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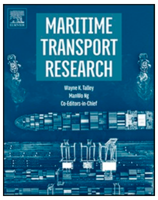

Accelerating the circular economy transition process for gateway ports: The case of the Port of Zeebrugge

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ABSTRACT

The transition towards a circular economy (CE) has grown in importance during the last decade, and ports are now being viewed as potentially important contributors to this move towards a more sustainable economy. However, several research questions about adopting CE projects in ports remain unanswered. The importance of clustering and secondary resources for circular loops indicates the importance of proximity to either industrial clusters or urban zones. However, gateway ports (GWP), contrary to industrial ports, metropolitan (or urban) ports and diversified port hubs (which combine an industrial function with the proximity to a large urban area), do not benefit from the vicinity of these secondary resources. Nevertheless, even without access to such secondary resources, any port and port managing body (PMB) needs to prepare for the changing competitive landscape, with new cargo flows, material streams and related businesses linked to the circular economy transition of value chains. Here, GWPs, thanks to their nodal position, still have potential to function as platforms for circular transition initiatives arising in other industries. In the present study, we conceptualize a CE transition process, consisting of six steps, especially relevant to GWPs. We then explore the case of the Port of Zeebrugge (Belgium), shortly before its merger with the Port of Antwerp. We propose that GWPs should rely mainly on their potential to attract 'new value streams' as the main driver of their CE strategy. Here, top-down initiatives emanating from internal stakeholders, and likely even external ones, appear to provide pathways to CE success.

1. Introduction

The circular economy (CE) and the role of ports herein, has increasingly gained the attention of scholars and practitioners. The CE as a systems transition is generally perceived to be an (economically) viable solution to the environmental and societal costs of the current linear economy. The linear model employs only primary resources as inputs into the production process. In contrast, the circular model transforms waste into a type of secondary resource, which then becomes an input in its own right in a process that has

Abbreviations: CE, Circular economy; GWP, Gateway port; PMB, Port managing body.

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circular loops (Bianchini et al., 2019). One example is the repurposing of key (raw) materials from cars at the end of their useful life to be inserted in a new vehicle. This circular model allows value creation and economic growth to be dissociated from negative environmental impacts (Haezendonck and Van den Berghe, 2020; Sehnem et al., 2019).

Port areas in particular, are expected to play a major role in the transition towards a CE, because they represent reservoirs of land, infrastructure and services for CE activities (de Langen and Sornn-Friese, 2019; ESPO, 2020; Haezendonck and Van den Berghe, 2020). Ports, as economic nodes, can positively affect other industries in identifying and engaging with CE opportunities (Carpenter et al., 2018). They can function as "matchmakers", linking producing and recycling industries; acting as logistics hubs for the trade of waste materials; hosting firms active in waste management; and fostering virtuous cycles of CE innovation (de Langen and Sornn-Friese, 2019). However, CE implementation is not yet widespread in ports, despite many stakeholders having shown interest in CE initiatives (Sehnem et al., 2019; Roberts et al., 2021). A number of ports have become circular hotspots, but other ones seem to be late movers. It is presently rather uncommon for port managing bodies (PMBs) themselves to play a lead role in 'new value streams' initiatives (Haezendonck and Van den Berghe, 2020).

Secondary resources for circular loops critical to CE initiatives are typically more widely available in industrial ports, metropolitan (or urban) ports, and diversified ports (Karimpour et al., 2019; Roberts et al., 2021). CE projects can include recycling activities; industrial symbiosis, i.e., usage of the by-product of one process as a (complementary) resource in another business (e.g., repurposing carbon dioxide); and orchestration of new value streams. Here, new cargo flows appear because of the CE project (e.g., new traffic flows because of wind energy projects) (Haezendonck and Van den Berghe, 2020). Unfortunately, secondary resources are less present in gateway ports (GWPs) as compared to industrial, metropolitan and diversified ports.

Here, we can apply Blomsma et al.'s (2022) concept of circular disruption, whereby purpose-driven stakeholders actively seek CE projects, rather than view these as resulting from exogenous demand. Cerreta et al. (2020), Karimpour et al. (2019), and Roberts et al. (2021) have all suggested ways to improve CE implementation in ports. However, the frameworks they construed are valid for ports that benefit from the vicinity of secondary resources, and with the main barriers being the high cost of labor, land use, etc. (Roberts et al., 2021; Van den Berghe, Dąbrowski, et al., 2020). Those are easy cases to understand, but little is known about the pathways of CE opportunity discovery and the subsequent implementation of CE initiatives.

In this study, we develop such a process-related pathway for identifying and subsequently engaging with CE initiatives in ports, whereby we focus especially on GWPs that lack the typical secondary resources arising from industrial production processes or urban waste generation. We build upon a single case-study, namely the Port of Zeebrugge, but our findings can likely be broadened to other GWPs and even to other port types seeking to become more active in the CE transition. We focus especially on the discovery phase of CE project development, i.e., the identification of a CE opportunity. This phase should then logically be followed by the actual pursuit or implementation of the CE project (which is beyond the scope of our research).

