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Ensuring circular strategy implementation: The development of circular economy indicators for ports

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ABSTRACT

Port clusters are expected to play a significant role in the transition towards a circular economy, both at the level of facilitating regional and global transport within circular production chains, as well as hosting circular activities in port areas. There is strong evidence that significant investments in the circular economy (CE) are being made in port areas, albeit without much knowledge on their impacts. To ensure an efficient use of port resources in view of this transition, these impacts should be adequately monitored. Research on circular economy indicators for ports is still in an exploratory stage, characterized by an absence of in-depth research on the development of port-related circular economy indicators. This paper focuses on the development of a comprehensive set of relevant and feasible CE indicators, which aim to support port managing bodies (PMBs) as well as port stakeholders to monitor the CE transition taking place. Through multimethod qualitative research, including content analysis, focus groups, a gap analysis and a qualitative survey, an actionable list of CE 12 indicators for ports was developed. Seven of which are highly feasible and five of which have medium feasibility in terms of stakeholder relevance and ease of implementation. Findings related to (1) the overall limited CE ambition levels of PMBs and (2) the difference in the values of some indicators for different port typologies are also discussed. The value of this study for practitioners lies in providing them with an actionable set of KPIs which can support their efforts and communication related to their CE transition.

1. Introduction

Today, (port) policy makers, and in particular port managing bodies (PMBs) are investing in ports to become more sustainable (de Langen and Sornn-Friese, 2019). This is not only being done out of intrinsic motivation but also due to its importance for the ports' social license to operate and for port competitiveness (Adams et al., 2009; Moeremans and Dooms, 2021). One of these types of investments is that in the circular economy (CE). These investments go beyond (simply) attracting CE activities. To illustrate, some ports are reserving land specifically for circular activities such as the NextGen District in Antwerp (Port of Antwerp Bruges, 2022b), the Carcoke site in Zeebrugge (Jacobus, 2021) and North Sea Port's North-C Circular industrial estate (n.d.-c). In order to ensure that these investments lead to sustainable value creation for the port cluster, it is necessary to monitor the outcomes and the impacts with appropriate indicators. Indicators can serve both internal purposes of the PMBs, i.e., to assess their competitive position within the

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circular transition, against objectives formulated within their strategic cluster development plans. However, they can also be used as a means of transparent communication to motivate and engage external stakeholders (tenants, local communities, supply chain actors, governmental agencies) towards achieving their own circular objectives.

In this study, a list of CE 12 indicators for ports is developed using multiple methods and along with an analysis of each indicator's feasibility and applicability for different port profiles. It must be noted, however, that the quantification or valuation of the indicators falls outside of the scope of this research. The paper is set up as follows, Section 2 discusses existing literature on the definition and upcoming of CE in various areas including ports and port policy. This is followed by literature on monitoring and different monitoring systems, and in particular on what has been done in the area of CE monitoring in ports. Subsequent to the literature review are the research questions which this paper aims to find an answer to. Section 4 then elaborates in detail the various methods used in this study and is followed by the final list of CE indicators for ports which can be found in Section 5. Section 6 then discusses various insights uncovered during the research while Section 7 presents the conclusions of this paper as well as limitations of the study and suggestions for future research.

1.1. CE definition

Despite the frequency with which the term 'circular economy' (CE) is used, its definition is still rather ambiguous. Kirchherr et al. (2017) attempted to conceptualize the CE by analysing 114 definitions. Based on their findings, the definition of the for the circular economy is "an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso-level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers." Kirchherr et al. (2017, p. 229). The main components identified here are, the reduction of waste, the prolonging of the use and value of materials, CE's relevance in all three operational levels and its link to sustainability.

Since the industrial revolution, the linear economy has become the dominant economic model (Eni, 2022; Rizos et al., 2017).[1] This model gained an even greater boost after the second World War when resources became cheap and widely available, reducing the need to maximize the value of resources for as long as possible.

As the limitations and dangers of the 'take-make-waste' system began to emerge, people started looking for sustainable alternative ways of living. Since the 2010s, the circular economy has become increasingly popular in society (Google Trends, n.d.) with governments adopting better waste management policies and customers pushing manufacturers to, for example, use more recyclable packaging and offer repair services. It is therefore no surprise that as citizens call for more responsible resource management, manufacturers set up circular initiatives and communicate them widely. This leads to CE becoming even more visible in our everyday lives.

The CE is not only gaining popularity in society, but also in the academic world. Statistics from a simple search on Web of Science show that before 2010, the term "circular economy" was only used around 100 times. Between 2010 and 2017 over 600 hits can be found while in the last five years, the term "circular economy" can be found in over 4500 publications. This shows that the scholarly interest in the topic is indeed growing at an increasing rate. The related themes are rather diverse. Many are case studies on specific sectors or industries (Aguilar Esteva et al., 2020; Hamam et al., 2021; Nozharov and Chobanova, 2017), while others discuss the link between the circular economy and how digital technology can support the transition (del Vecchio et al., 2020; Jones and Wynn, 2021). Some authors also examine how the circular economy requires a change in business models (Brendzel-Skowera, 2021; Pieroni et al., 2021).

Indeed, the circular economy is a concept which is becoming more widespread beyond society and academics and also amongst policy makers (Camilleri, 2020; Fitch-Roy et al., 2021; Johansson, 2021; Milios, 2017). In fact, goals related to the CE are being added at various policy levels. On an international level, the United Nation's Sustainable Development Goal number 12, Responsible Consumption and Production, directly relates to the wasteful society we currently live in. The targets set to reach this goal relate to better resource management and a reduction of waste (United Nations, 2022), which are two of the main components of the CE. On a more regional policy level, the EU has recently announced its European Green Deal which aims to "transform the EU into a modern, resource-efficient and competitive economy" (European Commission, 2019). One of the building blocks which will help the EU in achieving these goals is the EU's Circular Economy Action Plan which focuses on the EU's transition towards a CE (European Commission, n.d.). Looking at a more local level, cities around the world are also adapting their policy strategies in striving towards becoming more circular (OECD, 2020).

