What will be the effect of the circular economy on inland ports? Scenarios towards 2050.

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Preface

The most important achievements in life are never done alone. With a good friend, I always joke around that having walked the best trail in the Netherlands, Het Pieterpad, there is no greater achievement possible. My fiancé disagrees. But no matter what this thesis is competing against, it is high up the ranks for me personally.

And now comes the list of people who I remember and the omitted variables. Let's begin with the reason this thesis was written, my supervisor Dr. Bart Kuipers. I never understood why you were so happy with my application to this internship. Maybe you can level a bit more with my scepticism now after this process.

Then the powerteam that managed to keep me motivated through it all, Lotte and Lijdia. My two amazing supervisors at the NVB who have made the time writing this thesis possible. It might have been a strange time, doing most of the internship through digital meetings, but all in all I felt welcome and important. And that is all I could have asked for. Also, they are great supervisors to write a thesis for, given how much they know of the industry.

Then for the last row of people whom I will refer to as the omitted variables. All the people who are close to me on a personal level of course, but also the people who will read this and all the people I got to interview for this thesis. The entire reason this is written is for you. You're reading it. I hope you'll like it. So, thanks.

To get you all started, this thesis is my final academic work, probably. Time has come to say goodbye to an era and hello to a new one. While writing this, I've encountered lots of ups and downs in life and it's sometimes challenging to go on through tough times. But in the end, all that matters is the long run. Just like a trail, the reward is not just the end result, but also what you manage to find during the journey. What an awful cliché.

Abstract

The circular economy is a concept in which materials - which are being used - remain in use through a multitude of processes to save them. From repair to recycle, the goal is to prevent having to use virgin resources. One obstacle on the road is that it has to be cost-effective. The Dutch national government wants a fully circular economy by 2050. An important question for the members of the NVB is: What to expect from these developments and what effects does this have on their inland ports?

In order to figure that out, this thesis will explore four scenarios for the year 2050 in which different futures will be described. These four scenarios will be based upon two critical uncertainties, namely: Will the future of circular economy be based on centralised, or decentralised policy, and will the circular economy policy be focused toward decreasing the quantity of materials in use, or improving the quality of materials used?

The main question of the paper is: How will the development of the circular economy impact inland ports? With the sub-question of what policy would fit these developments? The quick summary of the scenarios is as follows:

- Less waste
  - This scenario means less growth of production and consumption, relatively less growth overall
  - In terms of policy this would mean the focus has to be on diversifying the port, as that would reduce the risk of lock-in
- Rethinking resources
  - This scenario means high port activity growth
  - Policy would have to accommodate a specific sector and aim to be selective of which companies get a place near the water
- Repair café
  - This scenario means shrinking growth of activities in the port
  - Innovation is needed in order to gain perspective for this port, as it is uncertain how the port will deal with loss of economies of scale and loss of consumed and produced goods at once
- Remanufacturing cycles
  - This scenario consists of similar growth to less waste
  - However, this has more opportunity for new flows of goods, but still has to implement policy to keep a certain level of economies of scale as that will be lost due to the decentral policy on CE.

Furthermore, it becomes clear that there is a shift towards more demand for storage and more circular processing in the inland ports. In terms of general developments, aside these demand changes, scrapyards might decrease in scale, waste incineration plants might get replaced with bioreactors and there will be less retail in ports. Overall, these are some general directions to take away for long term policy making.

There is also a general warning, in 3 of the 4 scenarios the growth of the ports will be less than expected in the literature. Therefore, it is important to keep this possibility in mind in order to remain flexible to this possibly occurring.

Inhoud

Introduction

Inland ports function as strong multimodal transport hubs of the supply chain. Serving sustainable hubs for point to point transport, multimodal throughput and industrial areas, these ports are of great value for the economy of the Netherlands. They serve a large role in the local economies and present an added value of €12.8 billion in 2018 (Streng & Kuipers, 2019). Cargo, bulk and more are transported through the Dutch waterways. However, some resources on earth are finite. Given that technology keeps changing and world population and welfare keeps growing, the demand for these goods keeps on growing. To remain supplied with resources to make the items we all consume there is a need to re-introduce used materials from already used goods back to the supply chain. This idea is the basic thought behind the circular economy (Ellen MacArthur Foundation, 2021-1)

Taking the idea of the circular economy to practice demands a new look on the supply chain. The concept of mine-refinery-manufacturing-distribution-store-consumer now also needs to accommodate flows between businesses, flows from waste collectors to recycling plants and other developing circular supply chains. This will be important to get the phases like re-use, repair, remanufacturing, recycling and recovering going. Many seaports have a vision on their sustainable goals, including on their role in the circular economy. However, the role for inland ports is less documented and not as clear. Therefore, the main question of this thesis is: How will the development of the circular economy impact inland ports? With the sub-question of what policy would fit these developments?

Practical relevance

This question was also raised by the Nederlandse Vereniging voor Binnenhavens (NVB), which is Dutch for 'Dutch Federation for Inland Ports'. This thesis is part of a research internship position at the NVB. The internship position helps progress this research by its large network of inland port authorities and knowledge inside of the organisation on the inland port and shipping business.

Members of the NVB are inland port authorities. Mostly these are municipalities, either directly or indirectly through a (semi-)independent organisation. Furthermore, the NVB has related knowledge partners. The main members, the municipalities, are responsible for waste policy of their inhabitants (VNG, 2021). That, and their roles in shaping economic policy in their municipality in a sustainable manner through their port are both reasons this research question is relevant to NVB, their members and their knowledge partners. For them, this research is meant to give insights in the possible scenarios for circular economy and what that means to the port for which they develop and invest in sustainable growth policy. It should complement existing policy and programs such as in the Port of Amsterdam (2021), the national circular economy plans of the government (Rijksoverheid, 2016) and local policy for sustainable economic growth such as in Rotterdam (Municipality of Rotterdam, 2021).

Furthermore, relevance can be related to the trends in the media as well. When it comes to developments now, one major example is the IPCC report that came out recently (IPCC, 2021). This in combination with recent events such as forest fires in southern Europe (AD, 2021) and floods in western Europe (RTL nieuws, 2021) has made some politicians see the urgency in making more sustainable policy (DW, 2021).

Looking at trends on Google, it does not show continually increasing searches in terms related to climate change or global warming.

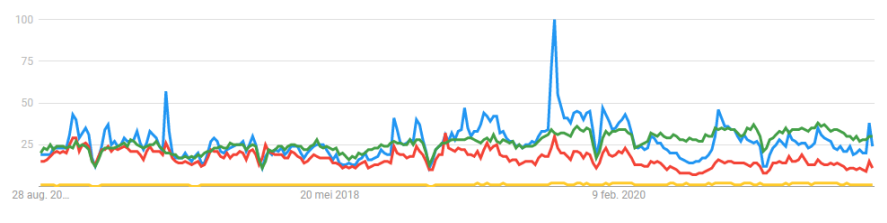


Figure 1: Google trends for climate change (b), global warming (r), circular economy (y) and sustainable (g) for the past 5 years. Source: Google trends

These are some smaller adjustments in the grand scheme, however on the side of national politics it recently came out the traditional governing parties are investing 7 billion euros in combatting climate change, which would be indicative of them investing in circular economy as well.

Looking at academic papers overall, using Scopus it can be seen that circular economics and circular logistics and circular port economics related search results have been gaining traction as well as topics of academic papers.

Term/year	2013	2014	2015	2016	2017	2018	2019	2020
Circular economy	141	190	196	425	822	1370	2117	3133
Circular logistics	33	42	27	40	52	71	110	154
Circular port	115	131	104	137	177	203	250	222
Inland port	87	77	88	105	98	112	125	152
Port economics	111	96	103	114	151	127	149	150

Table 1: Scopus results

Notable is that the relative growth within the circular economy subjects is larger than the average growth in total amount of publications. Therefore, it is interesting to note that if this relative growth pattern is to keep itself going, this could also be an area where innovation could be expected.

Furthermore, current government plans in terms of actions seem to head into the direction of the middle of the road, leaning to quality more than quantity based policy. It also seems to be going towards more central based circular economy. Based on acts and intentions like: Grondstoffenakkoord, statiegeld, plasticpact.

Theoretical relevance

Previous research to the role of inland ports in the circular economy are not clarifying the role enough to base policy upon. Some research focuses on circular logistics (Nozharov & Koralova, 2019). These researches are mostly contemporary or short to short-middle term and are less about long term development of the circular economy. The downside to this is the lack of concrete policy advice for the inland port authority to develop on. The same goes for a previous thesis on inland ports and circular economy. (Zhanzhora, 2019) This thesis focuses on the driving force behind circular policy. This is useful to understand where policy comes from and could help build a framework for decision making, but as the cases on reverse logistics does not look at middle to long term supply chain developments.

A wider look on research into port economics can also be supplemented by this research into circular economy related to inland ports. Looking at current port economics research, four main areas of research can be identified as supply chain research, directional development research, port regionalization research and institutional research (Witte, Wiegmans & Ng, 2019).

Supply chain studies look at the global chain and try and define a place for the inland port in the distribution. The point of view of these papers is usually from the seaport. That makes these studies usually network related and focussed on the role for the network of the seaport (Notteboom, Pallis & Rodrigue 2021). These papers once again show the reliance of inland ports on seaports, but also show how the inland ports as a function of capillaries of the maritime transportation network is important to mainports as well.

Directional development studies tend to look at the way incentives go between the mainports and the inland ports. Outside-in meaning that the seaport is steering the direction of the inland port, where inside-out means the inland port decides the path of the seaport. This can also de bi-directional and cause some competitive dynamics instead of hierarchical dynamics (Wiegmans, Witte & Roso, 2020). Interesting finds from this type of research is that in most cases the incentives still flow from the mainport to the inland port.

Regionalisation of ports sounds like the port itself is changing to a more regional function, but the translation from jargon it basically means that instead of only using mainports to serve the hinterland, regional inland ports are also gaining importance in the supply chain (Raimbault, Jacobs, & Dongen, 2016). This is partly an extension of the supply chain studies, but on a more dynamic perspective. Where supply chain studies are more static and looking at how the port fills a place, the regionalisation looks at the changing position of the port and the development of the port as a logistical hub. Last, but not least, of these is institutional research. This is partly looking at port types, governance and other topics like culture and law (Raimbault, 2019).

These papers are all showing the role of the (inland) port in their network and their functioning. However, on circular economy and ports, academic literature is still very much in development. Therefore, it is relevant to look at these developments and start building towards a better understanding of this growing dynamic, especially looking towards the future.

The goal of this research is to sketch scenario's between now and 2050 and make the coming circular developments as concrete as possible for inland. This is important, because it is not always clear to inland port authorities what the future holds. This became clear during first conversations with port authorities[1]. Clarifying the course of the development of the circular economy will help develop more sustainable policy, which in turn will keep the developments in the inland port relevant to the developments in the supply chains.