The paper is structured as follows. In the next section, we provide some background on the importance of CE, the role of ports within the CE transition, and the challenges they face in this realm. In the third section we provide an overview of the methodology used, and we explain the relevance of our case-study. In the fourth section we propose a six-step model within the CE initiative discovery phase, and we discuss how a proactive CE strategy can be established that involves the port's stakeholders. In the last section, we discuss our findings and formulate conclusions.

2. Circular transition and ports

2.1. Circular economy and the role of ports

Stahel (1982) popularized the CE concept, which has since been applied across a wide variety of business contexts (Kirchherr et al., 2017). One such context is that of the ports and maritime industry (de Langen and Sornn-Friese, 2019; ESPO, 2020; Haezendonck and Van den Berghe, 2020). The basic principle underlying the CE approach is to shift from a 'linear' process to a 'circular' one (Bocken et al., 2016; Kirchherr et al., 2017). Here, the addition of new, primary resources to manufacture a product is reduced to the minimum required, and the lifespan of existing primary resources in the final products is extended (Bianchini et al., 2019; Hapuwatte and Jawahir, 2021; Kirchherr et al., 2017; MacArthur, 2013; Morseletto, 2020).

Nine 'R' concepts appear important in the CE transition. At the 'product level', the efficiency of primary resources usage is improved (in other words: '*Reduce*'), and the primary resources that are included in production are not simply discarded at the end of the useful lifetime of the product (in other words: '*Reuse', 'Recycle'; 'Remanufacture'* and *'Repurpose'*). Finally, the product's lifespan can in many cases be extended (in other words*: 'Repair'* and *'Refurbish'*). Furthermore, the production process itself could be made more sustainable (in other words: *'Rethink'* and *'Recover'*) (Hapuwatte and Jawahir, 2021; Morseletto, 2020).

In sum, in addition to *reducing* the usage of primary inputs through efficiencies in the production process, circular loops can be created by promoting several 'Rs', as noted above: extend the time that these inputs can be used productively through the processes of 'Reuse', 'Recycle', 'Remanufacture,' and 'Repurpose'; extend the productive lifespan of the products themselves through 'Repair' and 'Refurbish'; redesign fundamentally the production processes through 'Rethink' and 'Recover' (Blomsma and Brennan, 2017;

Geissdoerfer et al., 2017; Kirchherr et al., 2017; Stahel, 1982). Circular loops are often achieved as a result of industrial symbiosis that transcends the boundaries of a firm's conventional business model, thereby requiring – or leading to – clusters with co-located economic actors involved in CE initiatives through their secondary resources (Köhler et al., 2022; Roberts et al., 2021).

The impacts of the CE transition on ports can be manifold. For instance, CE-related projects can affect maritime traffic flows and change the competitive landscape of the ports industry (de Langen and Sornn-Friese, 2019; Kirchherr et al., 2017). A CE transition could also reduce the income for PMBs and drive a rethinking of their business models (Flor and Defilippi, 2003; Haezendonck and Van den Berghe, 2020).

On the positive side, the CE transition can help ports to improve their corporate social performance (Angrisano and Girard, 2017). This is important especially because of the ports' unique role as nodes within local and global value chains, with port clusters sometimes considered responsible for any negative externalities related to the sourcing, transshipment, logistics and distribution of products, ranging from raw materials, to intermediate products, and end products (Carpenter et al., 2018). CE projects in port clusters can alter the function of the waterfront, the technologies used, the relative importance of recycled materials and renewable energy in production, etc.; and can therefore be an important component of strategic renewal of the broader port environment (Angrisano and Girard, 2017; Carpenter et al., 2018).

The CE transition in ports could potentially accelerate an equivalent transition in other industries, first because of their nodal position and second because of their potential to use secondary resources in their vicinity, as inputs into new or reconfigured production processes (de Langen et al., 2020; de Langen and Sornn-Friese, 2019; Jugović et al., 2022). Proximate industries (including industrial-scale agriculture) and dense urban areas are key suppliers of secondary resources for CE activities in ports (Jugović et al., 2022). But the supply of these secondary resources is sometimes fragmented, which can lead to complex logistics and affect the feasibility of CE development (Grafström and Aasma, 2021; Kinnunen and Kaksonen, 2019). Close geographic proximity of these resources is often a precondition for viable CE activities in ports.

Fig. 1 differentiates among port types based upon the presence of significant industrial activities (low versus high on the vertical axis) and population size and density in the port region (low versus high on the horizontal axis). The most challenging case for initiating CE projects is that of the 'low-low' quadrant 2 in Fig. 1. This is the case of the GWPs, not located in the immediate vicinity of secondary resources generation. GWPs mainly function as logistics hubs, and leverage their maritime accessibility for purposes of feedering, bunkering, reorganizing empty containers, etc. (Notteboom, 2009).

