban waterfront. Hayuth (1982) is one of the first authors to analyze the changing intrinsic relationship between the port and the city. Changes resulted in growing spatial and functional segregation of city and port and the changing landscape of the city-waterfront. The changes in the spatial and economic systems represent the same trend that other authors portray, but what is of particular interest here is the mentioning of the city waterfront, as this signals a new dimension for the port-city concept on a lower spatial level. Also, Daamen's (2007) study of the port–city interface in Rotterdam and Hamburg reports that local authorities are planning the redevelopment of current port areas and the development of new city areas close to the port. It is no longer only the abandoned port areas being redeveloped for city uses, as planners are also actively proposing to redevelop parts of the port near the city that are still in use for port activities. Daamen states the city and the port are engaged in "a similar battle to attract people and business." It is "often the city-waterfronts where the battle materializes, creating competing space-use demands and a zone of conflict for city and port authorities" (Daamen, 2007:19). This conflict could be further complicated by the ownership structure of the port authority (e.g. fully private, combination of public-private or fully public). What then needs consideration is how different port ownership models 'translate' into actual land allocation strategies pursued by port authorities acting as landlords.

Bird (1963) assumes that the port will retain much of the port areas adapted to new uses and develop new port areas suited to new ship types and cargo handling methods. The core question is: what will happen with port areas that have lost their initial function? Will they be redeveloped for port or city use? Charlier's (1992) work fits well within the literature on cities and their waterfront redevelopment. He argues that, before the port sites are transformed into city functions, the "residual maritime potential" should be assessed because this is "non-renewable." Once areas are transformed into city developments, the port functions will 'never' be able to return to these areas. These types of functional redevelopments were already mentioned in the light of the port regional level and new maneuvering space for creative industries (cf. Jansen et al., 2021; Witte et al., 2018), but recent research also brings to the fore the potential planning conflicts that can arise, for instance in terms of land ownership, heritage and culture, social and environmental justice and environment and resilience (Evans et al., 2022; Avni and Teschner, 2019). Together, these three spatial levels form the input for our theoretical framework to enrich the scientific research into the multi layered port-city interface.

2.2. A multi-dimensional perspective on port-city challenges

This section reviews the renewed challenges in the port-city interface, using Campbell, 2016, Fig. 1) to differentiate between multiple trade-offs. These trade-offs are linked to the development conflicts arising in the port-city interface of regional-economic, urban and socio-ecological development.

First, treating the port-city interface from the resource conflict between economic development and environmental protection, using or re-using raw- or building materials in the port-city interface, is a prime concern. Historically, port areas are sites of production and transshipment of building materials, which is a major driving factor for the productivity and economic growth of a port-city's region due to job creation, investments, agglomeration externalities, etc. However, on-site production is also often associated with negative externalities, such as environmental pollution, congestion, emissions, etc. (Yu et al., 2020). This negatively impacts the surrounding natural areas and those living and working in the port area (Teschner, 2019). Port expansion activities thus not only concern regional economic development opportunities but go hand-in-hand with increased environmental concerns (Daamen and van Bueren, 2016). This is also reflected in the contemporary discussions on circularity in relation to port development (e.g., Van den Berghe et al., 2020; Van den Berghe and Verhagen, 2021).

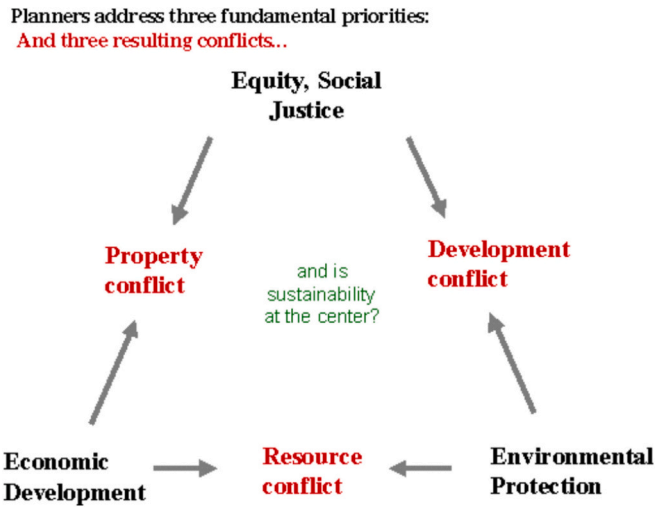

Fig. 1. sustainability triangle and trade-offs.
Source: Campbell (2016).

Second, the influence of the property conflict on the port-city interface is reflected best in the variety of land ownership structures in the port area, where publicly and privately owned land intermingle. This affects the potential of (re-)developing these areas for residential purposes. Different strategies can be pursued here, either aimed at integration and multi-functional land uses or focusing more on separation and avoiding mutually exclusive land uses. A relational approach is critical in analyzing how redevelopment of port areas plays out in practice (Bartłomiejski and Kowalewski, 2022; Hesse, 2018). When port areas are transformed, this is usually done in the context of urban waterfront regeneration projects (Wessells, 2014; Daamen, 2007). Such projects stimulate the attractiveness of these areas for commercial businesses and young urban professionals, leading to gentrification and rising real estate prices. This, in turn, affects the ability of port workers and the original residents or entrepreneurs in this area to continue living and working there.

Third, when the development conflict is applied to the port-city interface, any spatial interventions aimed at equitable and just urban development must be implemented environmentally friendly. This entails higher urban development and living costs for residents in the port-city interface (Yu et al., 2020). This is challenging, as a high presence of blue-collar workers historically shapes the socio-economic status of most port-city districts (Van den Berghe et al., 2023a). Urban development could negatively impact the availability of jobs within these districts. Next, new activities in these areas are often of a higher economic level and, therefore, unaffordable for the initial residents. In combination with rising real estate prices, this also influences potential displacement.

In redeveloping these areas, the ecological aspect needs to be considered, as the port-city interface is traditionally also an area that is

vulnerable to rising seawater levels (Punt et al., 2023; Daamen and van Bueren, 2016). However, the associated costs of climate-adaptive and green urban (re-)development likely further increase the already gentrified nature of the port-city interface. Also, the increasing spatial demands of accommodating water safety and the energy transition are an additional challenge that complicates the socio-ecological development of the port-city interface. This is, for instance, reflected in finding available space for offshore wind, hydrogen ecosystems, etc.