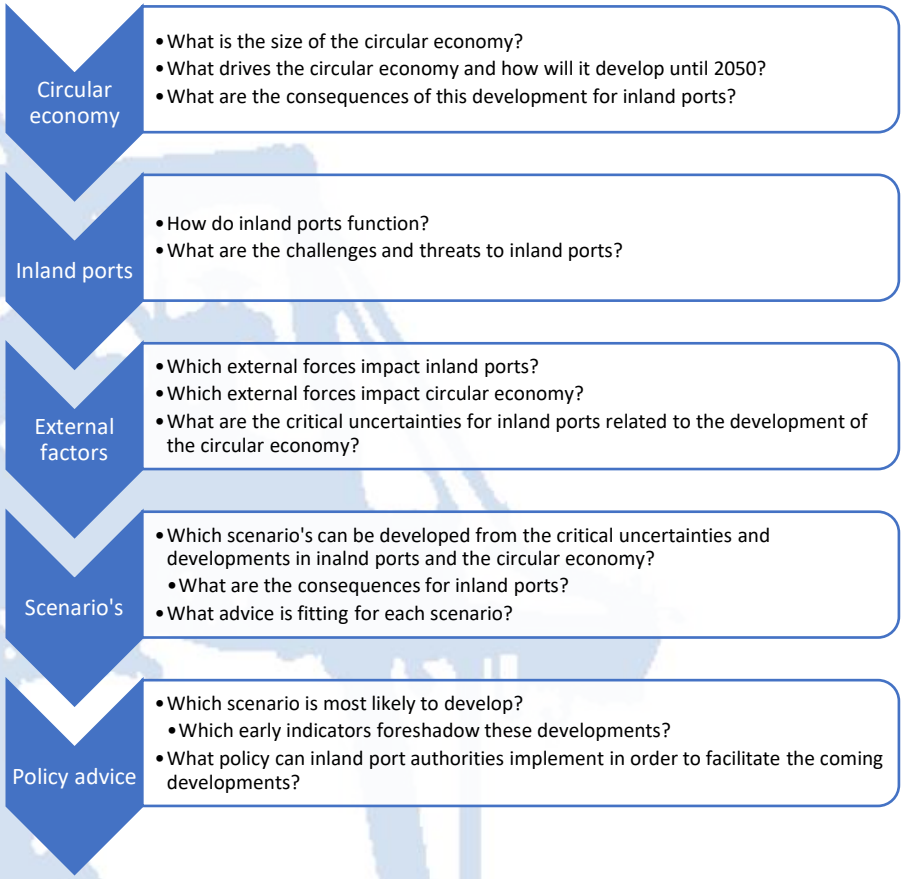
Methodology

In order to find out what the developments will be, scenario planning will be used. This strategic planning derived method helps build an understanding of the functioning of, in this case, inland ports and is designed to build scenarios for uncertain futures. Using this method, the functioning of inland ports and external factors will be analysed to find out what factors are the most uncertain. From there on, scenarios will build based on those factors. These will be worked out to four full stories which all have their own set of policy advices that come along with it. From there on, with the help of case studies the current developments

[1] Municipalities of Roermond (2), Maasgouw (3) and a representative for the inland ports of Friesland (1). Numbers in brackets refer to the position in appendix for more information

will be researched to find early indicators and from there on an advice for which scenario is most likely and which policy works for that scenario.

Alternatives to this method that could have been used as well are for example the multicriteria analysis. This analysis is based more around decision making later on in the process, where this research is more focused on strategy. This is the same reason why something like a societal cost benefit analysis would not work as well. Then looking at quantitative methods which could be seen as an option, for example regression. This is not feasible at all, since this research question deals with uncertainty and is attempting to cast a view to the future. A regression analysis can only attempt to show relations between certain developments and does not handle uncertainty towards futures very well. Extrapolating data or using less analytic quantitative methods would be able to show and work with uncertainty better, but these are better implemented on follow up research after this more explorative thesis.



Theory

This section is written in order to gain an understanding of the general developments in the academic literature and beyond. Understanding how the research question first in to the timeline of similar research and what gap it fills in the field of research. To structure this, first general developments in the field of (inland) port and/or maritime economy and circular economy. From here on building towards understanding where this question fits, what purpose it serves and derive which methods can be used to answer the general question raised in the introduction.

General developments

Port theory

Ports have existed since humans have started using water as a means of transport. That is if you define a port by the concept that it is a place for handling cargo, not ships (Palmer, 2020). Pinpointing when this could have started might be an everlasting research topic for port historians. However, it is clear that geography is destiny for most places. Despite this being refuted partly by some cases, it still a very important factor explaining the wealth of a nation (Blum, 2003; Fang & Jawitz, 2019). Still, rivers or access to a body water might not always be a reason to settle (Rashid, 2021). Furthermore, the geography does not always explain economic growth as well as some institutional factors do (Akçomak, Webbink & Weel, 2012), at least in data analysis. Despite the fact that a data analysis might have missed certain factors and causality reasoning which is important to the full picture of why and how certain socioeconomic development has taken place, this research is complementary to the qualitative research into sources and is a reminder to keep an eye open to alternate explanations to current paradigm.

To get back on track with the port literature, it is important to filter some categories of literature about ports in general. The research question posed in the introduction is regarding inland ports. These ports are different in characteristics compared to seaports, which most of the literature is about. Looking at the trends in port economics research, there are a few literary studies on what types of papers are being written and what they are about (Pallis et. al., 2009; Witte, Wiegmans & Ng, 2019). Looking at the important factors deciding the research question of this thesis, this paper will be in the corner of the policy and governance direction. This can be derived from the fact that the question and assignment from the NVB is made such that it is an exploration into a topic important for their members, which are mainly municipalities or related organisations. Therefore, the direction of this paper is less towards supply chain for example. It might overlap directional development or spatial issues too, as these are also at play on this scale and relevant given how the research question delves into the future.

To give some more insight on the place of this paper (based partly on the Witte, Wiegmans & Ng, 2019 paper) this paper would be fitting in diversifying information on inland ports. There are little to no real deep dives in scenarios towards circular economy and the effect of that in inland ports. Other direction the paper shows are less applicable, as this is not related directly to the workings of the port in its core and not on the directional relation to the mainport hubs in general. Although these subjects do come around a bit.

To delve deeper into the specific papers on (inland) ports and circular economy. Firstly, papers that write on the circular economy and its current status in the ports. This is more about the contemporary state of how circular a port operates and is thus more field research and less policy related. One paper to take as an example for this is Haezendonck & Van den Berghe (2020). This paper researches the circular maturity of ports in Belgium and discusses the internal situation of how the circular developments in the port have been and discusses how the port can

develop forward becoming more in line with other circular developments to become a more integral part of the regional circular developments. This type of research is interesting, but it treats the circular economy as a factor a port can influence. The reason this is less applicable to this paper is that the view on the circular economy is more external as a development that will take place and have its effects instead of a tool or policy that can be implemented in itself. This is mainly due to the fact that municipalities which are the main audience for this research question are not in control of the companies themselves, but they can put certain policies in place to nudge current companies or filter settling companies on and towards circular economical activities.

Towards the more practical side of what is happening in the shipping industry and circular economy is waste transport, there are also papers on that. One example of these papers is Inghels, Dullaert, & Vigo (2016). This paper deals with the concept of reducing greenhouse gasses by making municipal waste transport multimodal (switch it from road to rail or water). This type of research is more on the operational level. It is important, as practical examples of these types of experiments have taken place (van Huizen, 2017). In light of the research question of this thesis, this thesis is once again less on operations and more on global policy and a global forecast as to what might happen in the circular economy. The practicalities and limits of those are important, but relatively a mere aspect of the scenarios which are being researched.

Another way of looking at the subject is from an opportunity's perspective. This is the edge between governance and policy and business case building for circular inland shipping activities. Nozharov & Koralova, (2019) is an example of a paper making a case, in this specific one for the Danube inland shipping business. These papers have a lot of quantitative power, as they explore how big the circular economy in that part will be and what it might bring for the industry at large. These are complementary to this paper as they are more concrete in terms of quantity, but they built less for long term and work with forecasts as if there is one possible future within a margin of error. The research question in this thesis is broader and has more implicit uncertainty.

Then there is also literature more on the level of this research. Like a presentation highlighting facilitating and gaining growth from the circular economy or an example of a case where implementation of circular economy has helped save the port (sounds like the story of Roermond a bit). Compared to these this research will be broad like the presentation, towards port authorities, but also less case based than the Swedish paper.

Lastly, there are also more practical sources. One of those is this small paper on circular economy sectors in inland ports from the EFIP. But there are also entire databases on cases for industrial areas and ports such as available at Metabolic. This research will, again, be more globally directed towards municipal policy makers/inland port authorities.

Circular economy

Circular economics as a field has an unclear history. One clear source of the timeline of circular economics can be found at the Ellen McArthur Foundation (2021-1). There is a lot of literature there on the thought of circular economy and the general idea. The original though was with a system of recycle, reduce and re-use (EPA, 2021). However, more evolved thoughts on the process has sprung forth the idea of circular economy 3.0 (Vermeulen, Reike & Witjes 2018). This model has more steps compared to the previous model, 9 of them, but also showcases that the concept of the circular economy and the list of ways to implement the basics of reducing the introduction of virgin resources into the economic system is ever evolving.

Methodology part 1: Methods

From question to conclusion, method decides how to go from the knowledge that is out there, to data and to the eventual conclusions and the discussion.

In depth: Why scenarios?

Possible methods

To start in general, there are multiple ways to analyse a question. First of all, economists are taught to mostly run regression analyses. This type of analysis is a qualitative approach in which roughly the effect of one variable on another can be measured. This would be beneficial if the goal is to understand the effect of an intervention. The downside is that in order for this to work, data has to be available, preferably with a multitude of observations to increase the validity of the chosen model.

The regression analysis is a great instrument is there is a certain degree of certainty about the circumstances of the intervention. If all else is not possible to remain constant or stable, the analysis holds less ground. Therefore, this specific research question analysing issues related to the future (up to 2050) is not suited for a regression analysis. The data would not be able to produce a broad spectrum of possibilities of which might happen in multiple possible futures (Stundenmund, 2017).

Looking at other possibilities to analyse the question, it is possible to for alternative quantitative forecasting methods. Some options are input-output analyses, index methods, modelling or time series analysis. However, all of these face the same type of fallacy as the regression in terms of the uncertainty and multi-faceted issue at hand. Just differentiating the number of 'circular economy' is a take which has many buttons. It might be possible with bit data and algorithms, but the complexity of this issue makes it suited to go more qualitative methods.

A first one to discuss is in a grey area. The societal cost-benefit analysis. This method is used to evaluate certain investments on whether or not it is feasible from a broad welfare point of view. The method calculates both the actual monetary costs and benefits, but also softer indicators. In cases where it is about the circular economy it could be for example a monetization of the welfare increases of cleaner air. All of this is good for a single project which has a clear investment path and it at the point of greenlighting investment, but this method is also not suited for the evaluation of a broader policy question.

From there on there are more possibilities to look into softer criteria. A multi-criteria, and even a multi-criteria multi-actor analysis, is an analysis in which through one of many consolidation methods different policy actions can be weighed against the demands of the policy makers. So, for example, if there is a plan to invest in green energy, this method can be used to assess which type o green energy would suit the situation best depending on the wishes of the placer of these facilities. This is a step which can be seen as pre-societal cost benefit analysis, as this step is sorting a few choices back into one choice. Therefore, it is closer to the nature of the research question in this paper, but it is still working towards a specific solution. The research question would benefit more from a more open ended view on the outcome of the research.