2.2. *CE initiative development and the role of stakeholders*

CE initiative development first requires stakeholders to identify an entrepreneurial opportunity, which can also be referred to as the 'discovery' phase. Subsequently, the same or other stakeholders will engage with this opportunity and will pursue it towards implementation (Shane and Venkatamaran, 2000; Verbeke and Yuan, 2022). This pursuit involves actual project management, with a view to create and distribute value (Gareis, 2000).

Parameters at several levels (macro level, sectoral level and organizational level) can affect the processes of stakeholders

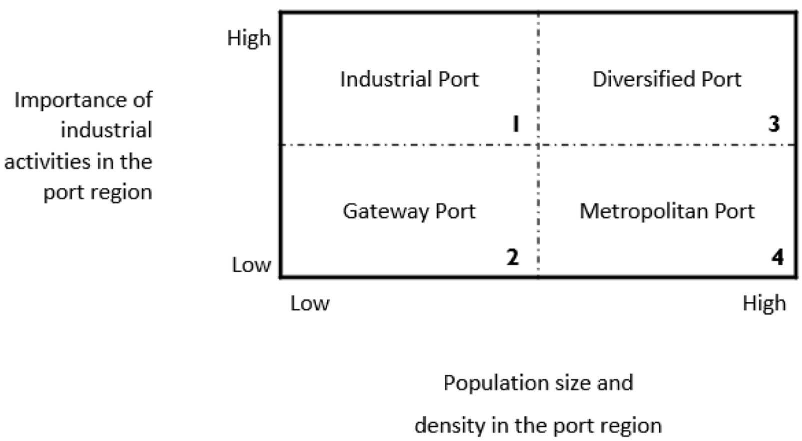

Fig. 1. Port typology according to the vicinity of industrial clusters and urban areas.
Source: Composed by authors, based on Faut et al. (2022). Circular Port Monitor. Explorative Research: Toward First Actionable Insights. Report commissioned by Circular Flanders and produced by ECSA, VUB, PLA.

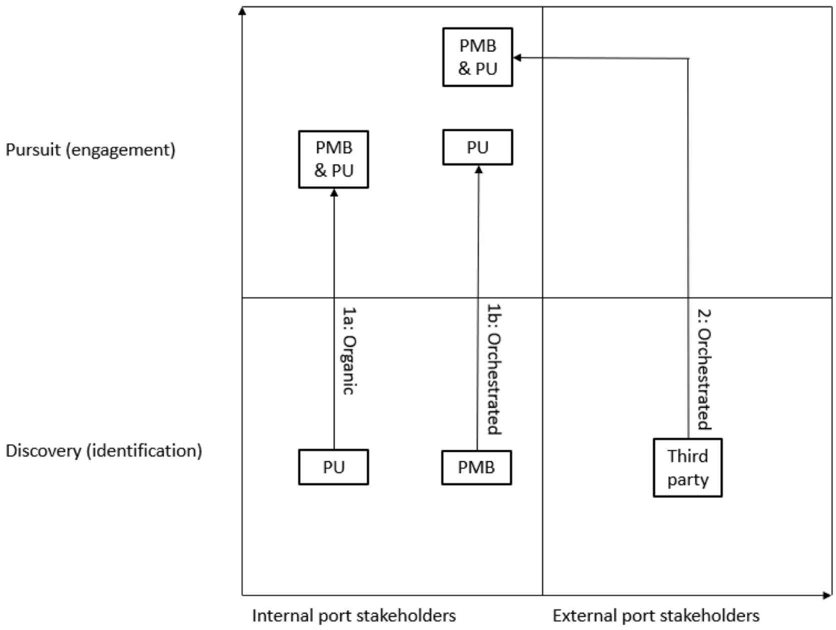

Fig. 2. CE Project Development.
Note: Port user (PU) and Port managing body (PMB).
Source: Composed by authors, based on Verbeke, A., & Yuan, W. (2022). Rethinking intrapreneurship in the established MNE. Global Strategy Journal.

identifying and engaging with a CE opportunity (Agyekum et al., 2022). The key stakeholders active in each of the two phases can vary substantially. Two approaches to initiative development seem predominant, as shown in Fig. 2, depending upon whether the key stakeholders are internal or external to the port itself. This dichotomy is represented on the horizontal axis of Fig. 2. In addition, in case of internal stakeholders being the key players, a further distinction can be made between a top-down or *orchestrated* approach (emanating from the PMB) versus a bottom-up or *organic* approach (emanating from present port users).

The *orchestrated* approach implies that the PMB identifies a CE initiative and subsequently motivates port users (for instance, transport operators or land leaseholders such as cargo storage and logistics companies within the port area) to pursue the initiative. In contrast, with an *organic* approach, port users themselves discover a CE opportunity, and then pursue this further, possibly in cooperation with the PMB.

On the right-hand side of Fig. 2, an external stakeholder is instrumental to identifying the CE opportunity. This third party can be a public agency or a sectoral organization, or a business firm not presently operating in the port but inspiring the PMB or port users to engage with the opportunity that was discovered.