[1] The first appearance of the term 'circular economy' originates from 1988 in Kneese's "The Economics of Natural Resources" (Kneese, 1988). While the term circular economy is indeed still rather novel, the concept itself has in fact existed since prehistoric times. Evidence shows that, as early as Neolithic times, people reused materials from old hand axes to make smaller flint tools (Kuijpers, 2019; Max Planck Institute for the History of Science (MPIWG), 2019; Shimelmitz, 2015). Sometime later, about 3000 years ago, people living in the Persian Gulf even repurposed broken ceramics to make new tools (Zdziebłowski, 2020). The Romans also recycled and melted down metals for reuse. What is interesting to note is that these activities were not all as a result of necessity due to poverty. Some of the recycling activities were entrepreneurial and profitable endeavours (Duckworth and Wilson, 2020). Medieval times even saw what we nowadays call industrial symbiosis where waste from, for example, slaughtered animals was sold and used for candle making (Davis et al., 2021).

1.2. CE in ports and port policy

The increased popularity of CE in policy making influences shipping and port industries, and shipping and port policies. The International Maritime organization (IMO) for example, participates in several CE initiatives. Amongst these is their participation in the Hong Kong Convention which aims to ensure "that ships, when being recycled after reaching the end of their operational lives, do not pose any unnecessary risks to human health, safety and to the environment" (International Maritime Organization (IMO), 2019c). The IMO also encourages the use of the FSI's (Flag State Implementation) action plan to "tackle the alleged inadequacy of port reception facilities" (International Maritime Organization (IMO), 2019b) and is one of the partners of the GloLitter Partnerships Project which "aims to help the maritime transport and fishing sectors move towards a low-plastics future" (International Maritime Organization (IMO), 2019a). These initiatives prove that globally active policy makers do promote CE, in this case particularly related to better waste management systems. At a more regional level such as that of the EU, CE is also given the necessary attention by various port organisations. The European Sea Ports Organisations (ESPO), for example, is an independent lobby for seaport interests. These interests span widely, with some of them relating to the circular economy. In fact, ESPO's 2021 Green Guide lists "Waste and Circular" as one of the five categories which cover European ports' top ten priorities and acknowledges that "many European ports actively reduce waste and encourage circularity through innovative green practices and projects" (ESPO, 2021, p.31). Other regional CE port initiatives include the LOOP-Ports project whose goal is to "facilitate the transition to a more circular economy in the port sector, where products, materials and resources are maintained in the economy for as long as possible, and the waste generation minimised" (LOOP-Ports, 2023; North Sea Port, n.d.-a).

Indeed, individual PMBs are also keeping up with the idea of a circular transition. In fact, ESPO, 2022 Governance Report reveals that as much as "70% of the respondent PMBs have a circular economy strategy in place" (ESPO, 2022, p.28). Examples of these include the Port of Rotterdam which "is working together with many regional and chain partners to develop new, circular value chains" in relation to their goal of becoming CO_2 neutral (Port of Rotterdam, 2022a) while the Port of Antwerp-Bruges asserts that the "transition to a circular economy is part of [their] ambition to be a climate-neutral port by 2050″ (Port of Antwerp Bruges, 2022a). Another port in the Rhine-Scheldt Delta, namely North Sea Port, explicitly discusses its commitment to CE in its "Connect 2025″ strategic plan, where one of the "8 programmes to realize the strategic plan" is indeed, investing in the circular economy. They further admit that "working with all stakeholders towards a fully circular economy is a key focus area" (North Sea Port, 2023b).

ESPO (2022) Governance Report, additionally acknowledges that the role of ports in the circular economy shifts away from the traditional role of landlord and more towards that of facilitator (ESPO, 2022). This is further supported by Balz and Qu (2020) and Ballini (2017), who mention that the value of ports in the circular economy is found in the way they can serve as a place where various actors come together which can help stimulate industrial symbiosis (Balz and Qu, 2020). In other words, ports can take on the role of "'matchmakers' and crossing-points" in the circular economy and would be particularly good at this because they are "active in the treatment, collection and shipment of waste and stimulate the emergence of innovation circles" (Ballini, 2017, p.18).

Besides the altruistic motivation to take part in the CE, ports can use their participation in the CE to their own benefit in several ways. By contributing to their sustainability, they can strengthen their social license to operate while the CE can also be a way of "securing a port's future" by becoming more resilient (Carpenter et al., 2018, p.539).

1.3. Monitoring sustainability in general

As CE is placed in the spotlight more often, public and private investments in CE are also on the rise. However, investors and stakeholders demand to know how these investments impact performance. According to Kotler (1984), performance is identified based on the effectiveness and efficiency with which the set goals are reached. Effectiveness relates to whether the goal was achieved while efficiency relates to how well the organization's resources were used to achieve these goals. In order to ascertain whether CE investments are indeed efficient and effective, the circular transition must be measured and monitored.

In their literature review on performance measurement system design, Neely et al. (1995, 1228) found that the "importance of performance measurement has long been recognized by academics and practitioners from a variety of functional disciplines." In point of fact, when setting organisational or policy goals, a monitoring system must be set in place to follow up on the evolution towards those goals. Without it, it is difficult to know whether or not the implemented actions are having the required effect or whether the set goal is being reached. A performance measurement system should be directly derived from the organisation's strategic mission and goals. This is particularly campaigned for by Skinner (1969), who advocates for a top-down approach in strategy development. The approach starts with the development of an overall corporate strategy which moves further down to form strategic measures. Kaplan and Norton's (1992) Balanced Scorecard (BSC) also focuses on the importance of the link between strategy and the indicators used to monitor progress. The novelty of the Balanced Scorecard was found in that it also considers non-financial parameters as part of performance measurement. In fact, besides the traditional finance perspective with indicators such as ROE (Return On Equity), cash flows and market share, the BSC also includes the customer perspective, innovation and learning perspective, and internal business perspective (Kaplan and Norton, 1992).

At the time, the BSC was indeed considered a breakthrough in performance measurement since it looks at organisations from a wider perspective than simply a financial perspective. However, some argue that this perspective could be further broadened. As early as 2002, Figge et al. (2002) identified the need to include all three sustainability components (economic, environmental, social) in the BSC. In fact, in their Sustainability Balanced Scorecard, Figge et al. (2002), introduce a fifth perspective which includes social and environmental aspects and is named the non-market perspective. This need for an additional perspective to include all aspects of sustainability is echoed by Fulop et al. (2014 p.341) who state that sustainability is becoming "a strategic pre-requisite for long term competitive advantages and business excellence" and by Labuschagne et al. (2005) who admit that global companies are more pressured to report on their sustainability performance.