Moving from that to the more open ended spectrum of analysis, qualitative research into literature would have also been an option. However, using just literature might leave gaps open that should be filled in by gathering at least some forms of data. Literature is always part of the analysis, but never the only thing.

In order to add more data and openness to the analysis it is possible to use the toolkit of strategic management. This is a broad subject with many possible analyses, from an assessment of the current status to an

evaluation of a certain policy input, there is a broad spectrum of scenarios, measurements and policy actions within the scope of possibilities.

For answering this research question, building scenarios is the most fitting way to deal with the uncertainty and working towards building an understanding of the possible future that lies ahead. In order to make these scenarios more academically solid, it is important to gain insight from the field. Interviews are needed to solidify the ideas presented in the scenarios. Furthermore, solid literature both academic and grey literature need to be used to build a solid foundation to them.

To build the scenarios, it is important to understand the steps required in order to come to the end result of scenarios. The order is as follows (Lindgren & Bandhold, 2009):

- Analyse the situation and formulate the premise
- Identify at the internal factors
- Identify the external forces
- Identify the critical uncertainty
- Build the scenarios
- Identify the early indicators
- Build advice
- (long term step, re-evaluate and do over)

Internal factors

Internal factors are the driving forces internally making something work. It is important to understand what the research is trying to forecast about and for in order to make fitting scenarios. Therefore, it is important to have a whole chapter devoted to understanding the internal factors.

Inland ports

What is an inland port?

An inland port is a logistical location which is served by ships through an inland waterway. So inland ports are not directly located at sea, however, some may be accessible by seafaring ships. So inland waterway connected transport hubs. This can sometimes coincide with what can be called a dry port. Of these dry ports the connection to an inland waterway is not necessary, however, it is still a logistical hub with a multimodal character catering to their respective logistical network (Notteboom, Pallis & Rodrigue 2021). Overall, the functions of the port can be different. As seen in the inland port monitor, the type of transport in a port can differ among ports (Streng & Kuipers, 2019; Korteweg & Kuipers, 2004). The categorisation in the inland port monitor is mainly between mainports, industrial ports, (smaller) agriculture ports, container ports and (smaller) sand/gravel ports and multifunctional variants of the specified specialized ports. This division is of course subjective in the sense that no one port in a category will behave and be used the same. However, it does give insight in the general direction ports can develop.

To build an understanding of what inland ports look like and how they function (under changes brought by developments in the circular economy) some reference ports will be used to showcase what might happen. Four port that are used as an example are Roermond, Drachten, Moerdijk and Kampen. See these as a running case study to showcase any related issue coming in the later parts. Short summaries are loosely based on case studies performed like the one on Wageningen by Kuipers (2004).

Roermond: The city of Roermond lies in the middle of the province of Limburg aside the river Meuse. Some key information on the port:

- 2 modalities
    - Barge and road

- Tide-steady river (the Meuse is a stowed river)
- Categorised as multifunctional container port in the inland port monitor
  - Container terminal BCTN
  - Concrete factory Kalle & Bakker, Smurfit Kappa paper recycling, BASEX Infra and Jos Menten metal recycling as dry bulk transport clients
  - VARO Energy with liquid bulk transport
  - SIF as industry in the port with loose parts transport
- Markets itself as highly circular port (Parkmanagement Midden-Limburg, 2021)
- Independent municipal port, working on an interregional port cooperation[2](Provincie Limburg, 2021)

Drachten: Drachten lies in the eastern part of the province of Frisia. It is connected via a channel to the network of channels and lakes that lead to the IJsselmeer and Wadden Sea.

Some information on this port:

- 2 modalities
  - Barge and road
  - Relatively tide-steady channel
- Categorised as a multifunctional sand- and gravel port
  - Sterk metal and piles, SMST Offshore equipment supplier, DBG building – and restmaterials, van der Wiel transport, Kijlstra concrete, Frieslandstaal steel production, Agrifirm, BoGroNed builing materials, Jongema Transport, BAM infra, BNM building materials and Kijklstra sweage

[2] Based on conversations with representative of the municipality of Roermond

(potentially Renewi as well) use the port for dry bulk storage and transport.
  - Van der Stelt BV uses the port for liquid bulk storage and transport.
- No strong marketing, just a municipal industrial area with a port
- Municipal port with a role in the Frisian Ports network which is yet to become more formal (Jager Media, 2021)
- TNO/NVB report 2004

Map 1: Port of Roermond on OpenStreetMap (2021)

Map 2: Port of Drachten on OpenStreetMap

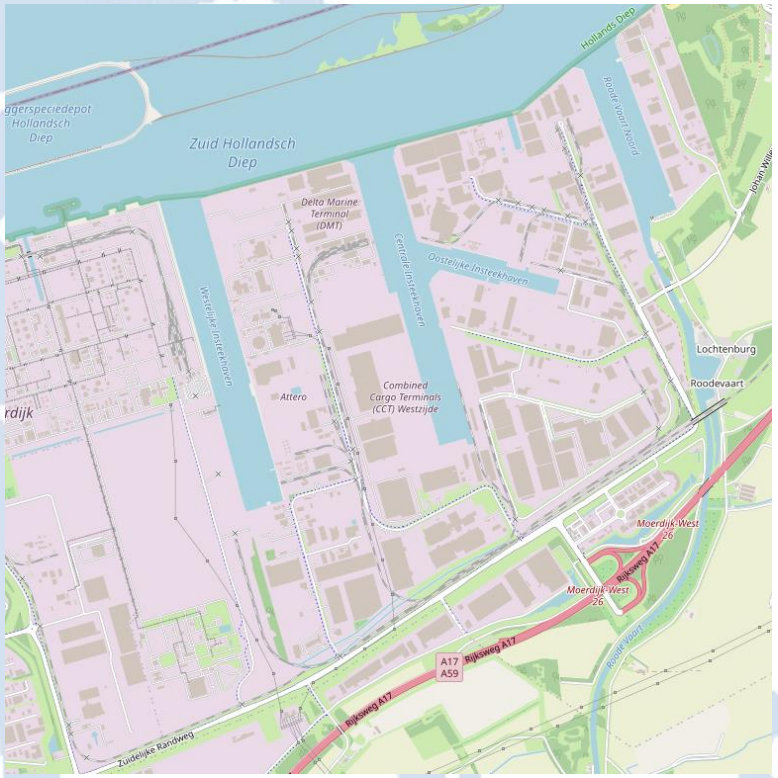
Moerdijk: This large inland port in the west of Brabant is one of the select few that are accessible to seafaring vessels. It has a large petrochemical industry and container terminal.

Some key information on this port:

- 5 modalities
  - Barge, seafaring vessels, road, rail and pipe (PoM, 2021)
- Categorised as a mainport
  - Strong petrochemical industry, but has companies in all kinds of industries (PoM, 2020-1)

Map 3: Port of Moerdijk on OpenStreetMap

- Markets itself as a circular port, with a speciality in circular chemical industry (PoM, 2020-1)
- Independent port authority owned by the municipality of Moerdijk (50%) and the province of Noord-Brabant (50%) (PoM, 2020)



Map 3: port of Moerdijk on OpenStreetMap

Kampen: A port along the end of the Ijssel river

Some key information on the port:

- 3 modalities
    - Barge, seafaring vessels, road
- Categorised as a multifunctional sand- and gravel port
    - EG Group fuel terminal and Sunoil Biodiesel for liquid bulk
    - Liprovit animal feeders, Graansloot, Hoebe Metalen, (Brink) Recycling, MBI stone traders, Wijma Wood, VBI, van Nieuwpoort and more using the port for dry bulk shipments
    - IJDT container terminal
    - A selection of shipyards
- Part of the port of Zwolle network, marketed as 'port of opportunities (PoZ, 2021)
- Municipal port, as part of the Port of Zwolle, but still publicly owned and managed by both the dedicated personnel at Port of Zwolle and policy advisors of the municipality of Kampen

A general remark: As many ports there are, there is equally as much diversity in their roles and functionality. Some functionalities as reported in the Inland Port Monitor (Streng & Kuipers, 2019) are industrial, agricultural, container, sand/gravel and any multifunctional options between them. These sectors are mainly involved in goods, but there is also a passenger vessel side, mainly in river cruises .

Map 4: Port of kampen on OpenStreetMap

Dutch inland ports characteristics

Performance

Inland ports in the Netherlands are an important link in the supply chain network of regional, national and continental importance (Kuipers, 2004). From the mainports of Rotterdam and Amsterdam or even from the other seaports like Zeeland's North Sea Port, Port of Harlingen or the Port of Moerdijk general cargo, bulk and containers are transported to the hinterland (Rodrigue, Debrie, Fremont, & Gouvernal, 2010) and also to other inland ports within the Netherlands and within Europe.

Figure 2: Source: CBS (2021)

In absolute terms, inland shipping in the Netherlands is handling about 350 million tonnes per year. This includes transit shipments which only pass from seaports to foreign hinterland destinations. This number has remained quite stable over the past few years. Looking at the other modalities, between 2010 and 2019 it all developed relatively stable, so a strong modal shift has not been taking place during the last few years. For most of the goods shipped the origin or destination is a major seaport (Korteweg & Kuipers, 2004)

Type of transport	2010	2020
Shipping within NL	103	120
Import	65	69
Export	133	115
Transit	44	43

Table 2: Shipped goods by barge split out per millions of tonnes transported. Source: CBS (2021-2)

According to CBS (2021-2) data in table 1, between 2010 and 2020 there has been a decrease of export to the hinterland, mainly explained by a decrease in transport of coal and steel ore to Germany. This has been compensated by larger flows within the Netherlands, mainly containers to and from logistical mainports such as Rotterdam and Amsterdam[3]. It is almost certain that by 2038 coal has been phased out as a power source in Germany (European Commission, 2020). That would indicate that coal export will drop further. An interesting question is whether the shipping within the Netherlands or other flows of goods will compensate for that loss. Transport related to circular economy will likely compensate for this loss.

The value added by inland ports is also quite stable. As said in the Inland Port Monitor issued by NVB, The Ministry of Infrastructure and Water Management and the Erasmus University (Streng & Kuipers, 2019) states a growth from €11.878 million in 2014 to €12.768 million in 2018, which is a gain of €894 in those 4 years. In terms of jobs, according to Streng and Kuipers the total amount of jobs directly located in the inland ports is 64,443, not counting indirect jobs as in the value added.

[3] Source unknown, given as feedback by B. Kuipers in one of the concepts

One final addition to the value of inland ports is on the passenger services. On national level, it was estimated in 2010 that the impact of the passenger services on inland waterways is 10% of the added value of the entire inland shipping economic impact. That accounts to about €332 million and 2814 FTE for 2010 (Plaisier, 2011). There was also specific research into the local situation in Amsterdam. In this paper it is estimated that in 2017 the value added of the river cruising industry, directly and indirectly, was €87 million and accounting for 1690 jobs in the broader region of Amsterdam alone (Meulen & Vegter, 2017).

The takeaway for the main question is that **input and output are major key factors** for the inland ports. They are **dependent on seaports** and function mainly to be regional logistical hubs, **serving either local producers, supplying the hinterland and serving as a destination for passengers on river cruises.**

Infrastructure

Ports are dependent on their waterways and hinterland transport options. When it comes to upkeeping waterways and policy regarding inland nautical and land based infrastructure there is a form of subsidiarity which divides the responsibility for infra through different levels of government.