2.3. *Strategic CE transition path according to port type*

Haezendonck and Van den Berghe (2020) studied the various CE initiative development patterns in ports and linked these to the proximity of industrial and urban activities. Industrial ports are more likely to have access to secondary resources in their CE transition process, for instance in the realm of energy recovery, because of possibilities for *industrial symbiosis*. They called such symbiosis the first CE strategic pillar for ports. Metropolitan ports tend to start CE activities with *recycling* initiatives: this is the second CE strategic pillar that ports can build upon. For GWPs, the opportunities for CE initiatives are less straightforward, even though such initiatives would help them to retain their social license to operate in the long run (de Langen et al., 2020; de Langen and Sornn-Friese, 2019). These ports need to focus on orchestrating *new value streams,* which constitutes the third strategic CE pillar for ports. In this context, we found only three studies addressing CE initiatives in GWPs, as compared to 36 CE-related studies for ports more generally (Web of Science database for the 2016–2022 period). These three studies focused mainly on transport and logistics, whereby CE-related subject matter was secondary (Budoc, 2017; Mańkowska et al., 2020; Uche-soria and Rodríguez-Monroy, 2019). In contrast, the non-GWP studies focused more on concrete pathways to integrate CE initiatives in port functioning (8 studies analyzed CE projects in industrial hubs; 18 focused on metropolitan ports; and 7 addressed CE projects in diversified ports). Here, the orchestration of new value streams has largely remained an unexplored path in the realm of CE opportunity discovery and pursuit. In the next section, we illustrate a possible pathway towards CE project development, building upon the case of the Port of Zeebrugge.

3. Methodology for case-study analysis: Developing a CE strategy for the Port of Zeebrugge[1]

As noted above, the discovery and pursuit of CE initiatives in GWPs has remained a largely unexplored area of research. A detailed case-study of such an initiative can therefore provide much-needed insight on the specificities of the decision processes at hand and can also support theory building (Yin, 1992, 2013).

We conducted this research for 'Circular Flanders', a multi-stakeholder partnership, itself embedded in 'OVAM', the Public Waste Agency of the Flanders region in Belgium. The main objective of this research was to explore the possibilities for the Port of Zeebrugge, a GWP, to initiate (more) CE projects in the port area. We focused especially on the potential of a large brownfield site of approximately 6 hectares, geographically positioned to operate as a deep-sea terminal. This site had recently been the subject of a brownfield cleanup operation and was owned by OVAM. Circular Flanders intended to return the site to the PMB of Zeebrugge, so that it would again be usable for performing port related activities. But the cleanup of the site had cost 72 million Euro, paid by the public purse. Circular Flanders, as an external port stakeholder, therefore wanted to use the transfer of the site to the PMB as an opportunity to push the PMB towards considering actionable CE initiatives. We were asked to provide support for identifying such initiatives. For this purpose, we conducted technical site analyses of the entire port area. We also interviewed a large number of stakeholders in collaboration with Circular Flanders and the PMB to assess Zeebrugge's potential as a node for CE initiatives. Our 'action research' approach should be viewed as instrumental to 'social learning and adaptive management' in this GWP context, which was characterized by the relative absence of CE initiatives at the outset, with only four projects in operation (Avison et al., 1999; Haezendonck and Van den Berghe, 2020; Mackenzie et al., 2012).

We interviewed three categories of economic actors who could provide insight on Zeebrugge's potential for CE initiatives. *First*, stakeholders within the Port of Zeebrugge who could provide primary data on the supply side, namely property owners within or near the port, including the PMB. *Second*, stakeholders on the demand side, namely companies within or near the port area with an interest in advancing CE initiatives. Third, company executives involved with CE initiatives[2] in other ports in the North Sea Region of Belgium and the Netherlands (Ostend, North Sea Port, Amsterdam), who could provide insight into the preconditions for (successful) CE projects. We should note that in these nearby ports, a large number of CE projects were already ongoing, and a discussion of these initiatives with the executives involved allowed us to canvass the typical surface area needed for (successful) CE initiatives, as well as the requirements (if any) for maritime access, and also other dimensions of requisite logistics availability.

Subsequently, we engaged in triangulation, whereby data and findings from different sources could be validated. Here, we attempted to compensate for any weaknesses in the data by the strengths of other sources, thereby increasing the validity and reliability of the results (Yin, 2013). The sources for triangulation included content-scans, interviews (with respondents from the different categories noted above), and available online data.

Our data collection took place during the period from April to June 2021. We gathered internal and publicly reported information, annual reports and masterplans, and conducted 35 in-depth interviews with port executives and CE entrepreneurs and investors. As a result of our desk research and interviews, we were able to map the available space in and around the port area, classifying sites based on size, modal access, deep sea connectivity, and other location factors. Next, we identified potential 'coalitions of the willing' at the port cluster level for possible CE initiatives or investments. By combining both inputs (potential sites and potential interested parties), we then analyzed the opportunities for CE projects in the GWP of Zeebrugge.