2.3. A multi-facetted perspective on port-city governance

In the last decades, the research into the port-city interface has broadened and deepened. This has led us to propose a new framework, reflecting these multi-facetted port-city challenges (Fig. 2).

First, the port-city has increasingly been understood from multi-level perspectives: the port region, the port-city interface, and waterfronts (Section 2.1). Secondly, the dominant economic perspective has come under pressure to give increasing room for multi-dimensional perspectives. We distinguish not just economic issues but also environmental, institutional and socio-cultural issues (Section 2.2). Finally, different modes of port-city governance come into focus. Governing these multi-level and multi-dimensional port-city challenges requires the engagement of a variety of stakeholders and adequate port stakeholder management (Notteboom and Winkelmans, 2002). Port businesses traditionally play a role from an economic perspective, but in light of a more multi-facetted understanding of port-city challenges it is also important to consider the municipality (formally in charge of land use zoning), the port authority (navigating their policies and management to also include environmental and urban interests, cf. Verhoeven, 2010, p. 254) and social acceptance of local communities (Moeremans and Dooms, 2024). Governing multi-facetted port-city challenges thus also requires a multi-actor collaboration between the port authority, port businesses, the local communities and governmental actors such as the municipality.

It should be noted that the relations between the elements of the framework (i.e., multi-level, multi-dimensional and multi-actor) are not deterministic. This is because the spatial level or sustainability dimension at which a potential land use conflict materializes is contextually dependent and therefore may vary from case to case. This is even more so because of the intermingling of different stakeholders, each with their own interests and agendas. For instance, whereas in one particular case a conflict between the economic and environmental dimensions may result in a port authority compensating port businesses' expansion by financing a nature conservation project elsewhere in the port region, in other cases it may be that municipalities try to alleviate negative social externalities to local community stakeholders by applying certain institutional rules or zoning conditions to industrial companies at the waterfront level. So, context is very important in applying this framework. It is for this reason that, in the following sections, we will apply this multi-facetted framework to competition for space in the institutional context of two Dutch port cities.

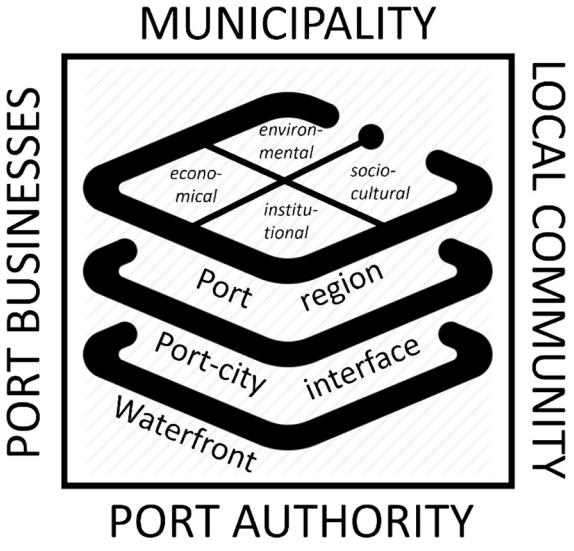

Fig. 2. Theoretical framework on the multi-facetted nature of port-city challenges.
Source: Authors' own figure.

3. Methods and case description: Development challenges in the Dutch port-city interface

3.1. Research methods

Land use conflicts in the port-city interface are particularly prevalent when large-scale port- and urban development ambitions meet in an already dense built environment with a relative scarcity of available space. The Netherlands presents such a context, in which we select two particular case studies: the port regions of Amsterdam and Rotterdam.[1] Some of the main characteristics of the cases are shown in Table 1.

Based on Flyvbjerg's (2006) work, we have the following arguments for selecting Amsterdam and Rotterdam as critical cases. First, they concern cases of large amounts of port activity taking place in densely populated urban environments. To illustrate, Rotterdam handled 438 million tons in 2023 Amsterdam handled 63 million tons in 2023. We might expect that insights derived from these cases may also hold for comparable cases in densely populated areas globally. Second, studying these cases allows us to zoom into the particularities of two different port-cities within the same overarching legal and institutional context (i.e. the Netherlands). Finally, because of the elaborate documentation on the respective port development strategies, these cases allow us to study the land use challenges not just quantitatively, but also qualitatively, which gives room for theory-building towards the more social aspects of port-city development.

We aim to investigate these cases through both quantitative and qualitative research methods. Quantitatively, we present an account of land use changes over the past 30 years (since 1985) to evaluate whether spatial pressure on the port-city interface is increasing. For the spatial analysis of the case study areas, we use the open-access IBIS database, which describes all Dutch port and industrial sites. Data are available from 1985 onwards. The database mainly contains planning-relevant information but no data on the actual use of space (i.e., company

Table 1
Main characteristics of the Amsterdam and Rotterdam port regions in 2022.

	Amsterdam	Rotterdam
Total transshipment (millions of tons)	95.1	467.4*
Share of Amsterdam / Rotterdam	83 %	96 %
Transshipment of containers (millions of tons)	1.3	139.6
Net area of port land in hectares	2491	6493
Share of Amsterdam / Rotterdam	56 %	97 %
Direct port employment	43,117	108,081

Sources: Yearly Reports of Port of Rotterdam and Amsterdam 2022, IBIS-database and Streng et al. (2023).
* Includes port of Dordrecht.

[1] With the port region of Amsterdam we refer to the entire 'Noordzeekanaalgebied' (NZKG), including the Port of Amsterdam. With the port region of Rotterdam we refer to the entire Rijnmond area, including the Port of Rotterdam. Whenever we refer to either 'Amsterdam' or 'Rotterdam' throughout the paper, we refer to this. Whenever we refer to the 'Port of Amsterdam' or 'Port of Rotterdam' specifically, we refer to the respective port authorities.

type). With the help of the IBIS data, insight can be gained into the size of the port sites and which sites are, over time, added to the port's perimeter (or removed). The analysis covers the period 1985–2022 and concerns the net area (the physical space in the port area that companies can use). This net area includes vacant land not yet used by companies. The analysis excludes the space for infrastructure (roads and port basins).