On the mainlines the national government is the most important factor. Main roads which are numbered with an A ('snelweg' or highways) and sometimes N-roads (slower highways) are managed by **Rijkswaterstaat** (RWS) (Rijkswaterstaat, 2021). These roads are considered of national importance to the network and service the entire country. Looking at waterways the same system is in place. Main waterways such as the Meuse, the Waal and the Rhine are also under the supervision of RWS (Rijkswaterstaat, 2021-2).

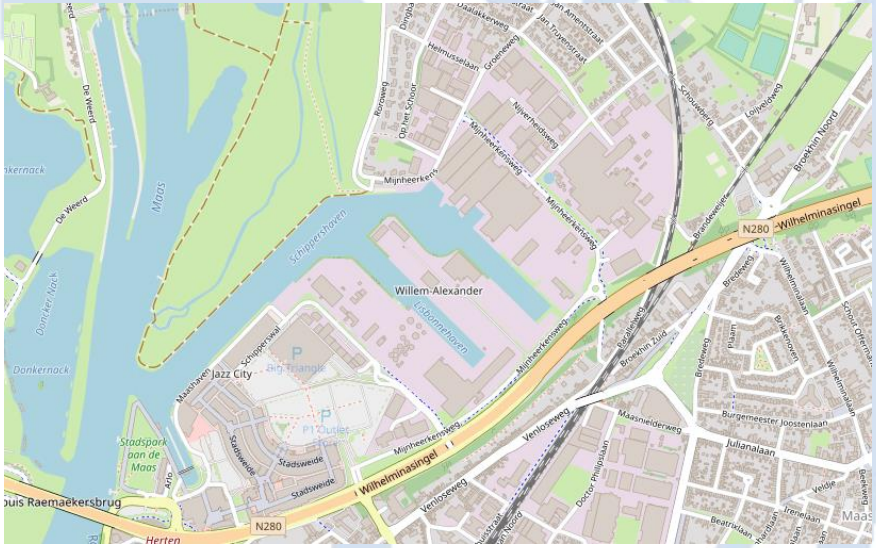
Other, less large waterways, are either the responsibility of the **province** or municipality. This is where the situation becomes more complex, because the province is the main responsible party for the waterways (water which is accessible by boat). However, it is given the freedom to delegate the execution of certain tasks to local water authorities or even municipalities if there is a certain interest like a port that constitutes local impact (InfoMil, 2021)

Figure 3: Structure of the Dutch waterway management

Spatial and environmental development

Inland ports are industrial areas. As shown in the first part which has a few examples of inland ports, these logistical hubs are basically water bound industrial parks. The location on a river usually means there is a lot of space to develop along the river, however space is scarce in the Netherlands.

One example is Roermond. Taking that as an example, the space the port can use is limited because the city has expanded and closed in the industrial area of the port. That means that the port can no longer expand at its current place and has to make due with its current size. This issue also strikes other ports, such as Venlo or Nijmegen.



Map 5: Roermond is closed in, via OpenStreetMap

Another contender for space is nature. Meppel for example lies very close to a nature reserve called the Weerribben and Wieden. This as a consequence means that expanding on the opposite side of the canal is difficult due to nature protection legislation. In the north, the seaports of Groningen and Harlingen both lie at the Wadden Sea, which also limits growth to those ports due to restrictions due to their natura 2000 status.

Environmental and ecological concerns also go hand in hand when it comes to the nitrogen deposition emission issue. Building new buildings is difficult due to strict regulation. Nitrogen emissions cause harm to the biodiversity in the close proximity of an inland port. This is currently a large issue holding back construction works in general (Rijksoverheid, 2021).

Map 6: Meppel next to nature, via OpenStreetMap

Aside from nitrogen deposition emissions, co2 and other greenhouse gasses are also an issue that require reduction. This issue will have to be tackled by government, a judge has decided that the effort to reduce carbon emissions has to be improved upon by the national government (Rechtspraak, 2019). However, individual companies are currently under trail as well for having to reduce their emissions. In a recent case, Shell was forced to improve efforts to reduce co2 emissions not just internally, but also at their customers. This could affect businesses in inland ports as well, for example in the port of Moerdijk, where Shell operates a large business in the port.

Governance

To understand what is uncertain about the role of the circular economy in the future of inland ports, it is important to understand how inland ports work and how they accumulated this much value. First of all, where does the added value come from. The Inland Port Monitor already has some insight in where jobs add the most value. The highest value added per working person in 2018 is highest in multifunctional industrial ports, at €165.565 per person. The lowest added value per working person is at multifunctional sand- and gravel ports, where the average value added per worker is estimated to be €76.729. The downside to the method of calculation here is that this is purely a total value added divided by worker. So inherently, a more labour intensive port is set to have a lower value added per worker overall, since an equal amount of value added might be divided by more workers. An important remark is that circular activities could very well remain to develop as highly labour intensive activities, intensifying this issue for ports inherently.

Nevertheless, inland ports are diverse. In the Inland Port Monitor they are divided by function, which has its own drawbacks. The main categories are mainport, large multifunctional, industry, agro, container and sand/gravel. However, since many inland ports, like seaports, are not specific to one function. Thus, many middle or larger ports are in a category filled with 'multifunctional'. Even without this term ports can serve multiple functions. So, measuring added value of a port this way can be difficult due to the combination of industries in the ports.

In terms of management, most inland ports in the Netherlands are under direct management of the respective municipality they are in. Except for the Port of Zwolle, Port of Moerdijk, Port of Twente and Dordrecht Inland Seaport, all inland ports are under direct supervision of their municipality. In terms of FTE dedicated to the ports there is no literature or database that describes that. Anecdotally, based on first conversations and experience, the amount of FTE allocated to the port are usually put under economic policy departments or city management in the municipality. Sometimes, as in Nijmegen or Port of Zwolle there is a dedicated account manager to upkeep the relation between the municipality and the businesses in the port. More research on the governance could help improve the policy making for (lager) inland ports.

Ports that are not under direct responsibility of the government can be divided in two types. One, the Inland Seaport of Dordrecht, is under the governance of the port of Rotterdam. The others, Zwolle, Twente and Moerdijk can be compared to a team of dedicated account managers and economic policy officers working for a port authority which is in itself owned by the municipality.

To summarize, inland ports are usually dependent on **municipalities**, as they usually are the government who are the responsible for the local environmental laws and the execution of those laws. The land in the ports is usually owned by businesses in the port. The facilities are being upkept by the municipality and sometimes the land in the port is owned and leased by the municipality or municipality owned port authority.

Legislation

Ports are subject to many forms of legislation. First and foremost, when it comes to international trade, they are subject to EU trade laws, which include the hard and soft barriers to trade (the taxes and the rules). Furthermore, there is environmental planning and legislation at the national and provincial levels debated previously. Lastly there are issues as for example nitrogen deposition limits and regulations on the protection of nature preventing unwanted overexpansion of industrial areas. Overall, ports are under quite some different legislation on different levels, which quite overlap with the subchapter on infrastructure.

Summary of Dutch inland port key factors

- Supply and demand
  - Mostly from seaports to hinterland
- Infrastructure
  - National government and provinces
    - Delegated tasks possible for water authority and municipality
- Space
  - Shortage
  - Nitrogen deposit emission issue
- Environmental
  - Emission reduction required
- Governance
  - Ownership usually in hands of municipality, sometimes (partly) province or private parties

Circular economy

Definition

The planet we live on has finite non-renewable resources. Current consumerism is leading to concerns on how long the supply of resources can last. Combine that with worries about the environmental concerns about mining these crude resources and ethical concerns regarding labour. The conclusion is that less new resources need to be mined or created from non-renewable sources and more resources should get a new purpose.

The first mentions of this new way of thinking about resources are unknown (Ellen MacArthur foundation, 2021-1). Even though there is not one person at the cradle of this field, it has been developing. Simple circular thinking has three major practices that have been defined. Rethink, re-use and recycle. That thought is the basis of re-development of the circular economic thought. One developed thought of circular economy is the circular economy 3.0. This is a much more elaborate combination of practices related to the basics of the circular economy.

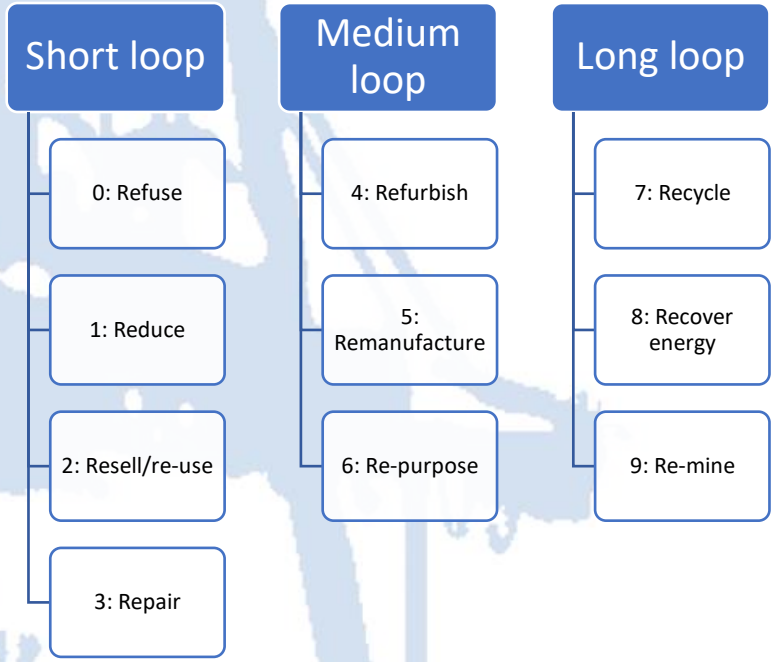


Figure 4: Circular Economy 3.0 as mentioned in Vermeulen, Reike & Witjes (2018)

The circular economy 3.0 concept orders the practices in the circular economy by the value retention. Where refusing using any resources at all prevents the loss of resources completely, repairing keeps the value relatively high. In Figure 2 all the options are ranked as in the paper by Vermeulen, Reike & Witjes (2018) . An interesting feature of this approach is the definition of the loops. This implies that there are short loops where the materials do not have to endure much change, but also

long loops where the material has to be stripped from a product and made into recycled materials. Since this is also insightful into circular cupply chains, this view on circular economy will be the one used throughout the research.

Size of the Circular economy in the Netherlands

In order to assess the circular economy in the Netherlands, the Netherlands Environmental Assessment Agency has created an integral overview of the current state of the circular economy. That report is now the Integral Circular Economy Report (ICER) (Hanemaaijer et al., 2021).

Use	Total loss	Of which waste
Added to stock (>1y use)	53 mt	53 mt
Short use products (<1y use)	25 mt	9mt
Other production waste	24 mt	0 mt
Total resources discarded	102 mt	61 mt
Recycling	52 mt	52mt
Unrecovered resources	50 mt	9 mt

Table 3: Loss of resources in 2018 according to Hanemaaijer et al., (2021)

The total amount of used resources which are not added to the stock are seen as lost. This can of course mean many things, such as that they are burned or used upp during production of a consumer good, but they are unrecovered and thuss amount to a loss of resources. Another loss of resources that is not waste per se is the short use products. These incluse food and thus a part of these losses are just consumption of food by humans or animals. So these numbers come with their own manuals.