4. Empirical findings

4.1. The Port of Zeebrugge and its CE development

The Port of Zeebrugge is a GWP, located in Belgium on the North Sea. At the time of the case-study, the Port of Zeebrugge was still operating as an independent entity. However, it formally merged with the Port of Antwerp – the second largest port in Europe on a volume basis, positioned approximately 100 km inland towards the East – on April 22nd 2022. This led to the creation of the Port of Antwerp-Bruges. Our research only covers the Zeebrugge area. Prior to the merger, the Port of Zeebrugge was characterized by low industrial activity, the absence of a proximate, large urban center, and volatile deep sea container traffic volumes (Haezendonck and Van den Berghe, 2020; Williams, undated).

A large site within the inner port, the 'Carcoke' site, was a brownfield that had previously housed a steel coke plant, serving the inland steel industry. This plant, which had started operations in 1900, was closed in 1996. OVAM, the Public Waste Agency of the Flanders region in Belgium, bought the site in 2002 for purposes of brownfield cleanup and regeneration. Many decades of heavy industrial activity had caused significant soil pollution with tar, mineral oils, polyaromatic hydrocarbons, cyanides, heavy metals and asbestos. All the buildings and industrial installations that had not been destroyed were contaminated with different types of hazardous

[1] This data collection and research were conducted in the period March-June 2021, prior to the official merger of the port of Zeebrugge with the Port of Antwerp into the Port of Antwerp-Bruges on April 22nd, 2022.

[2] The CE initiatives discussed included: (a) projects, referring to initiatives that recently started and have, thus, not yet reached a minimum efficient scale (often initiatives still in the pilot or test phase, and mostly financially supported by one or more organizations); (b) activities, referring to initiatives that have reached the minimum efficient scale or passed the pilot phase, and, thus, have moved to a greater maturity level; (c) platforms, best described as loci where actors are encouraged to meet, share information on CE opportunities and build projects or activities together. Most initiatives were either projects or platforms, which explains why we use the terms initiative and project interchangeably in this study.

waste. The site was therefore catalogued as a brownfield, and OVAM tasked itself with the cleanup of the site. The purification and selective demolition of the industrial installations began in 2004, whereas the soil remediation started in 2007 with the excavation being completed in 2015 (OVAM, undated).

After the brownfield cleanup operation, Circular Flanders — a multi-stakeholder partnership embedded in OVAM — sought to transfer the ownership of the Carcoke-site to the PMB of the Port of Zeebrugge — Maatschappij van de Brugse Zeehaven (MBZ). However, OVAM wanted to make this transfer conditional upon commitments from the PMB towards subsequent site usage for CE purposes. The exploration of such potential commitments formed the basis of this study, which was conducted in 2021. Circular Flanders, prior to the transfer of ownership, expressed its desire to examine how the Carcoke-site could potentially be used directly for CE projects, or as a lever for a broader port transition towards such projects.

Haezendonck & Van den Berghe (2020), in an earlier study, had examined CE projects in five Belgian ports. The authors concluded that the Port of Zeebrugge hosted only four CE projects, a very small number as compared to Ostend (industrial port) with 14 projects, North Sea Port (diversified port) with 19 projects, Brussels (metropolitan port) with 49 projects, and Antwerp (diversified port) with 65 projects. The small number of CE projects in Zeebrugge is unsurprising, because it is a GWP, mainly focused on transshipment, and lacking an industrial cluster or a proximate, populous urban area. Its principal activities are in short sea shipping, mainly with the United Kingdom and Ireland, but also Scandinavia. The port is widely known as a vehicle-handling port, and also as a transport hub for liquefied natural gas and for fresh and frozen food (Port of Zeebrugge: linking the UK and European hinterlands 2020; Short sea & deep sea | North Sea Express | North Sea Express, undated).

4.2. Port transition and the CE opportunity discovery process

Our action-research based case-study focuses on the discovery phase of CE project development, in this instance with a third party (Circular Flanders) driving the process. Upon being asked to conduct this advisory work, we proceeded with the process of CE initiative discovery using six process steps, namely:

- Determining supply-side boundary conditions for purposeful CE initiative discovery (1).
- Defining demand-side boundary conditions for purposeful CE initiative discovery, using benchmark projects in other ports (2).
- Matching the dual boundary conditions (1 and 2) with the available sites in the port area considered (3).
- Assessing the economic promise of CE initiative prospects that can involve port users (4).
- Identifying 'coalitions of the willing' around promising CE initiative prospects (5).
- Aligning available sites (3) with the most promising CE initiative prospects (4 and 5) in the port (6).

Circular initiatives typically require the involvement of various stakeholders, whereby different port users must work together (cf. 'coalitions of the willing') and with the PMB being involved. The following subsections discuss our empirical findings for each step of the proposed CE transition process.