Qualitatively, based on desk research and a policy document analysis of port visions, progress reports of the port visions and annual reports of our case study areas since 2011, we give insight into how the port authorities deal with diverging land use claims and balancing different economic, ecological and social interests. We have done this by treating the texts of the port visions and annual reports as transcripts. First, we have limited the transcripts to segments of texts that are directly relevant to the purpose of this study, by selecting paragraphs that are dominantly focusing on key-words such as 'space', 'land', 'land use', 'environment', 'hectares', etc. Next, using open coding, we have marked and analyzed these relevant passages of text to form a coherent picture of how the ports have dealt with land use strategies in their strategic visions. A clear limitation of this method is that only the perspective of the port authorities is incorporated, and the experienced reality of port users and local port communities less so. Finally, the difference in the selected range of years (since 1985 for the quantitative data; since 2011 for the qualitative data) is due to data availability of both records.

3.2. Amsterdam port region: Port of Amsterdam and adjacent coastal and canal ports

The port region of Amsterdam consists of the Port of Amsterdam in the east, the coastal port locations of IJmuiden with the adjacent multinational company Tata Steel works with its own privately owned quays, and the ports of Velsen, Zaanstad, and Beverwijk. It spans the territory of six different municipalities (Fig. 3).

The Port of Amsterdam is the largest in the port region and is a bulk and production port. It is economically strong in energy (gasoline, diesel, coal), food (cocoa, coffee, soja) and animal food. Next to these sectors, cruise, wastewater treatment, energy generation and waste treatment play an important role in the port of Amsterdam (Provincie Noord-Holland, 2022).

The smaller ports in the area (besides Amsterdam) are strong in food, offshore energy, cruise and ferry, and the production industry (Provincie Noord-Holland, 2022). The main advantage of the IJmuiden port is that the port areas are located outside the lock, with direct sea access. Expansion possibilities in the port are limited. An important sector in the port of IJmuiden is fish (50 % of jobs), and the energy sector (25 % of jobs) is important (oil and gas, wind energy building and maintenance). A third sector is the ferry and cruise activities. A final important part of IJmuiden Port is Tata Steel's industrial production site. Currently, Tata Steel uses large quantities of coal and steel, which must be made more energy-efficient and sustainable (e.g., using electricity and hydrogen). The ports at Tata Steel are owned and managed by Tata Steel themselves. The presence of Tata Steel works ensures that the port of Amsterdam is less dominant in the Amsterdam region than the port of Rotterdam in the Rotterdam region (Table 1).

3.3. Rotterdam port region: Port of Rotterdam and its coastal expansion sites

The Rotterdam port region consists of the Port of Rotterdam, which we consider here in its entire perimeter, so ranging from the redeveloped urban port sites close to the city of Rotterdam to the coastal expansion sites of Maasvlakte I and Maasvlakte II (Fig. 4). It spans four different municipalities: Rotterdam and the smaller municipalities of Maassluis, Vlaardingen and Schiedam (Fig. 4).

The Rotterdam port region is the largest European seaport. The port is over 40 km in length and spans from the inner port-city sites in

Fig. 3. Overview of the Amsterdam port region (note: blue area = policy definition of 'Noordzeekanaalgebied'). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)
Source: Authors' own figure.

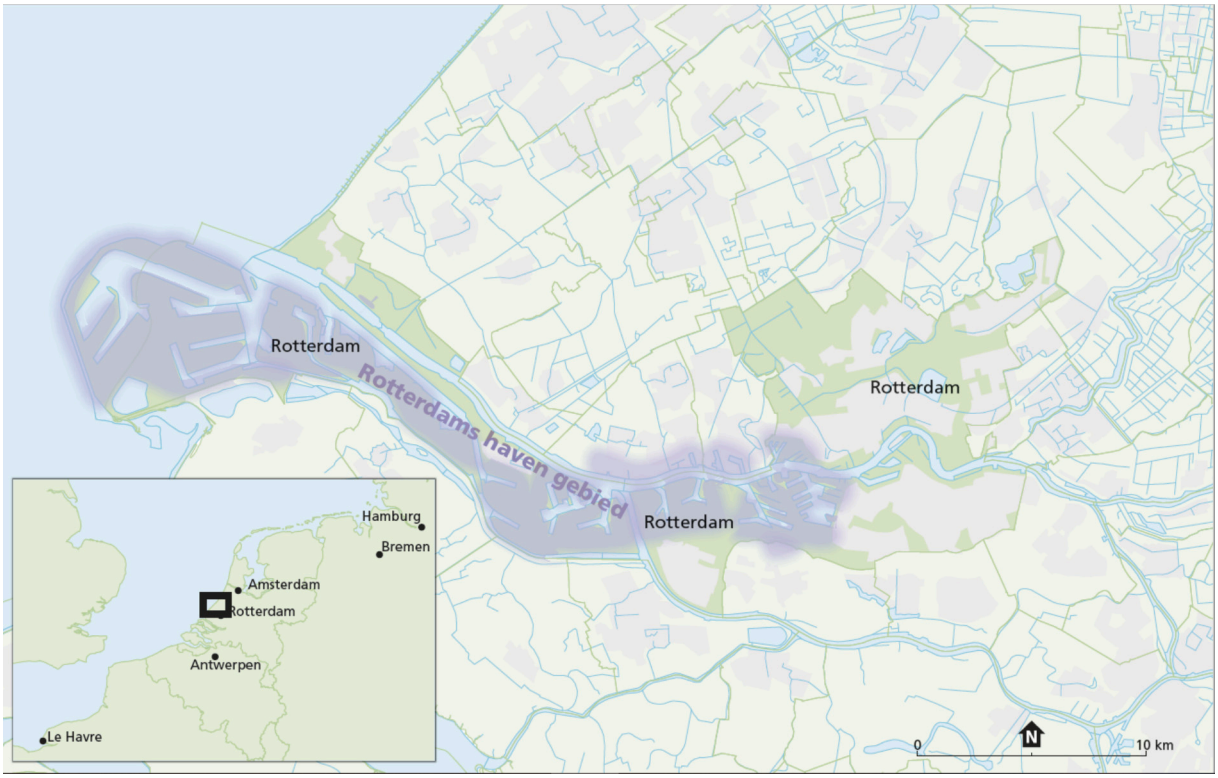

Fig. 4. Overview of the port region of Rotterdam (note: blue area = policy definition of 'Rijnmond'). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)
Source: Authors' own figure.