However, looking at the general waste category, 9 megatonnes of waste are still unprocessed and this is less than the goal of the government for 2020. That means that there is still potential to improve on the relative quality of waste processing, but it seems like the amount of recycling will contribute to the Hanemaaijer et. al.

What drives the circular economy? – key factors

Much research has been focussed on what the drivers (and barriers) to circular economy are most impactful. To make this insightful some literature is summarized in table 3. Some literature does not look at a ranking but gives a flatter overview of which factors drive the circular economy, this is demonstrated in table 4. Most of the research divides the factors in six dimensions, namely economic, environmental, technological, societal, governmental and behavioural (Pomponi & Moncaster, 2017).

Analysing the tables, the literature uncovers that profitability is an important driver of circular economy development. However, much of the literature also describes a strong role for the government. Laws, regulations and financial support play a role in all research. Governments have a large role in establishing these, as they can give subsidies to projects and lay out the rules enabling or hindering initiatives.

Based upon the gathered material, the following factors can be derived that are driving or hindering (the relation can usually go both ways) the development of circular economy.

Politics: Politics are defining the amount of effort put in the circular economy. Through their elected power politicians decide on government policy, public funding and the legal framework. In the Netherlands, politicians are elected in four levels of government, namely parliament, provincial, municipal and water authority.

National government has influence on the main waterways, mostly through Rijkswaterstaat. Provinces have influence via their environmental and spatial influence. One current development is the 'omgevingswet', which translates to the Environmental and Planning act, gives the provinces in the Netherlands a key role the spatial development.

Municipalities are the most local form of government. Smaller inland ports are under control of the municipality. Usually this is governed by either leasing the grounds the port has, or by steering the businesses that are allowed to buy or rent land in the port. Mainly the municipality can make policy for its own port and enforce that, which makes their politicians highly important to inland ports, but also to the way they are used.

Zooming out, the European Union is also making policy for circular economy (European Commission, 2020) and even has policy in place which have effects on multiple levels. They also have power over public spending and are able to fund individual projects as well.

On a more global level, geopolitical forces also have influence on the inland ports. Trade barriers, trade agreements, political disagreement and many other diplomatic nuances can change the behaviour of circular markets like waste and other resources (Wen, Xie, Chen, & Dinga, 2021).

Economics: This is the supply and demand part. How much resources are needed for production and how much waste is produced. The most important economic forces seem to

Financial: Profitability. This accounts for both the recycling process, which is from end user to the point of secondary resource, but also from secondary resource to product. Different sources and forms of waste have differing costs of collection. Then there is ease of processing and quality of secondary resource which differs among materials. Nevertheless, if it's profitable to use recycled materials, chances of using those is larger.

Labour: In terms of limits and possibilities, labour is an important factor as well. On the practical side, collection, separation and technical installations need people to get that running. This requires manpower a knowledge on the practical level. On the more theoretical side it's also important to have people on the research and design side, legal side, finances and other technical workers that are able to improve on the quality of the end product.

Environmental: As in ports, nitrogen deposition issues, but also greenhouse gas emissions, of which most notably co2, should be reduced. The burning of resources produces co2, but certain ways of recycling them as well. So overall, emissions have to be brought down.

From a less abstract standpoint, nature reserves are being damaged to gain new resources. The price of the damages to nature there might not be reflected by the price of the gained resources. If legislation wants to account for those costs one way or the other, recycles materials might become more financially interesting compared to new resources.

The effect of circular economy on inland ports

Circular economy and logistics

Based on the in the circular economy 3.0 concept (Vermeulen, Reike & Witjes, 2018) the effect on transport can be estimated as follows:

- 0: Refuse
  - Less transport, refusing goods or usage of resources
- 1: Reduce
  - Less use of goods/resources
- 2: Resell/Re-use
  - Some transport, from old user to new user. This might end up with a net effect of more transport if resell/re-use transport is less efficient than waste transport as alternative
- 3: Repair
  - Logistics to and from repair centres. This can add more transport. This is like a reverse logistics from consumer back to repair centre, so could be efficient
  - Maintenance as ex-ante repair work
- 4: Refurbish
  - Same as repair
- 5: Remanufacture
  - Same as 4
- 6: Repurpose
  - Same to resell/re-use, but likely disassembled
- 7: Recycle
  - This is following current waste management procedures
- 8: Recover
  - As 7
- 9: Re-mine
  - From old landfill to recovery centre new transport

The question is what are the net effects. On the transport network. That cannot be assessed immediately, so this could be seen as an uncertainty in the future development. This is partly due to an uncertainty in the scope of the circular economy. Right now, circular economy is a tale of some recycling and some ad-hoc solutions. Those recycling firms are doing what could be called concentrated circular logistics. They have a network of clients, they follow regular waste management procedures and collect, distribute, process and sell the secondary resource. This is kind of similar to a hub and spoke system, alike to the mainport-hinterland situation.

Another question arises about which part of circular economy will take place in a port. Logistics is an extension of the process that it supplies

Action	**Location**	**Port use?**
0: Refuse	Design/consumer	No
1: Reduce	Design/manufacturing/consumer	No
2: Resell/Re-use	Second hand store/user to new user	Logistics
3: Repair	Repair café/repair specialist	Logistics
4: Refurbish	Refurbishing plant	Logistics or industry
5: Remanufacture	(dis-)assembly plant	Industry
6: Repurpose	Disassembly	Logistics or industry
7: Recycle	Recycling plant	Industry
8: Recover	Recovery/recycling plant	Industry
9: Re-mine	Landfill	No

Table 4:Location of actions in CE 3.0

0 and 1: Refuse and reduce

Reduce and refuse are steps which in essence are executed at a research and design level, but also at a policy level. The place where this policy and these designs are made are offices and sometimes research facilities. Seats of government already have locations usually in urban premises. Research facilities and offices can be found in city centres and campuses which have this type of activities in their portfolio. Some examples, the government has its main office in this regard in the ministry of infrastructure and water management in The Hague. One example of office space in urban areas is the Zuidas in Amsterdam. A knowledge campus, in this case specific to the research and design of packaging can be found in Lenningen, Germany. Thinking of the role of the port as a logistical hub and the scarcity of these types of buildings have no place in the port area itself, as it moves no materials and does not store or process materials.

2: Resell, Reuse.

From a consumer perspective, this type of circular activity can be seen on eBay or Marktplaats online, but also in second hand stores. Industrially this happens on different bases. One is the reselling of used machines, such as Kusters Industrial is doing. Another is the direct reuse of certain (waste) products between or within businesses. Some of the most known ones are heat and water. These examples are locally implemented and distributed on side. As industrial processes require cooling during their processes. If cooling happens with water that water in essence contains heating energy which can heat blocks of industrial estate or power other processes which require less heat (thermodynamics, you always lose heat over time). One company well equipped in this market is Veolia water technologies. Overall, this process is part of the smaller circular cycles and thus has less of a scale and transport demand compared to other types levels of circular economy. Reselling and reusing are usually small scale or nearby (location advantage). However, if the scale of these operations is large enough, it might be something which can be considered to be handled in a port. This also leads to a follow up, the storage of these goods. In order for them to be re-used it might happen that they are stored temporarily in between owners. Therefore, an increase in this process might create more demand for storage facilities. If finished products are stored, they take in more space then when they are raw materials, which add to the scale of this potential growth. Therefore, this step might gain potential for storage in the port. Furthermore, since this step does not require processing in any way, it does not inhibit growth in that segment.

3: Repair (or responsible use)

This step is also relatively short-looped. Think about repair cafes and repair services offered by commercial providers as examples in this step. Now repair by definition is replacing a part when it is no longer deemed fit to use, either because it is not working well or not working at all (Cambridge Dictionary, 2021). So, this step takes place when it is necessary. However, there is also maintenance, which is used to keep something in working condition (Cambridge Dictionary, 2021-1). Now, maintenance is not in the model, however, in the source for the 9 steps, the one mention of maintenance is with the repair part (Vermeulen, Reike & Witjes, 2018). Therefore, maintenance is, as much as it is not in the definition of repair, a part of this process, but rather preventive than reactive in that sense. It could be debated that maintenance should get its own place in this scheme, or maybe rename this part to ‘responsible use’, as it keeps the items used safe and working for a longer time in the hands of its owners.

But there as for now, there is responsible use in two forms, the aforementioned proactive maintenance and reactive repairs. However, both are important. Maintenance is carried out by mechanics or just the users (consumers/producers) themselves. One notable example for maintenance in ports are shipyards. These are important for inland shipping and are an extension of the overall circular economy in the inland ports. For consumers an example of a very local repair place is a repair cafe. These places require little dedicated transport. Then there are commercial repair centres for things like (e-)bikes or furniture For industrial appliances there are companies who are dedicated to reparations. There are also full service suppliers for producers, like in automation. An example of this is Omron.

The commercial services can be divided into two, first of all there can be few which work on-site. These would not be interested in using the port for services besides for the supplies for the centre they are dispatched from. Then for repair centres which take their customer's goods to their centre to repair them. If there are economies of scale it might be feasible to have dedicated use of infrastructure, but it is likely not going further than regular logistics. For example, at consumer scale repairs are usually ad-hoc and are logistically handled via the regular parcel network and infrastructure. These parcel networks and infrastructure are affected by the availabilities of a port; however, it does not require the port per se (Montwiłł, 2019).

4: Refurbish

This step is an extra stap compared to repairing, as it is used to renew the item to sell again for a new lifetime of use. For regular consumers, phones or laptops can be an example. Items are being checked for defects and repaired, then sold off to a next user. It is more thorough than repairing, but less intensive than remanufacturing as it does repair and check upon its health, but not necessarily take it apart and replacing some parts. It does require some more logistics, mainly for supply, parts inflow and delivery back to a selling point or costumer depending on how convoluted the supply chain is. Direct access to a port can be useful is the scale is large enough to accommodate this. However, currently the refurbishment market seems to be more dependent on regular parcel logistics compared to large bulky shipments or containers.

5: Remanufacture

Remanufacturing involves taking apart an item and assembling it back together, replacing parts with new parts if needed. Compared to refurbishment, it is more rigorous and uses relatively more parts. Sites like these have the same type of characteristics as refurbishment sites, also benefitting from being supplied with parts, being labour intensive and depending on scale, they could benefit from being located in a port.

6: Re-purpose

This is about taking one item and using it for something else. Take for example hotels in a plane, dining facilities in old railroad cars and old phone booths for AED devices. Repurposing is something which is not yet done on industrial scales yet. However, it could be in 2050. So, assuming it has similar traits to the two steps above, refurbishing and remanufacturing, it depends on the scale whether a place in the port would be necessary.

7: Recycle

Recycling is something which is happening at large scales. In the ICER, the report states that trying to recycle more or better is currently not the activity that would bring the most benefits to the circular economy. However, it already is at quite a large scale an activity which causes a lot of transport between regions. To name one example, scraps. They are heavy and are already transported via barge on some occasions. Plastics could as well be a solid option to transport across water. One major downside for now is the regulation on the transport of waste. Regulations now are making it difficult to transport something classified as waste. If that would be lifted, eased or altered in the (near) future, these transports could regionally be bundled and transported to locations where the recycled product can be used.