Sustainability performance is not only measured in companies and organisations, but also in industries and supply chains (Labuschagne et al., 2005; Qorri et al., 2018). Findings show that literature on the sustainability performance of supply chains is fragmented and that “determining the sustainability performance of supply chains is challenging” (Qorri et al., 2018, p.570). One of the most popular monitoring systems in place is the publishing of a sustainability report. However, these have their own limitations as they are often “uncompleted and uncoordinated.” Other frequently used approaches for evaluating sustainability performance are the BSC and its modifications as well as the “Life Cycle Assessment (LCA) and its modifications” (Qorri et al., 2018, p.571).

1.4. Monitoring in ports

Since this paper focuses on the port industry, the next section dives deeper into monitoring in the port context.

Other than the general reasoning for monitoring discussed in previous sections, one of the reasons why ports monitor their performance is to strengthen their competitiveness. Besides, Otheitis and Kunc (2015), discovered that early adopters of performance management systems “in the shipping industry are among the leaders in the industry” which shows that the (early) adoption of performance measurement systems is linked to a higher business performance. Rijkure (2019, p.387) also emphasises that, since “ports are responsible for the quality assurance of port services, […], monitoring and assessing of the KPI must be part of the quality assurance process.”

So, while performance monitoring indeed appears to be necessary in the port industry, research on port performance measurement is limited, most likely due to the complex nature of ports with its various actors (Langenus and Dooms, 2015).

The most common KPIs for ports found in literature include, but are not limited to, operational and financial KPIs, followed by socioeconomic or environmental performance indicators (Langenus and Dooms, 2015; Morales-Fusco et al., 2016). The most crucial KPI areas for port stakeholders identified by Ha et al. (2017.p.4) include “core activities (CA), supporting activities (SA), financial strength (FS), user satisfaction (US), terminal supply chain integration (TSCI) and sustainable growth (SG)” while the most dominant KPIs for determining port competitiveness appear to be “transport costs and times along the transport chain” (Rezaei et al., 2019, p.396). Besides research on general KPIs for ports, recent research also focuses on specific themes such as KPIs related to port governance (de Oliveira et al., 2021).

Beyond traditional port performance measurement, ports are being pressured to report and monitor on their sustainability by their stakeholders (Lim et al., 2019). Several studies have recognised this and have attempted to identify sustainability indicators for ports (Hui et al., 2019; Schipper et al., 2017; Wan et al., 2018). The most common sustainability KPIs appear to be “water management, air pollution management, energy and resource use, and noise control” for the environmental component, health and safety and employee profiles for the social component, and FDI, port operations and financial performance for the economic component (Lim et al., 2019, p.59; Lu et al., 2016; Muangpan and Suthiwartnarueput, 2019).

1.5. CE monitoring

As the traditional monitoring systems have been updated over time to include wider sustainability indicators, so are current monitoring systems also being updated to include circular economy indicators.

The broadness of CE, however, does not make this an easy task (Howard et al., 2018; Moraga et al., 2019). Nonetheless, previous research has provided insight into the characteristics of CE indicators. To illustrate, Howard et al. (2018 p.7315) found that CE indicators are “likely to be sector specific” which contributes to the complexity of using general CE indicators in cross-sector contexts. In the meantime, Moraga et al. (2019) identified the prevailing focus on the preservation of materials in CE indicators, with little to no indicators looking at CE from a broader perspective to include, for example peer-to-peer or sharing initiatives. CE indicators are also most common at micro and macro level, with research on CE indicators at meso-level being rather scarce (Moraga et al., 2019).

In practice, different organisations provide monitoring guidelines at various levels with different sets of CE indicators. The EU’s CE monitoring framework for example, focuses on the macro level with indicators being split up into categories of production and consumption, waste management, secondary raw materials, and competitiveness and innovation (Eurostat, n.d.), while the Circular Economy Monitor for Flanders gathers more than 100 macro level CE indicators which are also split up into various categories including, amongst others, housing, food, and consumer goods (Circular Flanders, 2021). The OECD is, at the time of writing, also working on the development of their own CE indicators (OECD, 2020).

Micro level CE monitoring includes both the material and product level, and the company level. Here, several organisations have developed CE monitoring tools. To illustrate, the Ellen MacArthur Foundation’s Material Circularity Indicator (MCI) “allows companies to identify additional, circular value from their products and materials, and mitigate risks from material price volatility and material supply” and can therefore be used on a material, product and also company level (The Ellen MacArthur Foundation, n.d.). On the other hand, their second monitoring tool, Circulytics “measures a company’s entire circularity, not just products and material flows” and is already being used by over 1250 companies worldwide (The Ellen MacArthur Foundation & Granta Design, n.d.).

Reporting standard organisations also recognize the need for CE reporting standards. The GRI 306: Waste 2020 reporting standard, for example, is the “first internationally applicable reporting standard for businesses to provide a complete image of waste impacts across their value chain” (Global Reporting Initiative (GRI), 2021) while the International Organization for Standardization (ISO) is developing a new standard for CE. Namely, ISO 59,010 and ISO 59,020, which, at time of writing are still under development (International Organization for Standardization (ISO), n.d.-a; n.d.-b). Two other organisations, the Circular Economy Indicators Coalition (CEIC) (Circle Economy, n.d.) and the World Business Council for Sustainable Development (WBCSD) (n.d.), also aim to provide businesses with a unified framework for CE monitoring which can be applied to all types of businesses.

1.6. CE monitoring in ports

CE reporting standards or indicators for the meso-level still remain limited, not only in literature but also in practice. This, however, does not mean that they are not necessary. In fact, CE monitoring for ports is certainly valuable. Not solely due to the need for CE monitoring in general but also particularly because ports are clusters of high economic activity, with some of them even being industrial and/or metropolitan hubs. Ports' stakeholders also expect transparency in their activities which makes CE monitoring not only necessary from the PMB's internal point of view but also from the point of view of stakeholders.

Currently, most ports report on CE by listing initiatives (North Sea Port, 2023a; Port of Antwerp Bruges, 2022a; Port of Rotterdam, 2022b). This is a non-structured measurement system which allows neither for objective monitoring over time nor for the comparing of ports' CE objectives and goals.

While literature on CE in ports does exist, most studies are limited to discussing specific cases and examples (Angrisano and Fusco Girard, 2017; Carpenter et al., 2018; Karimpour et al., 2019; Nocca and Gravagnuolo, 2017) and not to the monitoring of the CE transition at the level of the port as a whole. Nonetheless, a limited amount of research has indeed been oriented at an improved understanding of CE indicators for ports (Cerreta et al., 2020; Gravagnuolo et al., 2019; Kovačič Lukman et al., 2022), however, each of these does have its limitations. Some focus on city ports (Cerreta et al., 2020), which limits the research to urban ports, leaving out ports which lean more towards industrial or gateway ports. Other research finds its limitations in the methodology used. Oftentimes, the method used is based on existing CE projects in ports (Gravagnuolo et al., 2019) or CE indicators already being reported by ports (Kovačič Lukman et al., 2022) leading to the risk of omission of valuable potential CE indicators, which are not (yet) being reported. These indicators originate from the perspective of what is being monitored, not of what should be monitored.