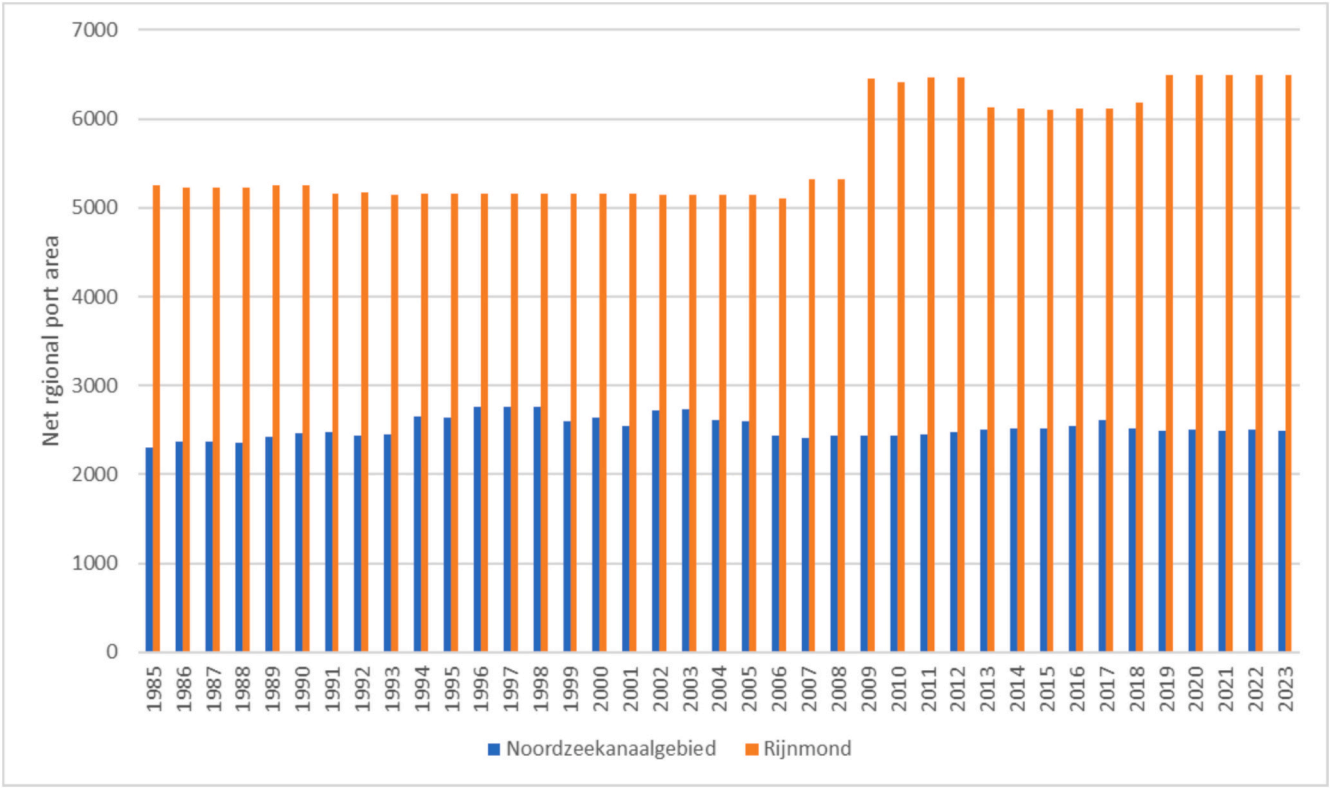

Fig. 5. Net area of port land in hectares in the Amsterdam ('Noordzeekanaalgebied') and Rotterdam ('Rijnmond') port regions.
Source: Authors' own based on IBIS data.

Rotterdam to the coastal Maasvlakte expansion sites. Due to the New Waterway, the port, for a large part, has direct maritime access. The surface area is 12,500 ha (land and water), of which over 6500 net hectares are dedicated to industrial sites (Port of Rotterdam, 2024). The Port of Rotterdam is economically strong in container handling and crude oil (on average 95–100 million tons yearly) processed by the four refineries in the port. Compared to the Amsterdam regions, the port of Rotterdam is larger in size and transshipment. Also, the port of Rotterdam dominates the port of the other municipalities in the region more than is the case in the port region of Amsterdam.

4. Empirical analysis: Land use and policy changes in the two Dutch port cases

The empirical section of this paper elaborates on the land use and policy changes over time in the two Dutch cases. The dataset concerning the land use changes has a timespan of approximately 30 years (i.e., since 1985). However, policy documents and annual reports do have a shorter time span and for a representative coverage we have limited this to anything published after 2011, as in earlier years the number of documents went down considerably. So, effectively, we have reviewed the annual reports from 2011 to 2023.

4.1. Spatial-economic development of the port-city interface: Land use changes over time

Fig. 5 shows the net port areas in the Amsterdam and Rotterdam port regions. It can be seen that the port area in the Rotterdam region is considerably larger than the port area in the Amsterdam region. The size of the port area in the Amsterdam area fluctuates around 2500 ha (including 700 ha of the Tata Steelworks). In comparison, the port area in the Rotterdam area expanded considerably in 2009 to almost 6400 ha. This is due to the coastal expansion of the Port of Rotterdam with the Second Maasvlakte.

Fig. 6 shows the share of the port area that is still vacant. This is land that is not yet officially transferred to companies and does not include land that has been transferred to companies but is not in use. In 1986, this share was approximately 20 % for both regions. After that, this share fluctuates sharply. The share in Rotterdam clearly shows that the increase in the port area in 2009 immediately led to an increase in vacant areas. Still, the share fell again as the Second Maasvlakte came into operation. The picture in the Amsterdam region is much more variable. Still, for both areas, the share of unused area in 2022 (Rotterdam from 20 % to 11 % and Amsterdam from 18 % to 8 %) is considerably smaller than in 1985, indicating that the percentage vacant land has decreased enormously which might indicate pressure on land use in the port areas.