8: Recover energy

Incineration of waste. This is one of the less desirable steps in the circular economy as the resource loses its place in the cycle as a material. However, even in a highly developed circular economy, energy recovery from waste is still something to consider. In the most positive form, it could be from fermentation of household green waste, turning it in to bio-gas and further into new energy further on. In the less desirable context, it would be the waste incineration plants as they stand in nearly every region. One example is in Duiven near the IJssel. Even though some of these facilities are near water, they are not yet using their water bound opportunities for transport that much. There are developments at national governmental level to work towards more waste transport via waterways (Topcorridors, 2021), so it might have potential in the future.

9: Re-mine

This is a diverse aspect of circular economy. Remining is trying to take back from what currently is in use. Known examples are old landfills being taken apart to salvage what is left, but in the construction sector, urban mining can refer to gaining back resources from old building materials of demolished buildings. Taking back from the stock. Where this differs from recycling might sometimes be a case of definition, as in the building materials case, which is recycling but with less flexible materials.

Overall, mining is not necessarily happening in the port, since there has to be something to mine at location. However, the mined materials can be a lot to transport, so as with the recycling step, this could benefit from long distance transport over water, from a local port to a larger or specialized recycling centre.

External forces

Intro

The idea of adding external forces is to account for anything not mentioned in the plans of actors regarding either circular economy and inland ports. To keep these forces organized, there is an acronym, PESTLE, which consists of political, economic, social, technological, legal and environmental/ecological factors.

Political factors

Politics

Politics are volatile and diverse. In democratic societies the chosen parties or elected representatives decide the policy. Who are chosen has a great deal of impact on what the policy for the circular economy will be. The fact that, for example, the university of Gent has a research team dedicated to researching the relation between politics and circular economy is telling or the importance of this factor on the developments in this field.

On the political spectrum there are a few movements that have gained traction over the past years. Populism in western countries has grown in popularity. Populist governments in Poland or Hungary are an example of how traditional values can come in to politics to have a voice against more progressive and unionist (EU) parties. Populist parties are usually against climate change prevention. This could be a threat to public investments in sustainable and circular economy. On the other side they usually are siding with liberal parties on the economical spectrum. So usually they will side with entrepreneurs and las that make it easy to start and run a business without government intervention.

On the other side of the spectrum are green parties. They are currently also growing; in the Netherlands the green left party has a stable representation in parliament of 9 seats currently. This development plays at all levels of government. To illustrate an overview of the influence of different levels of chosen government on circular economy and inland ports.

Government	Influence on port	Influence of CE
Europe	Laws and regulations on transport, investments like the TEN-T program	Makes global plans, laws and regulations of which the Green Deal is an important example
National	Laws and regulations on transport and personnel. Investments on waterways of national importance and investments like the Topcorridor programme	Laws and regulations at a national level, implementation and interpretation of European (guiding) laws
Provincial	Environmental and planning powers and responsibility for certain parts of the infrastructure	Environmental and planning powers
Watership	Mainly on water management and contracted upkeep of provincial waterways	Taxes on water management
Municipal (coalition)	Policy on the inland ports infrastructure and local economic policy and enforcement on environmental rules and regulations.	Execution and enforcement of environmental rules and regulations and execution of municipal waste management (through contracts).

Public view on public spending

Public money is being scrutinized more and more in a digital age where more information is accessible to check upon the workings of the government. Platforms like Follow the Money, where private and public actors are being monitored are shining light on inefficient use of (public) money. If a certain scandal comes to light, it might mean that after the event, public actors will be more sensitive about how they spend their money. This could make spending money in public interest more difficult, even if the returns over time would be higher than discounted by the financial experts. This uncertainty also overlaps social developments, as transparency of government is both good if it helps prevent fraud and misuse of public money. It could also prevent necessary daring investments.

All in all, it is the eye of the public that does have an influence on how and what the government is spending public money (Keefer, Scartascini & Vlaicu, 2020). Once again, since this influences politics and thus also the future of inland ports and the circular economy it is important to keep this element in the analysis as well.

Economic factors

Demand for goods and services in (western) Europe

In the western hemisphere, mainly Europe, demand for goods is falling overall. This would imply that less goods need to be produced but also less transport is needed. This could mean there is less need for resources and less need for transport. This would make developments in the virgin (new) resources uncertain, since it might decline. But it could also make secondary resources less necessary. In the western world. It is difficult to estimate the expected results, but it will change glocal economy.

Demand for energy

Demand for energy is an important factor, as it is both important to the flow of goods through the Netherlands (see inland port section, dependency on German coal imports). Petrochemical and dry bulk shipping might be affected. That is just one part of the story. Because where on the one hand fossil powered energy might decline, green forms of energy rise in importance. Even the International Energy Agency has multiple scenarios on which it forecasts the demand for energy in all forms, however fossil forms are the most uncertain of them all, dependent on policy made (iea, 2020) This has its limits in terms of what the network can handle. The power grid might be unable to keep up with supply and demand over the coming years (Netbeheer Nederland, 2021). This issue is also part of the technological forces. However, even auxiliary services like shore power could be affected if demand cannot be met. So, if a municipality has the use of shore power as a demand for being able to operate at a port, this might restrict the capacity of the port.

Currency uncertainty

This is defined as monetary uncertainty, as there still is a possibility that the euro will fail as a currency. In that case, international trade would be affected, thus changing the supply and demand forces currently at play. This could hinder all forms of inland shipping, in turn affecting the capacity in which the port is used.

One of the most important foreign currencies of which the development is important as well is the US dollar. Since oil prices are in US dollars, a sudden change in their currency might destabilize the oil and energy market[4] as well. Other important currencies like the UK Pound or the Chinese Yuan could in the long term how instabilities. These currencies are now seen as possible reserve currencies, however, as much as

[4] Depending on how oil-dependent the energy market will remain as well

speculation against the relatively stable western world has not been happening recently, the long term is unpredictable and a good crisis never comes in with a warning.

Trust among companies

This factor is important because if there is more trust among companies, there is a bigger chance of them sharing data on shipped goods and their waste output. But this could also go the other way. If waste is valuable, it is less likely that a company would share these competition sensitive data to just anyone. Already 'resource realtors' are struggling to find companies that are willing to share their data. Whether this in unwilling or unable is an uncertain factor, but it is definitely something which could influence the direction the circular economy might be heading in terms of centralised or decentralised developments[5]. This overlaps in part with the big data part in the technological factors.

Social factors

Workforce decline

This is acknowledged by inland ports and circular economy in parts, but there is no concrete solution to fill in the gaps that are forming on the labour market. First of all, the overall trend in the workforce. The society is ageing, meaning less workforce to divide overall in most Western countries and Asia (Eurofund, 2021). In the Netherlands the workforce is expected to decline unless migration would compensate for that (CBS, 2020).

Spill overs from demographic change

If global population is becoming younger, this might also influence certain other factors (Karahan & Rhee, 2014). Taking knowledge from the aforementioned paper, effects can be seen in the socio-economic mobility and related fields such as home-ownership. Looking further, into effects of those spill overs, this might just as well bring forth changes in political factors. For example, it might change this might change due to an ageing voter representation. Younger voters tend to vote more green-left-liberal compared to an older generation voting more conservative. The effect would be noticeable in, among others, cases like the Brexit, where differences in voting behaviour between demographical groups were quite large (Moore, 2016).

Changes within the workforce

Then within the group of workers, there is a growing change from practically schooled workers, mainly the MBO-students who are becoming scarcer. This wile technological developments are not that far yet that manual labour can be fully replaced by technology. However, decline is still expected and there is an expected increase in demand for highly educated workers with a more diverse and analytical skillset (RIVM, 2018) Overall, this would mean that there is a shortage of these manual workers. But it is not an easily predictable development, so therefore an uncertainty

Education

There is no specific study in higher education for becoming an expert on inland shipping or the inland ports. Usually this is part of the port economics or policy course[6]. Specific courses are not available in the Netherlands, so building knowledge is dependent on organisations like the NVB to pass on knowledge among their members or clients. One thing to mention is that currently, as the ports policy in municipalities is managed by public officers in the economics department and treated as

[5] No direct sources, but based on interviews with multiple municipalities

[6] Based on experience and not finding any, so standard deductive restrictions apply

an industrial area with specific facilities, this might showcase that general skills in account management and general economic policy development at the municipal level might be enough, however specific knowledge on the maritime sector is something that is usually acquired through working experience and networking at the moment. Overall, it does seem that the principle of skills over knowledge goes up in this field at the moment. Opportunities to improve knowledge levels and development in the field of (widely available) courses in the management of an inland port might can influence the course of the policy development and specialism in the field in general. Therefore, this is for this field an interesting external factor.

For circular economy the story is a bit different, since sustainability in courses in higher education is becoming more important and more widely available. There even is a master's degree (post-HBO) for circular economy. So, the field of education is moving towards a better understanding of sustainability and circular economy, especially in applied fields of knowledge and skills. However, despite starting a new year again in this specific master's degree, it remains a question whether it will hold its shape as it I in the future and whether it will be an integrated part of different curricula or will (also) remain an individual educational programme.

Not in my backyard

Or NIMBY for short, stands for the idea that people don't like changes in a certain radius around their homes (sometimes even extending to 'not in anyone's backyard, so overall protest regardless of distance to their own living). For example, windmills and solar panels are an important part of the development towards sustainable energy production. However, this gets resistance from the area they are planned to be placed in. So, this makes it difficult to change the spatial layout to gain in certain sustainable goals. Energy is one example, but in circular economy, one of the main actors are recycling plants. Given they might be better than incineration facilities, some resistance might be expected when building new facilities that produce emissions, whether greenhouse gasses, harmful fumes, light or sounds, in any area. In the end, it costs more to build new (as in the source mentioned sustainable energy) facilities (Jarvis, 2021).

As the Jarvis paper mentions renewable energy sources, polluting facilities also face public backlash, for example in Nijmegen with the asphalt factory or TATA steel in IJmuiden, leading to public action like investments or retraction of permits.

Strive towards sustainability

This is dependent on many other developments as well, but there is a public tendency to behave more sustainable. This can be derived from, among others, the demand for meat replacements (ING, 2020) or for example more travel with NightJet-trains (RailTech, 2020). This development is an interesting one, because in the European Parliament, there are political ambitions to reduce emissions and be carbon neutral (European parliament, 2021). This development also partially overlaps with politics. This development might lead to an increase in circular thinking among the citizens, which might indicate growth for CE and inland ports as sustainable logistics hubs.

Technological factors

More efficient production

This comes near the idea of reducing using resources as in the circular economy 3.0 model, but here it is more about the technological incremental changes. Where less resources are needed because of upgraded technology and maybe even better resources overall. Possible extensions to this are modular products or biobased products. In the grand scheme of things, this is something which is uncertain, as advancements come at an unknown rate. For computers there is the law

of Moore, which dictates that every year computing power doubles. For industrial technology no such thing exists, but it could be useful to keep these changes in mind as well.

Small data - digitalisation

Data driven solutions for circular economy and inland shipping are becoming more widely used (Wilson & Daugherty, 2020). Big data is a popular term In circular economy things like a resource passport, which keeps track of what resource goes where and maybe even how to extract that. Small data, however, is data more manageable by people and less by algorithms. In inland shipping in the form of technology like Routescanner, which helps ports gain insight in what arrives when and how. All this data can be used to gain more useful insights in what is where, how much is consumed and other things. But it also comes at the threat of privacy for companies. This uncertain factor is also described at the economic factors. Concerns regarding data protection might decrease willingness to work along on these resource passports or other innovative changes like the resource realtor concepts.