2. Research questions

In order to overcome the aforementioned limitations, in this paper, we develop a process to develop CE indicators for ports using a multimethod approach (Creswell and Creswell, 2018), and answer the question of what should be monitored (i.e., the acceptability and relevance) in light of the circular transition for ports, as opposed to what is currently being monitored. Therefore going beyond the mere feasibility of CE indicators. The indicators are developed in a way which aims to be relevant for all port profiles, in view of a common baseline calculation. The research questions in this paper are as follows:

1 Which CE indicators are relevant for ports and in relation to CE ambitions?
2 Are they feasible in practice?
3 What are the CE indicators' limitations?
4 Are the CE indicators equally relevant for all port types?

These questions are answered and discussed in Sections 4 and 5.

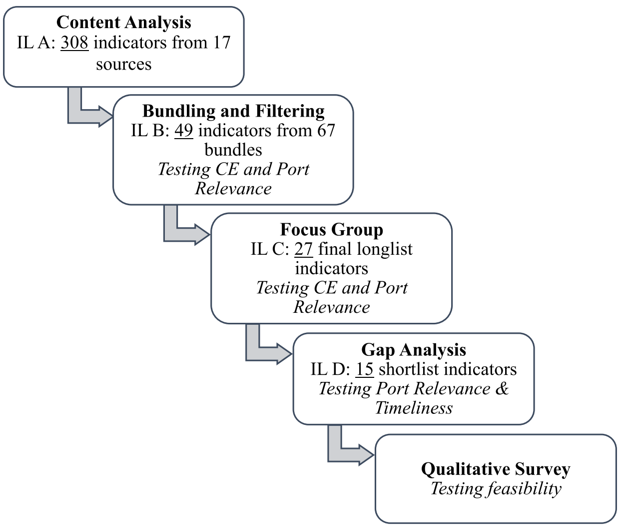

Fig. 1. Summarizing overview of the methods used in this study to funnel 308 potential indicators to a final list of feasible CE indicators for ports. (IL = Interim List).

3. Method

The way this research was conducted was on the basis of multiple methods. The main reason for this is the exploratory nature of the study which implies that the available data and information needed to carry out a comprehensive study is limited. Making use of different methods allows for the collected data to be more robust and grounded since it is subjected to different points of stakeholder views and confirmed by different sources. In fact, the combination of various methods allowed for an extensive and in-depth development and analysis of potential circular indicators for PMBs. Each additional method used further strengthens the interim list of indicators by confirming its relevance or by adjusting it to be more adequate.

Throughout each consecutive step in the methodology, it was ensured that a balance was held between limiting the indicators to only include those which are highly relevant for port cluster development in the context of the circular transition, while ensuring that each indicator is sufficiently vast to encompass the concept of the circular economy. The indicators were also kept broad enough to be used in different cases (e.g., for different types of ports and for different types of projects).

The multimethod approach used to develop a list of CE indicators for ports comprised of content analysis, a focus group, a gap analysis and a qualitative survey. The combination of these methods allowed for the funneling of 308 indicators to a final list of 12 feasible CE indicators for ports. A summarizing overview of the methodology used is presented in Fig. 1, with each step further discussed in Sections 3.1 through 3.5 and the final indicator list being presented and discussed in Section 4.

3.1. Content analysis

The first method used was that of content analysis. The aim here was to collect a vast number of circular indicators which would be used as Interim list A. The reason for collecting a large number of CE indicators was to ensure that the first interim list included indicators from all areas of the circular economy. For example, instead of limiting the CE indicators to those related to waste and recycling, indicators which measure the CE from a governance, land use, and economic point of view were also included. The idea here was that in this way, the CE was covered from as many aspects as possible, and indicators could be further combined and filtered in later stages. It is for this reason that a broad range of sources was used. From a CE perspective, sources included reports and documents on circular economy monitoring in general and on more specific monitoring of CE on macro and micro levels. Sources used to identify current CE reporting in ports include documents and reports on port performance from, amongst others, industrial, metropolitan, gateway and inland ports.

Here, a number of CE and port related documents were screened on terms including “circular”, “circularity”, “indicator” and “KPI”. For each hit, the context of the term was analyzed to identify a potential CE indicator for ports. In case of a positive analysis, the potential CE indicator for ports was placed in interim list A. Due to the lack of explicit reporting of CE indicators, an additional manual scan of the documents was done in order to identify CE indicators which were less explicit.

The output from the content analysis was an interim list of CE 308 indicators (Interim list A).

3.2. Bundling and filtering

Having a sufficiently large first set of indicators, the next step was to analyze and filter out Interim list A on the basis of duplicate indicators, CE relevance and port relevance. For this, similar or identical indicators were grouped into bundles.

These 67 bundles were then analyzed on their CE relevance in its sensu stricto form (Moraga et al., 2019). The generally accepted definition for the circular economy includes maximizing the value of resources, minimizing waste, and ensuring sustainability (Kirchherr et al., 2017). For this study, however, CE focusses on reducing waste and extending the value of materials / products (including CO2, materials, water, energy). The idea is that there are already sufficient indicators which have been developed for the sustainability context (Hui et al., 2019; Lim et al., 2019; Schipper et al., 2017) and the focus of this study is on contributing to the development of CE indicators rather than sustainability indicators.

Therefore, while the authors acknowledge that sustainability is a strong component in the transition to a circular economy, bundles related to the development of a sustainable system or pure environmental bundles were filtered out. This includes, for example, those relating to biodiversity (quality of marine ecosystems), to air quality (CO2 emissions), or indicators which relate to sustainability in a broader sense (e.g., transport mode, level of multimodality).

After this analysis and filtering, 49 bundles remained. For each of the remaining 49 bundles, a CE indicator which is relevant in the port context was developed. This was done by choosing an overarching indicator from the bundle or by developing one based on the indicators in the bundle.

This resulted in an Interim list B which includes CE 49 indicators which are relevant in the port context.