4.2.1. Step 1: Determining supply-side boundary conditions for purposeful CE initiative discovery

The first step in the CE initiative discovery process was to define supply-side boundary conditions, which are related to the port's geographic, economic, regulatory and technical context, as well as the port's strategy as determined by the PMB and port users. Here, any CE initiative discovery must acknowledge these boundary conditions and be consistent with the port's strategy, for it to have perceived merit. Gaining a proper understanding of these boundary conditions was done through a content scan of relevant policy documents, sustainability reports, data about available sites in the port, etc., as well as interviews with stakeholders on the supply side. These include the PMB, other owners of commercial sites in or near the port, and salient stakeholders who could likely influence port strategy and operations.

The regulatory context covers a wide-ranging set of policy areas, including environmental and waste management policies, spatial planning and permit approval policies, etc. In addition, governments at various levels, including the regional (e.g., EU), national and subnational levels may have set long-term objectives for CE initiative development (Carpenter et al., 2018; Van den Berghe, Bucci Ancapi, et al., 2020). Both mandatory and soft regulations affecting CE initiatives needed to be considered.

For a GWP, the presence of suitable supply chain partners can be particularly important (Mańkowska et al., 2020), depending upon the type of CE initiative considered. For instance, if hazardous materials are involved, the availability of specialized services may be more important than would be the case with a conventional value chain.

According to de Langen et al. (2020), the PMB itself may be in a position to offer services and tools (e.g., coordination role, joint information management) that can make the port more competitive to attract CE activities (Ballini, 2017). Here, public ownership of the port permits increased attention to the societal benefits of CE activities, in addition to the financial benefits thereof.

4.2.2. Step 2: Defining demand-side boundary conditions for purposeful CE initiative discovery, using benchmark projects in other ports

To determine the demand-side boundary conditions for purposeful CE opportunity discovery, it may be important to gain insight from benchmark projects in other ports. We conducted such a benchmark study, analyzing CE projects in three other, nearby mediumsized ports that were more advanced in this realm than Zeebrugge at the time of our study, namely the Port of Ostend, North Sea Port, and the Port of Amsterdam. We analyzed 44 CE initiatives in these ports, based on data collected by Haezendonck & Van den Berghe (2020), and we discussed these in our interviews with PMB representatives from Zeebrugge.[3] We were able to describe these benchmark projects in considerable detail, thanks to surveys conducted with the relevant port users and PMB representatives (for 23 projects), available online data (for 5 projects), and measurements using the Google Earth Pro-software (for 16 projects; for instance, presence of waterway access; distance to railway track; etc.).

The goal of the benchmark analysis was simply to determine, from the demand-side perspective, what the sites look like where (successful) CE projects are being operated. The information gathered included measurements of requisite surface area, length of the waterfront, labor intensity, usage of waterways, etc., that could reasonably be considered as relevant to future initiatives in Zeebrugge.

We found that only few port users engaged in these benchmark CE projects made extensive use of the waterways (37%), despite their intent to improve upon this situation in the future. In addition, in many cases the usage of the waterways was mainly for these firms' primary activities, rather than for their CE projects.

Most companies operating benchmark CE projects were located at the waterfront (36 out of 44), whereas the other ones (8 out of 44) were located relatively close to a quay. For the latter, the hypothetical, shortest route 'as the crow flies' to the quay was 89.5 m; the average actual distance was 202.1 m. The survey with port users showed that those with a waterfront had an average of 146.7 m of waterfront, but not necessarily with a quay that would permit ships to moor. These companies often used quay walls located elsewhere in the port for loading and unloading, due to the limited cargo or materials volumes associated with their CE projects.

We assessed the site surface requirements of the benchmark CE projects, based on an estimate of the share of CE activities in the total activities of the companies involved.

Table 1 shows the size of the benchmark CE projects, according to their CE focus: recycling, industrial symbiosis and new value streams, based on the three CE categories distinguished by Haezendonck & Van Den Berghe (2020). Classifying each benchmark project as falling into one of these three types, was not always easy to do. In each case, we started from the port user's primary activity to make such determination. In most cases, recycling projects required a larger surface area. Only North Sea Port had a higher average surface area for industrial symbiosis projects, but this result is due to a single outlier (300 ha) in this category.

Analysis of the benchmark projects, thus, led to the conclusion that many CE projects in ports do not really require direct access to the waterfront (and especially do not need direct deep-sea accessibility or a quay for loading and unloading of cargo). Given the nature of Zeebrugge as a GWP, with most future CE projects likely in the realm of creating new value streams, small sites would appear sufficient for these projects. We therefore suggested to Circular Flanders, which had commissioned our study, that the Carcoke-site could (or even should) be 'swapped' for smaller sites dedicated to CE initiatives, with the sum of these dedicated areas being equivalent to the surface of the Carcoke-site, and without each of these smaller sites necessarily needing to have a direct connection to the waterways.

4.2.3. *Step 3: Matching the dual boundary conditions with the available sites in the port area considered*

We assessed all available sites in Zeebrugge on the basis of the boundary conditions highlighted in Sections 4.2.1 and 4.2.2 above. This assessment led to a weighed score for each site, reflecting its suitability to host CE projects. More specifically, we conducted a comprehensive site analysis and divided the Port of Zeebrugge into seven distinct geographic zones, containing a total of 41 available sites. Based on the above boundary conditions, it appeared that 19 sites were suitable for CE initiatives.