Big data

Powerhouses such as Amazon, Google and other large players in the field of data collection and usage might be able to provide services in inland ports or circular economy (Perella, 2016). They possess much data and know how to use it. Currently they are usually using it to sell more ads, but a commercial holder of data like Amazon is not afraid to venture into new business models. They are acquiring their own fleet of transport vehicles and might shake up the logistics field in the long run. The role of more service based companies is even more uncertain, as they do not disturb the business environment through tangible assets like ships and planes, but more on the insight level.

More efficient separation

Specialized mechanical separation of waste would be able to improve the efficiency level of circular economy by a fair bit. Even though the PBL ICER report is stating that more recycling might be marginal, the quality of recycled goods could improve quite a lot, making the secondary material gained from the waste a better substitute compared to virgin materials.

Legal factors

Environmental legislation

Environmental legislation such as a co2 reduction laws and nitrogen deposition laws are an uncertain factor in regards to circular economy. If these kinds of laws start affecting resources used in production they might boost or hinder the circular production. These laws are largely dependent on the political factors, populists would vote against, others might vote in favour of these kinds of laws.

Further expanding the issue of environmental legislation are lawsuits filed against governments and companies. Outcomes demand stricter protocols and show that responsibility for emission reduction is not an abstract issue, but an extension of human rights interpretations.

Environment and planning laws

Already mentioned elsewhere, the development if this new 'omgevingswet' has not been smooth. The process has known delays and changes. As much as it is certain that this law is coming, the effects of it and the true scope and implementation leave much to the imagination. So, overall, this is quite an uncertain development. It might mean a different approach to planning in the future.

Economic legislation

This is partially geopolitical as well, but economic legislation might mean a different approach to circular economy overall. China has banned inflow

of plastics waste from other nations, meaning that what was once the recycling hub of the world is now closed for business. That means countries are dependent on other countries, which also slowly stop their intakes and leaves countries self-dependent for their waste management. Barriers to trade could have also been political and economic, partially social factors even, but regardless they are in writing and legally binding. The development of this type of barriers is unknown and thus also a possible external force to reckon with.

Patents

These are less obvious, but patents to something can keep the technology of a new innovation in the hands of a single party for quite a while. These might not immediately form a threat as this is very long term and the effects of patents on circular economy or the inland ports is difficult to assess. But nonetheless, this could be hindering implementation of new technology in the medium term.

Waste transport

Transporting waste has its own caveats. One of those is that is has certain rules to abide by for the transporters, which makes it a costly business[7].

Environment/ecology

Nitrogen deposition

While writing this thesis, the situation gets updated every so often. One recent development is a rapport from the PBL (Tiktak et. al., 2021) on the possibility that agriculture might face closure in a few provinces due to nitrogen deposition limits. Once again, the effects of the law and the measurements and the controlling of this might play a role in the future of port development.

Threatened species

Often overlooked small animals such as bats, salamanders and others might threaten development as well. Strict regulation on these might end up throwing off a planned building schedule, causing delays of up to a year.

Climate change – extremely dry or wet

This speaks for itself partially, but high tides can throw the logistics schedule off in tidal rivers. This and the threat to port itself being under water if not protected well enough. This is a concrete threat, as shown in the case of Roermond, where the parties in the port had to cooperate in order to get to a better protected port by the water authority.

Dryness on the other hand can also cause damage to quays and other infrastructure. Overall, this can be seen in the city of Amsterdam already (for a bit, as far as it is not caused by over-use there).

[7] Based on interview with Port of Rotterdam

Methodology part 2: Scenario logic

Uncertainty

In order to build the scenarios, it is important to find which external forces are the most critical. To measure uncertainty is difficult. It is not a tangible thing, thus it requires certain methods to estimate the uncertainty. In this case, the four levels of uncertainty will be used. This method divides the uncertainty in four levels (Courtney, Kirkland & Viguerie, 1997).

Level	Name	Uncertainty
1	Linear	One clear future
2	Alternate	A set of clear possible futures
3	Range	May options within a bandwidth
4	Ambiguous	True infinite options

Table 5: Levels of uncertainty according to levels Courtney, Kirkland & Viguerie, 1997

This method divides these four levels, however more levels of uncertainty can be found by looking at the variance within these levels. For example, a linear and clear future might be just the one outcome possible, but the context of the outcome might also influence the uncertainty it might intrinsically have. To explain, take for example the building of Berlin Brandenburg Airport. During the decision making process it was clear at a certain point that in the future this airport would certainly be built, in this case in 1996. In this case the outcome is certain, but the peripherals, like when or how, are less certain. It could be considered more uncertain than having an appointment at the dentist tomorrow for just clearing out the plaque, but in the same sense linear as the outcome is certain. On the side of alternate uncertainty, a similar way of thinking can be used to divide those uncertainties in to two as well.

When it comes to the range and ambiguous levels of uncertainty there is also the possibility for a certain division to be made. On the third level, range, it is possible to make that distinction based on the size of the range. For example, a locally produced housing plan for a new neighbourhood could be between 40 and 400 houses, but a national plan to build houses on a larger scale might have to incorporate up to a few dozen of opportunities in each of the 355 municipalities in its plan. Where to put the divide between a small and a large range might be difficult to pinpoint, so for this specific case it might be beneficial to set it at the point where there is a clearly defined range, like in the case of the local housing issue, or a less clearly defined range which might change like in a more broad or national plan.

For the ambiguous level a same sort of definition can be implemented. For example, scenarios are a set of outcomes, but reality will probably fit in between a few of the scenarios. In this case the ambiguity is there, but it is a bit narrowed down by the arbitrary boundaries of the scenario writer. On the other hand, there is a rogue ambiguity, for example how will the geopolitical climate evolve. This is both not easy to capture in scenarios as there are too many critical factors (could be debated, but in reality, it is) and there are too many outcomes for the factors themselves. This places geopolitics at an even more uncertain position than the scenario example, as it has a less defined scope.

Overall, the conclusion is that for the level of uncertainty the four levels of the Courtney, Kirkland & Viguerie paper will be doubled in order to keep in mind that within the four levels there might be different intensities of the uncertainty. In short it makes the uncertainty look like this:

1. Defined linear
2. Undefined linear
3. Defined alternate
4. Undefined alternate
5. Defined range

6. Undefined range
7. Foreseeable ambiguity
8. Unforeseeable ambiguity

Impact

Impact measurement is done with a different method. As the internal forces are quite broad, the impact must be measured broadly. Therefore, it is important to use a method to decide on the score of impact that also can account for these criteria.

In the realm of strategic thinking, multi-criteria decision analysis is used in order to get an evaluation on a set of possible (policy) interventions (Dodgson, Spackman, Pearman, & Phillips, 2009[8]). Part of that analysis is getting to a set of criteria to weigh the decision on. This part of the method could be used in order to gain an estimate of classifying what the impact of a certain external force is on the inland port in the future with regards to the developments in the circular economy.

In order to build this, it is important to have insight in which places these external forces have impact and whether to weigh these. For this analysis the impact on the internal factors for the inland port and circular economy will be estimated a binary scale of 0 or 1. This might be disputable as it does not nuance how much impact something has. Given the nature of this research, which is a scenario planning, the nuance is relatively less important as these are more explorative of what a future might be rather than an estimation of the actual outcome of a certain scenario. Therefore, this binary input to build the measured impact variable is acceptable.

[8] It is possible to cite an array of literature on this methodology. This paper is a decent summary of the main method of MCDA.

The internal forces that can be seen as impacted are the following;

- Imports and exports
- Labour supply and demand
- Spatial dimension
- Municipal decision making
- The actions in the CE 3.0 model
- Profitability of CE actions
- Perceived impact based on preliminary interviews

These forces will not be weighed as the importance of each of these individual variables will differ per scenario and per port. As the outcome is not a specific for one port but rather a general insight into the impact in a future scenario this can also be simplified like this.

Adding the scores of all the factors together gives creates a score between 0 and 7, which will be used to display the impact of the specific external force on the internal factors.

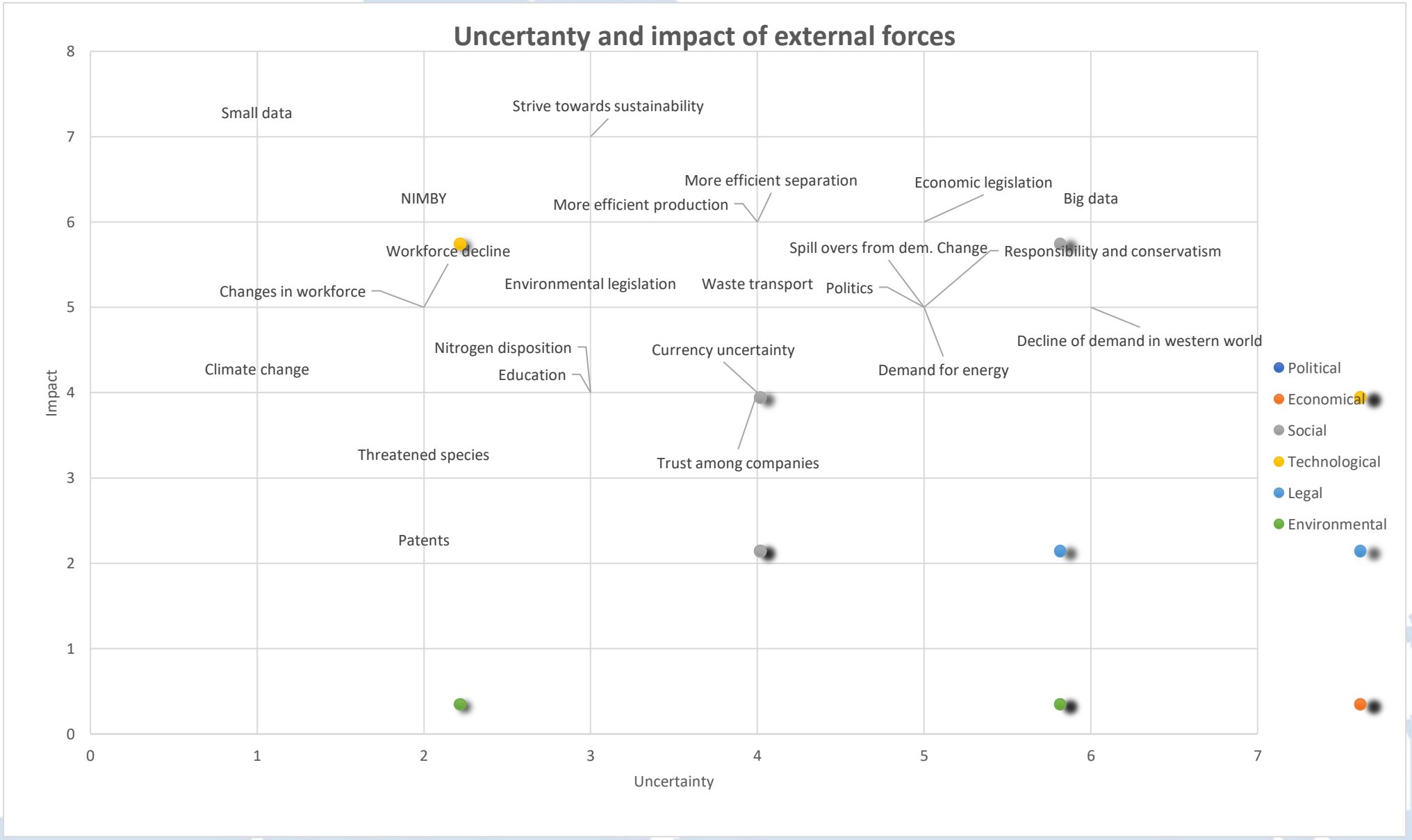


Figure 5: Uncertainty and impact of the external forces

From external factors to critical uncertainty

First of all, policy. What can be seen in all types of policy throughout are two distinct dichotomies. On the one hand there is central versus decentral organisation and on the other side there is policy based on the restriction of growth in terms of quantity of materials in circulation and on the other hand there is policy made for improving the quality of materials in circulation.