3.3. Focus groups

As a second method, a focus group of CE and port experts with international expertise was set up to improve the quality of Interim list B. The aim was to ensure that all indicators were both CE relevant and port relevant and that no important CE indicators were missing as a result of possible “over-filtering” of Interim list A.

A diverse and gender balanced group of both CE and port specialists was brought together. The 18 focus group members took part on a voluntary and non-remunerated basis. The participants included academic experts, policy makers and port sustainability and business development managers.

During the focus group, each indicator from Interim list B was discussed and analyzed in detail. The participants were asked to give their opinion on whether each indicator was sufficiently relevant from both a CE perspective and a port perspective, and whether the indicator should be adapted or removed in a next stage. They were also asked to identify whether any potential indicators were missing which should be added to the list.

No new potential indicators were suggested by the focus group. However, 22 indicators from Interim list B were filtered out or integrated with the remaining indicators. This resulted in an Interim list C of CE 27 indicators which were fully adapted to be relevant in both the CE and port context.

3.4. Gap analysis

In a next stage, a gap analysis was conducted on Interim list C. The aim here was to identify any gaps between the indicators and the CE goals set by PMBs. This was done on the basis of the principles of strategic management, which explain that goals must be translated into indicators and indicators must correspond to particular goals (Kaplan and Norton, 1992). Here, we analyzed whether or not the Interim list C indicators were relevant to PMBs' current CE goals.

For this analysis, two sets of data were used. The first was Interim list C, consisting of 27 port relevant CE indicators. The second dataset was a collection of CE goals set by Flemish PMBs. The latter consists of agreed CE goals between each PMB and the regional circular agency as well as internal CE goals stated in the PMBs' strategic reports.

The reason for choosing Flemish ports in this analysis was twofold. Firstly, ports in this region are considered to be circular frontrunners (Haezendonck and Van den Berghe, 2020; de Langen et al., 2020) and secondly, because the research team was given access to the required confidential agreement documents by Circular Flanders. The chosen ports were North Sea Port, Ostend, Zeebrugge and the Port of Antwerp.[2]

The gap analysis based on both datasets was executed by comparing the indicators from Interim list C to the ports' CE goals to check for a match. If no indicators corresponding to the CE goals were found in Interim list C, this meant that an additional indicator had to be developed (Group i – 3 instances). In other words, this step checked whether any missing indicators could be identified in relation to the port's circular objectives. On the other hand, if a corresponding indicator was found, this proved the indicator's relevance and usefulness in the short term (Group ii – 15 instances). Finally, an indicator from Interim list C without a matching goal indicated that the indicator is not useful in the short term but may have a higher potential in the future, when ports' CE goals possibly become more ambitious (Group iii – 12 instances). Fig. 2 gives a clearer overview of the different gap analyses and their conclusions.

A relatively large number of indicators did not have a matching goal (Group iii). This shows that PMBs' CE goals are not as broad and extensive or ambitious as the indicators from Interim list C. Instead of simply eliminating these indicators, they were retained and condensed into a shorter list of five potential future indicators. These are further analyzed and discussed in Section 5.4.

For the three goals without a corresponding indicator, the aim was to develop additional CE indicators. However, a closer inspection of the goals showed that these were too abstract, vague and undefined to create a corresponding indicator. For example, one of the goals was to increase circularity. It is unclear however, what the PMB understands under this term. Moreover, it is uncertain on how the PMB expects to set concrete objectives related to this goal. Due to this ambiguity, no additional CE indicators were developed.

The result of the gap analysis is a new Interim list D made up of the 15 indicators which comprise Group (ii).

3.5. Qualitative survey

The last method used to reach a final list of CE indicators for ports was to test Interim list D in practice. In other words, to test the indicators' feasibility. For this, a qualitative survey was conducted with the PMB and various port companies of North Sea Port. The reason for choosing North Sea Port to test the indicators' feasibility was that this cross-border seaport over Belgium and the Netherlands is highly active when it comes to the CE. In fact, there are currently CE 59 projects, activities and platforms found within the port area. North Sea Port has also shown its commitment towards the CE transition in particular by taking part in studies related to the CE transition in ports as well as by taking on an active role in CE coalitions (Smart Delta Resources, n.d.).

The target port companies for the qualitative survey were those which take part in circular activities or projects. This list was provided by the PMB of North Sea Port. For the CE 41 activities and projects taking place in North Sea Port, the PMB provided the contact details of 17 representatives from the various port companies, within the required timeframe. These were all contacted with the request to take part in the qualitative survey. 12 of these contacts completed the survey, as well as a representative from the PMB of North Sea Port.

As mentioned, the aim of the qualitative surveys was to test the feasibility of the indicators in Interim list D. Therefore, the participants were asked to review each indicator and rate its feasibility based on several variables. These were, the ease of measuring the indicator based on the required data, the ease of access to the necessary data, and the ease of measuring the data if it is not available. Participants were also asked to consider the time required and cost for each of these steps. The participants provided an overall feasibility score of low feasibility, moderate feasibility or high feasibility for each indicator based on the aforementioned components. The respondents' answers were rather unanimous, the results of which can be found in Section 5.1.

The opportunity was also taken to once again ask respondents whether they believed that a potential indicator was missing. This

[2] Part of this research was executed before the formal implementation of the merger of Port of Antwerp with Port of Zeebrugge (22/04/2022), and the transition to Port of Antwerp Bruges.

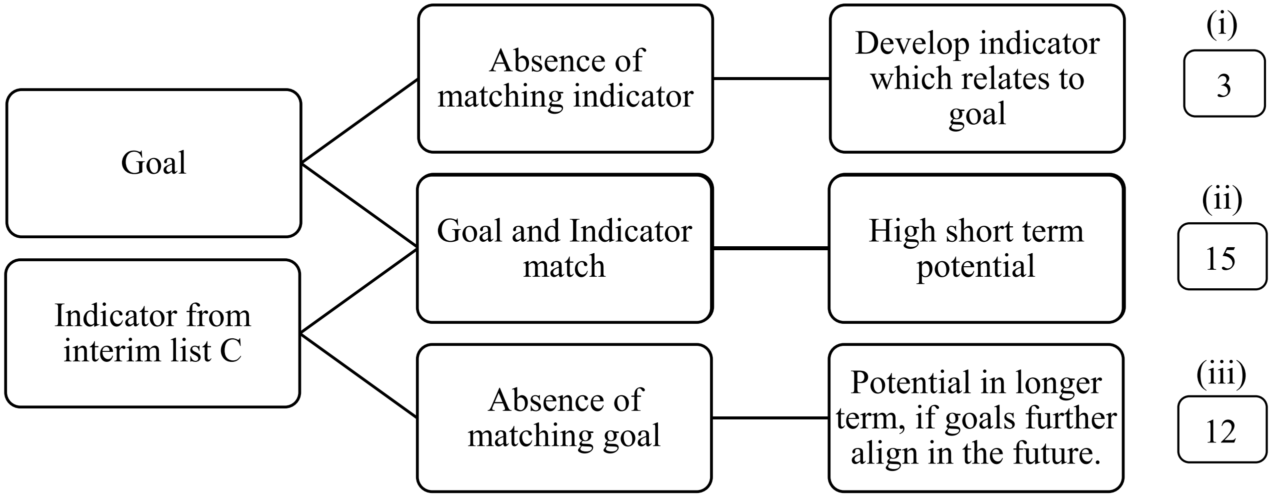

Fig. 2. Visual overview of the gap analysis.