4.2.4. *Step 4: Assessing the economic promise of CE initiative prospects that can involve port users*

The purpose of this fourth step was to determine the economic promise of CE initiative prospects that could reasonably be considered attractive to companies already engaged in CE projects as core activities, and located inside or close to the port area, as well as companies for which CE projects could become auxiliary activities. We assessed the promise of CE prospects through interviews with company executives working for port users. The interview questions addressed the firms' strategy, with a focus on possible CE initiatives; requirements related to space and location; the alignment between each firm's strategy and site-specific characteristics; and the physical input-output, logistics characteristics of possible CE initiatives.

Table 1
Initiative characteristics per type of CE activity.

	Ostend		NSP		Amsterdam		Total	
	Count	Average (ha)	Count	Average (ha)	Count	Average (ha)	Count	Average (ha)
Recycling	5	4,7	5	35,8	9	5,1	19	14,6
Industrial symbiosis	3	1,2	13	28,7	4	5,8	20	21,7
New value streams	1	2,7	1	10,6	3	1,8	5	3,7
Total	9	3,3	19	29,6	16	4,7	44	16,6

Source: Authors.

[3] This set of CE initiatives is not necessarily exhaustive for each port, but it is representative of CE projects in those ports during the period of our study.

Our in-depth interviews with port users were both exploratory and meant to lead to actionable outcomes (at least tentatively), in the sense that we attempted to gain market-based insight into CE initiative prospects. We inquired whether the port users were already contemplating CE initiatives, and whether these were related to existing activities in the port. Close linkages between new CE developments with ongoing, core activities can greatly improve the economic promise of such initiatives and facilitate a broader, CE-related transition. We also thought it was important to include in our interviews respondents from commercial and industrial companies in the port's proximate hinterland, because such actors could also be instrumental to CE initiative discovery and enactment. Finally, we interviewed respondents from firms actively involved in CE initiatives in other ports, to assess whether their business model was potentially replicable in Zeebrugge, or could potentially be emulated by others in the context of this GWP.

The interviews allowed identifying concrete prospects and more high-level ambitions from individual port users and interested parties, as well as their (potential) willingness to collaborate on specific CE initiatives through forming 'coalitions of the willing' with other port-related companies.

4.2.5. Step 5: Identifying 'coalitions of the willing' around promising CE initiative prospects

The aggregation of the individual responses allowed identifying three CE initiatives around which a 'coalition of the willing' could potentially be built in Zeebrugge.

(1) *Complex (offshore) project recycling.* This opportunity revolves around reconfiguring and expanding port sites for vessel dismantling and the dismantling of offshore drilling rigs and wind turbines at the end of their productive life.
(2) *Battery recycling and complex automotive recycling.* These are projects in the realm of 'reverse automotive logistics' including an R&D component. This opportunity arises because of the port's current status as a global hub for the shipping of new vehicles (passenger vehicles, as well as commercial and industrial vehicles), with several firms in and around Zeebrugge already active in automotive logistics.
(3) *Green energy fuels.* This opportunity involves the import and production of green/blue H2, as well as Bio-LNG, with the latter in collaboration with the potato processing industry from the Flemish and Dutch hinterland.

4.2.6. Step 6: Aligning available sites with the most promising CE initiative prospects in the port

Building upon the above steps, it became possible to align available sites (see Section 4.2.3) with the most promising CE initiative prospects (see Section 4.2.4 and 4.2.5) in the port. It was important to judiciously match the supply and demand sides, so as to maximize the probability that interested economic actors would actually form coalitions of the willing and explore further, in an actionable sense, these 'co-discovered' CE opportunities.

This sixth step concluded the CE opportunity discovery stage, and also our action-research advisory project. We should note that subsequently, when moving from discovery to pursuit, support from the PMB and Circular Flanders was viewed as critical to implementation (inter alia, to receive permits, to gain access to incentives, to exchange knowledge on scaling-up challenges, etc.). The implementation stage was ongoing at the time of writing this paper.

4.3. The CE initiative discovery process as the foundation of a proactive CE-related port strategy

CE-related initiatives in ports, similar to other projects, start from a discovery phase, with a process that can follow different paths. The process can start bottom-up or *organically* at the level of port users, with the discovery phase initiated by internal stakeholders in the port (see pattern 1a in Fig. 2). Alternatively, a top-down or *orchestrated* process unfolds. Here, internal stakeholders such as the PMB drive the process (see pattern 1b in Fig. 2), or external actors do this, as was the case in Zeebrugge with Circular Flanders - OVAM (see pattern 2 in Fig. 2). In the case of GWPs, a bottom-up or *organic* approach (pattern 1a) is less likely as compared to what is common practice in other port types. Port users in GWPs will typically not initiate CE projects, due to the absence of market-based stimuli in the port's immediate proximity (for instance, easily discoverable and scalable opportunities for industrial symbiosis or waste management). Here, a knowledge platform shared by port actors and possibly external stakeholders such as public agencies may be required for opportunity discovery (Karimpour et al., 2019).