Table 2 shows the extent of the loss of port sites (due to transformation) in 1985–2022 and the plans for transformation in 2023 and beyond. It is striking that the extent of the loss of port sites in the Amsterdam region is higher than in the Rotterdam region. Transformation not only concerns the transformation of former port or industrial sites into residential destinations but also transformations into mixed residential-work destinations. From these figures, it can be deduced that the pressure on the area of port sites in the Amsterdam region is greater than that in the Rotterdam region. In Amsterdam, the transformation area is larger than in Rotterdam, but the share of port land not yet in use is also smaller, so overall, the pressure on space is higher in Amsterdam.

To conclude, the port-city interface is in full development in both

Table 2
Area of transformed port site and area of transformation plans for port sites (in net hectares).

	Actual transformation between 1985 and 2022	Planned transformation in 2023 and onwards
Amsterdam	240	*153**
Rotterdam	64	*115**

Source: Authors' own based on IBIS data.
* Partly estimates based on planning documents.

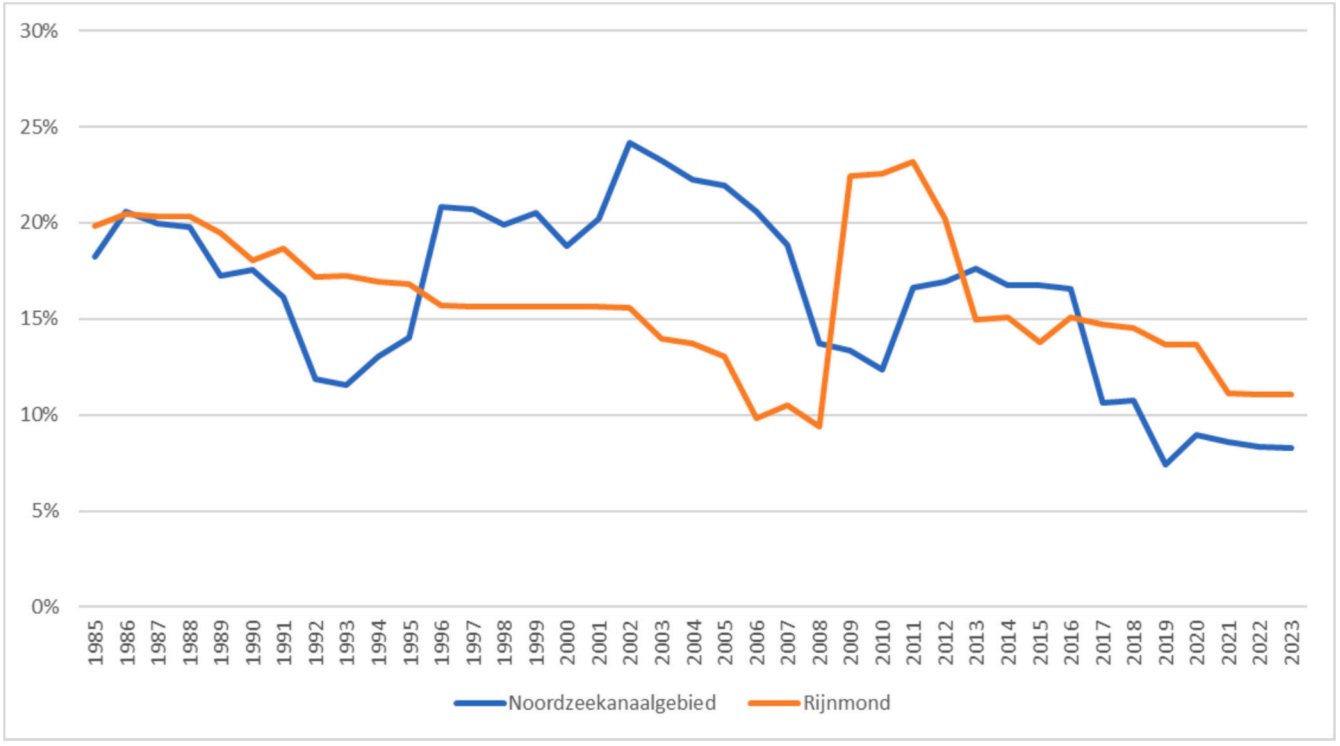

Fig. 6. Share of the vacant port land in the Amsterdam ('Noordzeekanaalgebied') and Rotterdam ('Rijnmond') port regions.
Source: Authors' own adaptation based on IBIS data.

port regions. New port areas were used from 1985 to 2022, while old areas were transformed. In the net surface area, the port in the Rotterdam region has grown during this period, while the surface area in the Amsterdam region has stabilized. The new port areas are far from the urban areas, while the transformed port areas are directly adjacent to the urban (residential) area.

The expansion of the port area is not planned for the Rotterdam region. In Amsterdam, an additional 15 ha (an 'Energy Port' base for constructing and maintaining offshore wind farms) near the Tata Steelworks is planned. Additionally, the provincial vision for the port region of Amsterdam includes a reservation for the Houtrakpolder area as a potential port expansion of the port of Amsterdam (Provincie Noord-Holland, 2018). This reservation is contested by the municipality of Haarlemmermeer, under which this area falls. The reason was the Haven-Stad project of the municipality of Amsterdam, which envisions extensive housing development in the port area of Amsterdam resulting in a loss of 135 ha of port sites. At the same time, the Houtrakpolder is being considered as a possible area for excess rainwater storage. What is notable about this discussion is that it resembles the mechanism described by Wiegmans and Louw (2011), namely the spatial conflict between the advancing city (housing) and the port area at the interface between city and port (Van den Berghe et al., 2023a). What is new, however, is that a spatial conflict is also emerging at the location where the port can still expand in the future. These claims on the same area clearly show the increasing tensions between the environment (emissions, climate change, biodiversity) and economics (port expansion).