was done in order to ensure that the remaining CE indicators covered all CE aspects which are relevant in the port context and no potential indicators were left out. No additional suggestions were made.

4. Results

The combination of four consecutive methods in the search for relevant and feasible CE indicators for ports resulted in a final list of 12 indicators as an answer to the research questions: “Which CE indicators are relevant for ports?” and “Are the CE indicators feasible in practice?” These, along with their corresponding unit of measurement are presented in Table 1. Indicators 1 through 7 are highly feasible while indicators 8 through 12 are moderately feasible.

The extensive research from beginning to end, including comments and suggestions made by the focus group and survey participants, resulted in the collection of more detailed knowledge on each indicator. What follows is a short description of each indicator, based on this information.

IC 1. Number of CE business activities located in the port area

IC 1 directly relates to the number of CE business activities taking place in the port area. This includes activities which have proven themselves to be economically sustainable and therefore free from, for example, being dependent on subsidies. This is an example of an output indicator and is one of the most intuitive indicators to measure and interpret. Examples of CE activities include recycling plants and waste-to-biofuels plants.

IC 2. Number of CE projects in the port area

IC 2 is similar to IC 1. However, CE projects are those CE activities which have not (yet) proven themselves to be economically sustainable or are limited in time, scale, and / or business model. The long-term value of these projects is therefore likely to be less than that of CE activities. An example of a CE project is that of Plasticity in North Sea Port. This is a temporary project which aims to develop technical solutions for lost plastics (PlastiCityProject, n.d.).

IC 3. Share of CE start-ups in the port area which make use of incubation services

IC 3 gives an indication of the R&D and services which can be used to push circular initiatives in becoming economically stronger. Incubators can provide start-ups with services related to, amongst others, administration and applications for subsidies. The idea here is that CE start-ups which use incubation services will grow faster and further than those which do not use these services, and therefore have a higher long-term potential. Embedded in this indicator is another interesting value, namely, the number of CE start-ups in the port area. This gives an idea of the CE innovation taking place in the port area. While specific CE incubators do exist, for this indicator, any incubator is applicable. An example of (circular) incubator is the Circular Kickstart located in Antwerp, Gent and Bruges.

IC 4. Share of tender specifications which include a circular procurement policy

IC 4 relates to the circularity of port infrastructure and to governance measures used by PMBs. Circular requirements referred to in tender specifications could include, but are not limited to, building infrastructure in a modular way or that a minimum percentage of the used materials must be of secondary nature. An example of the presence of a circular procurement policy in a tender specification for a new pipeline could be the requirement that at least 20% of the materials used must be of secondary origin.

Table 1
Final list of feasible CE indicators for ports.

	Indicator (IC)	Unit
1	Number of CE business activities located in the port area.	Absolute value
2	Number of CE projects in the port area.	Absolute value
3	Share of CE start-ups in the port area which make use of incubation services.	%
4	Share of tender specifications which include a circular procurement policy.	%
5	Share of port companies which are members of a CE platform/s in the port cluster.	%
6	Share of non-recyclable waste generated onboard ships.	%
7	Share of cargo volume of end-of-life materials.	%
8	Share of non-recyclable waste generated in the port area.	%
9	Share of hectares of CE activities in port area.	%
10	Share of direct employment from CE activities and projects in port area.	%
11	Amount of end-of-life material processed in the port area.	Tons, L, kJ
12	Share of secondary material consumption in the port area.	%

IC 5. Share of port companies which are members of a CE platform/s in the port cluster

IC 5 introduces the notion of a CE platform. This is a network of actors and players which enhances collaboration, innovation, and/or knowledge transfer. The more members it holds, the greater its value as a result of synergies. This is particularly relevant in the context of the CE because it facilitates industrial symbiosis. For example, the production waste of one port company can be used as a valuable input in the production process of a different port company. An example of a CE platform is Smart Delta Resources (North Sea Port).

IC 6. Share of non-recyclable waste generated onboard ships

As specified in its name, IC 6 relates to waste generated onboard ships, and in particular to the non-recyclable waste. In this case, it is assumed that the recyclable waste deposited at the port reception facility is actually recycled. The non-recyclable waste, however, is disposed. In order to distinguish recyclable from non-recyclable waste, the D-codes set by the EU (European Parliament & Council of the European Union, 2008) are used to define non-recyclable waste. An example of D-coded waste is that which is incinerated.

IC 7. Share of cargo volume of end-of-life materials

IC 7 is one which has two components, namely, (a) import and (b) export. This indicator identifies the volume of the cargo streams which relate to the CE. As the CE transition evolves, it will be interesting to identify how this is reflected in ports' cargo streams. Several categories of cargo which can be considered as EOL include but are not limited to, wastewater, wastepaper and paper waste, scrap and wood waste. An example of this indicator would be that 20% of export is end-of-life cargo comprised of wastepaper, stone debris and scrap.

IC 8. Share of non-recyclable waste generated in the port area

IC 8 is analogous to IC 6. However, in this case, it concerns waste generated in the port area rather than onboard ships. Once again, the assumption is made that recyclable waste collected by the waste collection system is indeed recycled. The reason why this indicator is not highly feasible is because waste collection systems (currently) do not have data on the collected waste by location and, R and D code.

IC 9. Share of hectares of CE activities in port area

IC 9 relates to the land use within the port area and to what extent land is used for circular activities. This indicator is highly relevant as more and more ports are dedicating specific areas to circular activities.

For concessionaires whose activities are fully circular, the calculation is rather straightforward as the whole plot area can be included. However, for plots where circular activities are only a part of the total activities taking place, the feasibility of being able to provide an accurate value is limited.