An *orchestrated* (top-down) approach is therefore more likely in GWPs, whereby the discovery phase of CE projects is driven by the PMB or an external stakeholder. In the case of Zeebrugge, we identified – and were actively involved in setting out – a pathway whereby the discovery phase was prompted by an external stakeholder (Circular Flanders – OVAM), which then incentivized the PMB to involve port users and external actors in the discovery process. This is an example of the PMB evolving from its traditional public landlord role in the port, to that of an architect of meaning and strategic resource orchestrator, in this case involved in implementing the CE transition (van der Lugt et al., 2013, 2017; Verhoeven, 2010).

As a recommendation for other GWPs, the PMB should not have to wait for a top-down process initiated by an external public agency to start the CE transition process. As we have documented above, the transition to a CE approach in essence consists of aligning effectively the supply side (available sites inside the port) with the demand side (commercially viable CE opportunities). Such alignment can be greatly facilitated by developing a port vision for the CE transition, as an integral component of the port's strategy (Grafström and Aasma, 2021). Similar to what holds for more conventional masterplans in the initiative pursuit phase – and subsequent to the discovery phase that we highlighted in the present study – executing on the CE transition strategy then requires continuous monitoring of the progress achieved and strong resilience when facing new external circumstances.

5. Conclusion and managerial implications

We have described how ports can start a CE transition process that encourages and guides the adoption of CE projects, whereby we have focused on an under-researched type of ports, namely GWPs. This category of ports does not benefit from the presence of secondary resources in the immediate proximity of the port. GWPs can, however, play an important role in CE initiatives because of their hub position for transshipment cargo.

Haezendonck & Van den Berghe (2020) identified three possible pillars that can facilitate a transition towards CE projects in ports and concluded that industrial ports tend to have the greatest potential through 'industrial symbiosis' in their industrial clusters *(first pillar)*. Metropolitan ports tend to act as 'recycling hubs', due to their proximity to sources of urban waste *(second pillar)*. Finally, ports can also orchestrate 'new value streams' *(third pillar),* but this option has remained relatively unexplored. Our view is that GWPs should precisely pursue CE initiatives in this area of *new value streams* because of their hub position in transshipment flows. Here, CE initiatives can arise out of collaborative efforts among actors within the port cluster or include stakeholders from the fore- and hinterland.

The process towards a CE transition in our case involved six steps within the identification or discovery phase for each project: (1) determining supply-side boundary conditions for purposeful CE initiative discovery; (2) defining demand-side boundary conditions for purposeful CE initiative discovery, using benchmark projects in other ports; (3) matching the dual boundary conditions (see 1 and 2) with the available sites in the port area considered; (4) assessing the economic promise of CE initiative prospects that can involve port users; (5) identifying 'coalitions of the willing' around promising CE initiative prospects; (6) aligning available sites (see 3) with the most promising CE initiative prospects (see 4 and 5) in the port.

Our benchmark research in neighboring, leading ports (step 2) suggests that the current CE initiatives in these ports do not require substantial levels of surface area, at least to date. It also appears that few CE initiatives in ports make substantial use of the hinterland waterways, and those that do only use this transport mode for rather small volumes. This suggests that GWPs, which typically cover only limited surface areas and play a role mainly in transshipment (often with limited hinterland transport options) could still be successful in implementing CE projects. A critical condition for success appears to be the top-down support of either the PMB or a key external stakeholder. This implies that we could add a seventh component to the CE project discovery phase described above, namely: (7) *Orchestrating 'coalitions of the willing' by co-creating pathways with these stakeholders for implementation and possible scaling-up.*

Our case-study of a single GWP will hopefully be extended to include other ports, to validate our findings for GWPs more generally. In our case-study, the initiatives for a CE transition stemmed from the interest of external stakeholders, rather than from a more organic process involving existing port users. In other GWPs, the PMB and existing port users may take on a more prominent role. As to the future, it is likely that the CE transition will drive changes in the competitive landscape of ports, and will generate a 'new normal', with many traffic flows becoming part of CE-related value chains.

In our case-study, external pressure imposed on the PMB was critical to legitimizing the very idea that potential CE projects in the port could flourish. This external pressure emanated from a public agency (and individual policy makers within this agency) outside of the port, that had been responsible for an expensive brownfield clean-up and had the regulatory mandate to engage in a 'conditional return' of the site to the PMB (which would then supposedly grant new lease concessions to port users). This external pressure imposed on the PMB was instrumental to changing its attitude towards recognizing the potential value of CE projects. This externally driven, top-down or *orchestrated* approach, whereby the port's strategy evolved towards including a CE transition component, merits further attention and complements the more conventional CE project development, which is initiated *organically* (bottom-up) by the port users themselves.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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