4.2. Social and environmental port-city dynamics: Policy changes over time

In the previous paragraph, port-city dynamics in a spatial-economic sense have been the focus of attention, analyzing the pressure on port space due to actual land use development and changes (either through expansion or transformation). This paragraph explores the 'softer' aspects of port-city dynamics, paying more attention to the social and environmental dynamics, and focuses on the ports of the municipalities of Amsterdam and Rotterdam. In both ports, the port authorities are fully publicly owned private companies (i.e., by the municipality and the national government, not listed), that issue the land under leasehold to companies, and the amount of privately owned land in both ports is small. Judicially speaking, they are subject to public procurement and also the issuing of land in the port is subject to public law. However, the port authority is not a public decision-making entity *sec*, meaning that for instance the municipal council has little direct influence over the port authority, and the port authority does not have to comply to the Dutch act for transparency of public administration ('*Wet Openbaarheid van Bestuur*'). Nevertheless, even though the port authority on paper is a private entity, its public owners will likely in their practices still mostly act as if it were a public entity (cf. de Langen, 2023).

4.2.1. Policy changes in the port of Amsterdam

The pressure on the existing port area in the Amsterdam region is greater than in the Rotterdam region. This pressure is evident in the reservation in the Houtrakpolder and in the policies regarding land use within the port itself. Unlike in Rotterdam, active policies are pursued in Amsterdam to intensify land use. In the port vision 'Smart Port' of 2008 (Gemeente Amsterdam, 2008), intensive and efficient land use is explicitly identified as a policy issue. The targeted throughput growth to 125 million tons by 2020 must occur within the existing port area. Specifically, land policy instruments such as leaseholds are mentioned. It is also mentioned that the environmental space will not be restricted until 2020.

Although a reduction in the port area (back in 2008) was not anticipated, it was explicitly mentioned that the Minervahaven would be designated as a 'transition area' between the port and the city. The area will be developed for businesses oriented towards the city, particularly the creative industries. Notably, the port vision identifies that environmentally disruptive companies, which are 'city-bound,' have established themselves in the port area. This is also reflected in the type of employment: the share of port-related jobs per sub-area of the Amsterdam port decreases as the area ages, which might not be desirable given the social aspect of port development. Thus, a 'silent' transformation of the 'older' port area regarding employment is underway. The port vision also addresses the transition to sustainable energy sources. In 2008, it was decided that no new terminals for transport fuels (gasoline, diesel, and kerosene) would be established. One of the three coal terminals was closed in 2023 (the leasehold contract was not renewed). The municipal port vision of 2020 (Gemeente Amsterdam, 2020) sets a goal of phasing out the handling and storage of fossil fuels by 2030. This is expected to free up approximately 370 ha of port area for generating and producing new sustainable energy (hydrogen and electricity) and circular industries.

Comparing the visions of 2008 and 2020, a few interesting differences come to the fore. First, it is notable that the previously held principle of maintaining the constant size of the port area has been abandoned. As a result of the Haven-Stad plan, in the future, 10 % of the total port area in the municipality of Amsterdam will be transformed into residential areas (Van den Berghe et al., 2023a). Second, the port vision 2020 also addresses the province's role. It is stated that: "*Westpoort, except Minervahaven and Hempoint on the east side, has been designated by the Province of North Holland as […] an "industrial area of provincial importance*." (Gemeente Amsterdam, 2020, p. 20).

In addition to the port visions, from the annual reports, it also appears that 'noise' is a topic that demands increasing attention. For example, the 2015 Annual Report states that an expanded noise zone has been established, which obliges the port authority to insulate homes in the nearby municipality of Zaanstad. Furthermore, some vacant plots are unavailable for allocation' due to a lack of noise capacity. Therefore, the Port Authority is working on a 'noise distribution plan.' The 2016 Annual Report (p. 53) states: "*If the total environmental space is unevenly distributed across Westpoort, there is insufficient available environmental space for the undeveloped areas. Consequently, these are not optimally marketable*." There is increased 'pressure' on space in 2017 and 2018 (years of significant economic growth). There is explicit mention of 'space shortage' (encroaching residential development and space demands from the energy transition and circular economy). In response, the Port Authority has 'tightened' its settlement policy for companies (2020); it assesses potential establishments, reservations, and expansions against the 'strategic objectives' of the Port Authority. In 2021 and 2022, this is more or less reiterated, and congestion on the electricity grid is mentioned for the first time. Another problem also arises. The existing environmental space (as well as external safety and noise) begins to constrain efforts to achieve circular and energy transition goals and to use space more efficiently. Notably, in the risk assessment (for the port authority's operations), the risks related to the environment (external safety, environmental space, and noise) are now assessed as higher than economics ('space shortage').

4.2.2. Policy changes in the port of Rotterdam

The port vision of the Port of Rotterdam Authority (2011) states that the intended growth of the port (in tons) will be realized within the existing port area. It is also mentioned that: "*The transition to sustainable energy generation and biobased chemicals is in full swing*" (p. 4), and there is attention to environmental space and the CityPorts project. One goal of the 2011 vision is to "*utilize space in the port more efficiently*" (a nuanced difference from the Port of Amsterdam, where they often talk about the 'intensive utilization' of the port). The port vision already focuses on environmental space and the relationship between the city and the region: "*Making living and working in and around the port attractive*." In Rotterdam, the relationship between the region and the urban economy (for example, concerning education and the labor market) is mentioned more often than in Amsterdam. The annual reports for 2012 and 2013

mention investments in intensive space use. This refers to the redevelopment of existing port areas, discussions with companies that do not fully utilize their sites, and reducing the duration of space reservations and site options. Sustainability criteria are also considered in the allocation decision, which points to a more balanced environment and economy.

In Rotterdam, the CityPorts area's spatial transformation and the Maasvlakte's expansion are related (see Teisman et al., 2009 for an elaboration). The CityPorts project in Rotterdam (Daamen and Louw, 2016) emphasizes that the relationship between the municipality and the port authority in Rotterdam differs from that in Amsterdam. The transformation includes transforming older port areas to housing, revitalizing port areas, and maintaining economic functions. Regarding strengthening the relationship between the city center and the port, a reference is made to the 'Maritime District' (RDM/Heijplaat and M4H). These locations have been referred to in the literature as the 'Makers District' (Jansen et al., 2021) and have some resemblance with the (smaller) Minervahaven in Amsterdam because both aim at creative industries. This CityPorts project started in 2004 but officially no longer exists. However, various individual area-related projects, such as the Maritime District, still do.