IC 10. Share of direct employment from CE activities and projects in port area

IC 10 considers the issue of employment in the CE. Employment is an important factor for ports' social license to operate which makes it worthwhile to know how the CE transition may affect this. Similarly to IC 9, the feasibility of measuring this indicator depends on whether the circular activities comprise the total business activities or not.

IC 11. Amount of end-of-life material processed in the port area

IC 11 is made up of four components, namely, (a) material (tons), (b) water (liters), (c) energy (kilojoules) and (d) CO_2 (tons). This indicator relates to the processing of end-of-life material. Here, processing does not only pertain to recycling but also encompasses other R-levels such as remanufacturing or repair. This includes processing for internal as well as external reuse. Material, water, energy and CO_2 are prepared to be used as a new input. The reason for choosing these categories is that the focus groups and qualitative survey revealed that these are the main types of resources which are given a second life in the port area. An example of end-of-life CO_2 processing would be the tons of CO_2 captured for reuse.

IC 12. Share of secondary material consumption in the port area

IC 12 relates to the use of secondary material in the port area and is once again made up of the same four components as IC 11 ((a) material (tons), (b) water (liters), (c) energy (kilojoules) and (d) CO_2 (tons)). This indicator provides insight into the use of secondary materials as opposed to virgin material by port companies. An example for this indicator would be that 20% of water used in the port area is reclaimed water.

5. Discussion

Having presented each individual indicator in Section 4, this section further discusses the set of indicators as a whole.

5.1. Feasibility of indicators

This section provides a more thorough answer to the research question: "Are the CE indicators feasible in practice?"

Without going into detail on the quantitative character of the indicators, it is expected that the collection of data for the indicators is subject to challenges. This is likely due to the fact that the "port industry is characterized by numerous actors coexisting within one port complex or cluster" (Langenus and Dooms, 2015, p. 269) and therefore the required data is not centralized but rather scattered across different players including amongst others, the PMBs' own departments, the concessionaires, service providers such as waste collection services and local or national governments.

As mentioned, IC 1 till IC 7 are (relatively) highly feasible indicators due to, amongst others, good access to data and straightforward measurement of data. For example, in the case of IC 4, the PMB has a list of tender specifications which can relatively easily be checked on whether or not anything related to a circular procurement policy is included.

Those indicators which are only moderately feasible are named so due to various factors. For example, in the case of IC 9 and 10, accurate measurement of the indicator is impractical while collecting the necessary data for, for instance, IC 11 and IC 12, requires data collection through, for example, annual surveys. The feasibility of other indicators such as IC 11, 12, is also limited due to strict confidentiality policies of the companies which hold the required data.

While the feasibility of the indicators in this study was tested on the basis of qualitative surveys, the real feasibility test will occur when the indicators are actually measured in practice.

5.2. Quality of indicators

In order to answer the research question: "What are the CE indicators' limitations?", this section provides an analysis of the quality of the developed indicators. Eight out of 12 indicators are presented as a percentage, which makes them vulnerable to being used as a misleading statistic, particularly where the law of small numbers is involved (Quine and Seneta, 1987). Users and interpreters of these indicators should therefore interpret these indicators' values in a critical manner. In the case of IC 1 and IC 2, on the other hand, the size or (circular) quality of the activities are not taken into account. In other words, they do not consider which R-level of circularity (Reike et al., 2018) the activities relate to, meaning that all circular activities, ranging from sharing activities (high circularity) to energy recovery (low circularity) are in this case considered to be equal. A limiting factor for IC 5 is that it does not measure the quality of the output from the platform. To illustrate, many port companies may be members of the platform, however, if it is mismanaged or not actively consulted, the platforms' value could be negligible. Moreover, in the case of IC 6 and IC 8, the assumption is made that all recyclable waste is indeed recycled while, in practice, this may not always be the case. Therefore, the value of this indicator may be a misrepresentation of reality.

5.3. Potential differences in indicator values for different port typologies

Throughout the study, it was attempted to define the indicators in a broad enough way so that they are applicable for all port profiles. As argued in Haezendonck and Van den Berghe (2020), defining one potential CE transition strategy for all ports is difficult due to the large variety of ports in terms of size, governance model and port activities. In fact, during this research it was recognised

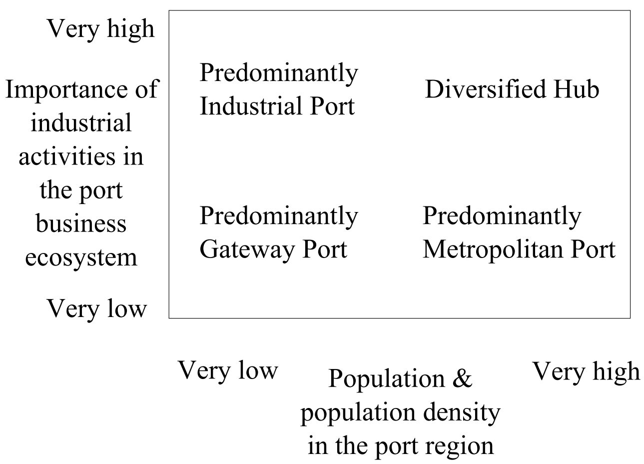

Fig. 3. Port typologies.

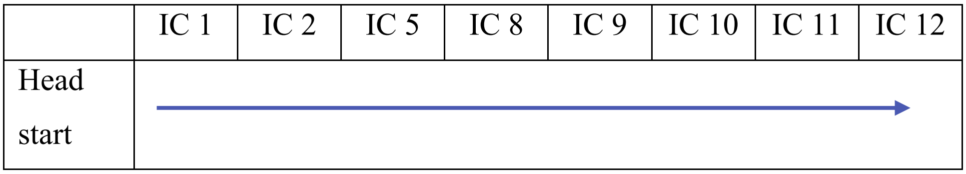

Fig. 4. Industrial ports have a head start for some indicators.

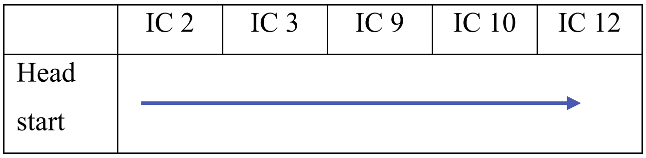

Fig. 5. Metropolitan ports have a head start for some indicators.

that the circular transition is different for different port types. For this purpose, ports were grouped together on two dimensions, namely, the importance of industrial activities, and the population and population density in the port region. Based on these dimensions, a graph was developed showing the position of different port types. This is presented in Fig. 3. It must be noted that the borders between the port types are not strict ones since different port types can evolve towards other types of ports, with a combination of all port typologies found in the form of a diversified hub.

When analyzing the final list of CE indicators, it appeared that the values of some indicators would be higher for different types of ports, giving these ports a greater maturity in CE monitoring. Industrial ports will likely score higher on indicators related to industrial activities or industrial symbiosis than predominantly metropolitan ports. Metropolitan ports on the other hand will likely score higher on for example innovation and R&D related indicators as a result of their high proximity to educational institutions. These potential differences on indicator results are visualized in Fig. 4 for industrial ports and in Fig. 5 for metropolitan ports.

This also shows that the indicators should not be used to compare results amongst different ports since each port is different. These differences, however, do not imply that certain indicators are only relevant or measurable by specific port types. All port types should be able to measure each indicator. The answer to the research question “Are the CE indicators equally relevant for all port profiles?” is therefore that they are indeed relevant to all port profiles. However, the values of the indicators are expected to be higher or lower depending on each port’s profile.

5.4. Indicators to be developed in the future

As mentioned in Section 3.3, several indicators which are not ready for use right now can still potentially be of value in the future, for instance when PMBs’ CE ambition levels are higher, and/or more at the forefront of intended port strategies. Indicators which the qualitative survey showed were not currently feasible may also become feasible in the future. This could be as a result of compulsory reporting of data which until now is considered confidential. Table 2 lists potential future CE indicators for ports along with the reason why each one is not relevant or feasible in the short term.

Table 2
Potential future CE indicators for ports.

Indicator	Term of potential usefulness	Reason
Share of revenue from CE activities of PMB in port cluster.	Medium Term	Currently no matching objective.
Presence of waste management ISO standards.	Medium Term	Currently no matching objective.
Presence of a CE strategy or roadmap at the PMB.	Medium Term	Currently no matching objective.
Dedicated CE investments in the port area.	Medium Term	This is not (yet) being reported by companies, except for when it is published in the media.
Availability of training and education offerings in CE.	Long Term	Currently no matching objective and does not (yet) exist.
Number of CE certifications held by the PMB and companies in the port area.	Long Term	Currently no matching objective and, at the moment, there are no high-quality CE certifications.
Gross added value from CE activities in port area.	Long Term (or never)	Companies are not willing to share this sensitive information. This indicator could be measured if reporting of gross added value from CE activities becomes mandatory.

6. Conclusions

This paper provides a framework of CE 12 indicators which can be used by PMBs in their CE monitoring. By studying existing literature on the circular economy, on monitoring frameworks and in particular, on CE monitoring in ports, the authors found a gap in the lack of existence of a comprehensively developed, feasible set of CE indicators for ports. By applying multiple methods in the research, the final set of CE 12 indicators was validated throughout the different stages of the research. Each final indicator was analyzed on feasibility, resulting in two separate sets of seven highly feasible indicators and five moderately feasible indicators. It was also found that the developed indicators had their own limitations and that while all final indicators can be measured by all port profiles, different port typologies will likely have different values for some CE indicators. Finally, it was determined that several interim CE indicators which are not relevant or feasible in the short term, could still have a potential value in the middle to long term.

The managerial value of this research lies within the development of port related CE indicators in a comprehensive way, including an evaluation on their feasibility and how they can be used in practice. PMBs can use these indicators internally to measure their evolution in and contribution to the circular transition. They can help to identify their strengths and weaknesses in the context of the CE as well as act as a motivator for PMBs to reach their CE goals. The CE indicators can also be a means for PMBs to identify opportunities to further grow in the circular transition and increase their CE ambition level.

From an external point of view, PMBs can use the indicators to communicate their circular performance to stakeholders in a transparent and objective way. This in contrast to the current approach where different CE projects and activities are simply mentioned in the ports' annual or sustainability report. Reporting on these indicators also allows stakeholders to determine whether their circular investments in the port are warranted.

At first, reporting these CE indicators may seem as a threat to PMBs who are performing poorly in the circular transition. However, the possibility to measure and report on these indicators should be seen as an opportunity. Chances are that the CE transition will happen, and stakeholders will push for more reporting on circular indicators. Therefore, as is the case with general performance monitoring in ports, the early movers will benefit most (Otheitis and Kunc, 2015) because they already have experience and have had the time to align their CE goals to be more ambitious.

In fact, the findings from this study revealed the lack of ports' current ambitions in the context of CE. The research could thus be used as a signal to PMBs and other policy makers to increase their CE ambition levels in coming years. PMBs should recognize that the list of CE indicators are enablers and can even be sources of competitive advantage in the context of the circular economy (Seles et al., 2022).

The way this study was conducted attempted to reduce any limitations to the extent possible. The use of multiple methods, for instance, provided a more robust final list of CE indicators for ports than if only one method were used. Nonetheless, this research has its own shortcomings. One of these is that no scientific papers were used as a source for the content analysis in the compilation of Interim list A. While the sources were already rather diverse, the inclusion of indicators from scientific papers would have further increased this variety. A second limitation is that only one port was used to test the indicators from Interim list D's feasibility. For instance, testing feasibility for a port which has less resources or data available, might provide poorer feasibility results. In other words, this study's feasibility test may be criticized as being overly optimistic relative to all ports.

6.1. *Future research*

Through this in-depth study, CE 12 indicators for ports were developed and tested for feasibility. Further research could be done to test the indicators in different contexts. For example, a multiple case study in which the indicators are measured into a baseline for different port profiles and for ports with different CE ambition levels. This would give the indicators a more quantitative form. Moreover, potential future research includes the analysis of the various players and stakeholders involved in the monitoring of the circular transition in ports. Research on the importance given to CE by port stakeholders, their acceptance and adoption of the indicators, and to what extent they believe that the port should play an active and proactive role in the CE transition is another alternative path for future research. Finally, while a first proposition was made in identifying and presenting different port profiles, further research could look into the various ways in which ports can be categorised.

CRediT authorship contribution statement

Lynn Faut: Investigation, Writing – original draft, Visualization, Project administration. **Fanny Soyeur:** Investigation, Project administration. **Elvira Haezendonck:** Conceptualization, Methodology, Validation, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Michaël Dooms:** Conceptualization, Writing – review & editing. **Peter W. de Langen:** Investigation, Writing – review & editing.

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.

Role of the funding source

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.martra.2023.100087.

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