From the annual report in 2014 onwards, attention is given to the number of odor and noise complaints/reports. Steering on noise mitigation through the revision of the port zoning plans is more complex than expected; the inclusion of 'noise zoning' in the zoning plans has not yet occurred. It is stated that: "*the limits of environmental use space are being reached and that the intensification task for the port complex is under pressure. This applies particularly to aspects such as nitrogen deposition and industrial noise.*" (Port of Rotterdam, 2015, p. 26). Rotterdam is also working on transitions to sustainable energy. "*We expect many currently established companies to develop new activities and thus adapt to the 'port transition.' The amount of available space is deemed sufficient according to the current estimates*" (Port of Rotterdam, Annual Report, 2017, p. 71). They also aim to restructure and modernize existing port areas. Existing markets (such as fossil fuels) will coexist with new markets for quite some time (thus, both will require space). This 'and-and-approach' differs from Amsterdam, where there is more focus on directly replacing functions and land uses.

An interesting claim is that: "*Rotterdam is less attractive as a location for investment due to stricter local, national, or European laws and regulations regarding, among other things, the environment, and the lack of a level playing field with other (European) ports.*" (Annual Report 2017, p. 140). To continue growing, environmental space usage must be optimized as efficiently as possible, a point that is reiterated in the Annual Reports of 2018, 2019, and 2020. Flexible use of vacant port spaces is repeatedly stressed when dealing with this. Since scarcity is less of an issue in Rotterdam, space can be used simultaneously to modernize the petrochemical cluster and develop innovative energy sources (i.e., the 'and-and-approach'). The revamped Port Vision 2019 (Port of Rotterdam, 2019) also outlines this combined strategy, and energy transition goals are synched with the United Nations' Sustainable Development Goals.

The 2020 Progress Report (Port of Rotterdam, 2021) states: "*...it is common for new housing plans to be planned and realized within the environmental space of the port and industrial area, which spans 11 municipalities. Last year, there were 230 plans to construct approximately 5,550 new homes. […] the port and city intersect. The pressure on available physical and environmental space is significant here*" (p. 39–40). Notably, related to noise mitigation, reference is made to the 'responsibility' of the municipality, whereas in previous editions, the language often emphasized 'collaboration.' This arguably marks a shift in how the Port Authority stresses the environmental problems of the port, specifically in these cases where port sites are in the vicinity of residential areas (such as Merwe-Vierhavens, Waalhaven-Oost, Maashaven).

Next to residential development, there is attention to water safety, nitrogen issues, and hydrogen and biofuel production. The 2022 Progress Report (Port of Rotterdam, 2022) discusses the collision between energy transition and circular ambitions and the uncertainty in legislation (including nitrogen), which negatively affects business investments. In the Annual Report 2022, this 'headwind' regarding nitrogen capacity is also mentioned. Finally, the agreements made in the context of the construction of the Second Maasvlakte are monitored every year since 2010, and it appears that the so-called 'Voordelta' nature compensation lags behind economic targets (DCMR Milieudienst Rijnmond, 2024). According to European regulations, this should have been carried out before the construction. However, in the covenant on the construction of the Second Maasvlakte (from 2008), it was agreed that this would be done simultaneously with the construction. In 2024, the nature organizations (who signed the covenant) threatened to go to court. This also highlights the increasing pressure between the environmental and economic goals in the port city interface.

4.3. A brief case comparison of multi-facetted port-city challenges

Comparing the two cases both quantitatively and qualitatively, the following picture emerges when we relate the outcomes to the theoretical perspectives identified in Section 2 (see Table 3). First, looking at land use dynamics from a multi-level perspective, we can conclude that although the net area of both ports remains relatively stable over longer periods of time, there are many internal dynamics at the different port-city levels. This is an interesting extension of the observations by Wiegmans and Louw (2011) and Van den Berghe et al. (2023a), in the sense that spatial conflicts do not only arise within the port-city interface but also in potential development locations either at the waterfront or at the port regional level.

Second, looking from a multi-dimensional perspective on sustainability trade-offs, we explored how the port stakeholders try to deal with the spatial development of the port in light of conflicting economic, ecological, and social interests. We found that both ports are busy transitioning to sustainable energy. In Amsterdam, this is going directly at the expense of the current space for port activities, and many port sites will be transformed either for energy and circular industries or for additional residential development of the Haven-Stad project. In Rotterdam, an 'and-and-approach' is pursued, in which innovative energy transition projects are set up side-by-side with renewing the existing petrochemical industries.

Third, zooming in on multi-actor collaborations in dealing with the renewed port-city challenges, we see the different stakeholders in both

Table 3
Summary of the case study findings according to the analytical perspectives.

	Amsterdam	Rotterdam
Multi-level perspective: Decreasing land availability, with different internal dynamics at the port-city levels	Decreasing share of vacant land; much ongoing and planned transformations in the port-city interface and at the waterfront level due to the Haven-Stad project	Decreasing share of vacant land; but fewer transformations due to buffer capacity at the port regional level (Maasvlakte II)
Multi-dimensional perspective: Pursuing sustainability transitions through different instruments and approaches	Attention to sustainability transitions (e.g. energy and circularity), with a focus on intensive land use, through issuing or terminating leasehold contracts	Room for innovations in energy transition, using a more flexible and joint approach, next to increasing the sustainability of the existing petrochemical industries
Multi-actor perspective: Changing balance in stakeholder interactions, generally more protective, risk-aversive behavior	Shift from economic primacy to environmental considerations in how port authority and municipality deal with strategy and risk assessment in the port	Clearer division of responsibilities in addressing environmental issues, more pro-active approach in addressing urban economy issues (education, employment)

Source: Authors' own based on empirical analysis.

ports struggling with issues related to noise odor, CO2 and nitrogen emissions, external safety, water safety and quality, and capacity constraints on the electricity grid. This may indicate an intensification of port-city conflicts in the years to come. Where in Amsterdam, the privatization of the port has been partly 'reversed' as exemplified by the municipality taking charge of writing the latest port vision again, in Rotterdam, the port authority seems to 'mind its own business' more (e.g. attention to energy transition, etc.) and increasingly points towards the municipality for addressing environmental problems in the port. However, in Rotterdam the Port Authority is more active in urban economy issues such as education and urban employment. It should be noted that the general tendency is that Rotterdam addresses port-city development on a larger scale than Amsterdam, as this last example also shows.

To conclude, the empirical results seem to underline the importance of studying the port-city interface in a multi-facetted way. Seeing the port-city interface as 'just' the waterfront is too narrow, as dynamics extend even to the polycentric port region level (Van den Berghe et al., 2023b). The results also confirm the intensified pressure on internal space in the port area, quantitatively due to fewer vacant lands and increased land transformations, but mostly also qualitatively due to interests beyond the economic function of industrial port sites, such as residential developments, but also environmental space (for concerns of noise, odor, CO2, nitrogen) and room for innovative forms of new energy production.

5. Conclusions: Multi-facetted challenges in the multi-layered port-city interface

This paper aimed to enrich the scientific discourse on the port-city interface by arguing for a more multi-facetted understanding of the port-city interface beyond arguments of economic efficiency, and to explore empirically what this implies for how land use conflicts materialize and are dissolved.

We found that, in the scientific literature on the port-city interface, the port-city has often been analyzed in a conceptual and often one-dimensional way. Over the years, the body of literature has grown enormously and we now propose to further specify the port-city concept in two ways. First, by acknowledging that the different port city levels (port region, port-city interface, waterfront) that up to now have been mostly analyzed in isolation, should be treated in a multi-level and comprehensive way. Secondly, the focus in discussions on land use in port areas has been mostly on economic efficiency. However, increasingly other issues (such as sustainable development, climate change adaptation, heat stress reduction, circular economy, housing, etc.) also demand land. Therefore, the supply and demand for land use become more important to analyze the land use conflicts in densely populated areas with ports. Land use claims stemming from different levels (region, port-city or waterfront) might also require different solutions from the involved stakeholders to solve conflicts, as might the different land use demands resulting from a broader consideration of urban and environmental interests in the port area, and new challenges that demand space, such as circular economy, energy transition, climate adaptation and mitigation, or water quality and external safety.

Given the often conceptual approach towards the port-city, and the importance of contextual sensitivity in analyzing port-city challenges, we have aimed to gather empirical data to be able to identify the supply of land in two different port areas. The cases of Rotterdam and Amsterdam in the Netherlands have been selected for the empirical part of the analysis. This analysis shows that over the last decades the available space for land use in port areas has been decreasing. Combined with increasing demands for land use (driven by economic but also environmental demands) this might increasingly result in conflicts in densely populated urbanized areas as space for land use is insufficient. We can see that although the net area of both ports remains relatively stable over longer periods of time, there are many internal dynamics. One is the decreasing share of areas not yet used by companies (i.e., vacant lands or buffer spaces), and the other is the loss of port areas due to the transformation into other land uses.

We should however also note that analyzing vacant and unused land in port areas is a complex issue, as the usability of unused plots may vary, and because just looking at the amount of vacant land disregards the influence of (increased) land productivity that may be impacting the use of space in the port area, and also the 'maneuvering space' of port authorities regarding environmental emissions. Land productivity is a topic that is mostly addressed at the individual level of the (container) terminal (e.g., Wiegmans and Dekker, 2016), but is not yet extensively researched for the port in its entirety. This paper has discussed the total area of the port, with a focus on how this area changes quantitatively (i.e., size) and qualitatively (i.e., the transformation of type of land uses) in relation to urban and environmental concerns that impact port policy-making towards the future (e.g., sustainable production, energy transition, etc.). Further research could further clarify and detail this.

Next to this, it is worthwhile to contextualize the applicability of our findings. First, it should be noted that our scope of addressing the port regions in its entirety differs from most other research, as the above example of land productivity stressed. Second, we have highlighted that the type of ownership model of the port judicially matters for its degree of conformity to public law, and that the relative size of the port in relation to the city matters for the primacy of port or urban affairs within the port area. For ports with more flexibility in their port area, like Rotterdam where the port authority is currently considering a third coastal extension of the port, this leads to more room for maneuvering than in other, more confined ports, like Amsterdam. This also has implications for policy making, in which ports with more 'puzzling space' may be more agile in accommodating new land use challenges (related to energy, climate, etc.) relative to the phasing out of traditional land uses like oil and coal. The port's relative share of transport and production functions may also matter in this regard.

The main conclusion in answering the central research question 'How to identify and mitigate land-use conflicts in the port-city interface in densely populated areas?' is as follows. To identify the supply of land it is needed to analyze the available land supplied by port authorities over a long time period. In this paper, this has been done for two cases and this shows a reduction in the supply of available land over the years in densely populated areas with one or more ports. This might hold for other port areas as well, but further research is needed to confirm this. What we can conclude is that land use challenges in port areas increase considerably (both quantitatively and qualitatively), due to energy transition, water storage, economic growth, climate change, housing, biodiversity, (European) environmental regulations, etc. These are common challenges that many ports in Europe likely share. It is interesting to further analyze what this means for port governance models and public decision-making. To this end, also more insight is needed in the demand for land from different stakeholders with different interests. To mitigate these rising tensions (materializing in conflicts, e.g., related to energy transition vs. housing supply) it is needed to distinguish between different levels (region-port-city-waterfront) and to also distinguish different land use claims resulting from urban and environmental concerns, next to the economic ambitions of ports. Our proposed framework could help structure conflict types and mitigate tensions and solve conflicts across different institutional contexts.

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The authors have nothing to disclose.

CRediT authorship contribution statement

Patrick Witte: Writing – review & editing, Writing – original draft, Visualization, Conceptualization. **Bart Wiegmans:** Writing – review &

editing, Writing – original draft, Investigation, Conceptualization. **Erik Louw:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis.

Data availability

data is publicly available online

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