Central/decentral: In terms of organisation there are multiple levels. Central vs decentral usually goes up for governments, but in this case, central vs decentral also shows relations between companies and their insights.

On the governmental level and policy side there is the question of where which power lies. On the one hand legislative power is mostly at a national level. Policy decisions are broadly made at Eu level and moulded to fit on national level. However, due to subsidiarity, responsibility trickles down to the lowest level where it is feasible to have it executed. At the moment, for example, there is legislation regarding municipal waste. This legislation was made so that household waste is the responsibility of the municipality and business waste is the responsibility of businesses themselves in an open market for collectors and processors.

Another reason for the divide between central or decentral matter is data. Small and big data are expected to have large impacts. The difference between the types of data also shows a central or decentral difference. Big data is accessible to companies and government with many client profiles and knowledge about citizens. Small data is more accessible and processable for all sizes of companies and governments. Big data fits large corporations which would take a large market share and are able to function with more insight in the market than smaller players with only access to smaller data. This drives a divide between organisations with vastly differing economies of scale. To summarize, big data leads to a more central CE as big data tends to benefit larger conglomerates such as amazon, google and others which profit from the knowledge which is inaccessible to small players who only have more regular and comprehensible datasets and analytical tools. Small data leads to more decentral CE. Sidenote, if small data is important, trust among companies is important to make the circular economy work even better, so that external force would also play a large role in whether or not these approaches would work.

On the side of quality vs quantity there are again regulations which go both ways. On the one hand something like Diftar is currently a piece of policy used to help nudge citizens to reduce the amount of ‘rest’ household waste. The system is comprised of multiple bins; however, you pay only for what is not separated as a recyclable waste stream. This is policy made to reduce the amount of waste and materials in the cycle. On the other side of the spectrum is for example the way EU policy on disposable plastics has an effect on what is consumed. Plastic straws and containers for takeaway have been replaced with biobased counterparts. This development shows it is also possible to change the quality of a product in order to make it have less of an environmental impact. In agreements as the PlasticPact, reduction of the number of types of plastics might make the waste flow of plastics easier to recycle. That would possibly have less of a strain on production compared to trying to reduce the amount consumed overall, thus making it more stable from an economics point of view. The sidenote here is that de development of technology in separating waste is important here. The better the technology, the less need for products to be made of less of different products as innovation would have solved for this. However, policy made with that progress in mind in a scenario where that progress is not as

advanced might encounter difficulties reaching separating and recycling targets.

Scenario context

The scenarios are built with a certain place in time. The year for these scenarios is 2050. The reason for this specific year is because of the national government's goal to have a fully circular economy in 2050 as stated in the ICER. This goal is quite far away, but in order to understand what might happen in the port this year is crucial, as it will be the point of arrival, so to say, for current circular economy policy.

Years like 2030 or 2040 are intermediates. They are mostly on the path to a circular economy but are not yet fully there yet looking at the ambitions of the CE.; That does not necessarily mean that the timeline in 2050 is already fully circular. As much as that is possible, there is scepticism about whether or not this might happen end it is not unreasonable to think that a fully closed loop circular economy is not yet possible by that time.

However, the goal of this research is to show the scenarios for the ports and the effect of circular economy. By picking 2050 as the reference for the scenarios the place in time for the scenario is in that regard able to showcase the extremes of the chosen critical uncertainties.

Then next to time there is a place. No one port can speak on behalf of all ports and that makes it difficult to pick one. The goal of the scenarios is to show what might happen, and because that is an abstract, the place where the scenarios will be referencing to will be fictional as well. In order to visualise the scenarios there will be a map of a fictional port which represents an average port based on the Binnenvaartmonitor. This will show a bit of all sectors and an average use of the port of about 50% (which is above average). The images will contain a legend that will explain the picture.

In order to compare the scenarios, there will be a structure as to how the scenarios will be presented. First of all, a few of the activities in the port will be assessed, these are;

- Container shipments
- Dry bulk shipments
- Liquid bulk shipments
- Storage
- Industry (processing)

These will be assessed and based on that an example of a reference future port will be made in order to showcase the effects of the scenario.

The four scenarios are named after different steps in the circular economy 3.0 model and some interventions or innovation that could take place in the future

- Less waste
    - Based on reduce, the idea of Diftar and such
- Rethinking resources
    - Re-inventing resources to make them more suitable for recycling for example
- Repair café
    - A repair café is usually a local initiative to prevent wasting (electronic) goods
- Remanufacturing cycles
    - Great challenges to re-build the cycles to have more regional production and processing of goods and materials.

Scenario's

Central

Economies of scale
More transport between processing 'hubs'
(inter)national businesses
National gvt as policy driver

(inter)regional knowledge and networks
Less transport
Local businesses
Decentral gvt as policy driver

Decentral

Focus on quality (better waste)

Less types of waste
More modular products
Responsibility for producers

Less production and consumption
More second hand products
Responsibility for consumers

Focus on quantity (less waste)

Central

Central CE and policy for quantity:

Central CE and policy for quality:

Quantity

Quality

Decentral CE and policy on quantity

Decentral CE and policy on quality

Decentral

Reference growth and current expectations

References for expected growth

This scenario planning approach is assuming a few different scenarios. To measure the relative effect of the scenario's it is important to feature some kind of reference point. In this case, that will be based mainly on studies toward growth in the inland shipping sector.

One PBL study (Sneller, Romijn & Hilbers, 2015) shows an expected growth in weight of goods shipped in the inland shipping industry to be between a relatively low 10% and a relatively high 34% between 2011 and 2050. It is expected that inland shipping might lose market share, but will still maintain a bit of growth. One opportunity that is being named in the rapport s the trend of nearshoring, bringing production back to western countries (opposite of off-shoring). However, that could be curbed by processes like truck platooning which brings down costs of dry shipping methods and 3D-printing possibilities. ING (2017) also has high expectations of this phenomenon and expects world trade to drop by 25%.

The downside of the PBL studies is that it does not contain any sectoral views. It mainly describes the average trends per modality and leaves it at that.

An older report from 2011 by NEA (2011) does make sectoral overviews. However, they are sometimes quite specific and not per 'sub modality' like container, dry bulk, etc. One other issue with this reporting is that it is currently relatively outdated and it shows a relatively positive expectation compared to the PBL models. Overall, taking the two reports, it is possible to find a midway point to assess the expected impact. This way it is possible to create an arbitrary quantitative expectation for the growth of the different parts of the inland shipping sector, explaining the reference point from which the scenarios will deviate. Dry bulk will be the average of coal, steel/ore, agrobulk and construction and liquid bulk will be assumed to be just the petrochemical industry as in the NEA report. .

In order to build this reference point, the high expectation of the 2011 report will be corrected in a way by averaging out the expected growth of the individual sector/good by the growth of expected by the PBL. This method is, as said before, arbitrary. However, any other method would be as well. These forecasts are what they are, forecasts. The 2011 report is already outdated and the effects of covid, expected slowing of growth by changes in technology and diminishing world trade are not taken into account in an extent that fits modern expectations. Averaging the numbers from the 2011 report with the low expectancy numbers from the PBL report from 2015, which is also not fully up to date anymore, would result in a dampened expected growth for individual sectors from the 2011 report. Then after averaging out with the PBL 2015 low scenario, it will be averaged out based on sector, namely dry bulk, liquid bulk, container. In order to keep up with the times, the reference growth of the NEA report will be taken as the growth relative not to the 2007 reference numbers, but to the 2020 expected growth index.

$$Arbitrary\ 2050\ reference = \frac{\frac{NEA2040minindex}{NEA2020minindex} * 100 - 100 + 10^{PBL\ min}}{2}$$

Good	2020 NEA min	2040 NEA min	Arbitrary reference
Coal	*+17%*	*+37%*	*+23.5%*
Steel/ore	*-1%*	*+14%*	*+12.6%*
Agrobulk	*+4%*	*+23%*	*+14.1%*
Construction	*0%*	*+9%*	*+9.5%*
Dry bulk			+14.9%
Liquid bulk	+1%	+4%	+6.5%
Containers	+42%	+162%	+47.3%

This table is based on NEA (2011) and PBL (2015).

Referencing the scenarios

The scenarios will have an expected effect on the projected growth set as the arbitrary reference. Since scenarios are mean to showcase different independent possibilities for future developments, these effects will have to be significantly impactful to showcase the future developments in the scenario.

One way of possibly doing that is by setting a different arbitrary growth number as an estimate of what the effect of the scenarios will be. However, these need a reference point in order to work. So, for example, if expected growth in the reference case is about 47% for containers and the effect of a scenario is highly negative, growth could be estimated to go down to about 20%. The downside of this way of thinking in these scenarios is that the direct relation to the reference is not clear.

Another option to relate the effects of the scenarios is by referring to some multiplier effect relative to the growth. The way this works is about the same as in a lickert-scale type situation where it is possible to select, within a certain range, the effect of the scenario on a sector and using that to make a multiplier suggesting the effect on the expected growth.

This method has the advantage that the reference growth is leading the main indicator that is being showcased is the relative effect on the reference growth. So, for example, if a part of a scenario could get a score on a scale between 2 and -2. A score of 2 means double growth compared to the reference, a score of -2 means half the expected growth compared to the reference.

Another advantage of this method is that it could be considered to be neutral to differing expectations. A system of double expected growth or half expected growth is neutral to the view of policy makers. Whatever the expected growth within the port authority is, an effect on the relative growth can be implemented either way. Therefore, the power of the tool of scenario planning will be more versatile compared to just picking adjusting the reference growth.

The one downside to this method is that inherently there is no possibility to go from negative to positive growth numbers or the other way around when applying the multiplier in that way. This should not have to be a problem for the reference numbers created in the previous segment, but it could become difficult when facing low inherent expected growth in the long term. That's why the scale will be applied in an intrinsic manner and not a relative manner. A score of 2 in that case means an expected net growth of two times the reference growth (whether reference from this study or internal policy growth numbers). A score of -0.5 would mean the expected growth of the sector is expected to be negative half of the expected growth. The only issue this creates is the situations where expected growth is exactly 0 or really low. However, in those cases policy makers should interpret studies with caution when comparing scenarios of any nature because of the difficulty of showcasing the net expected effect in those cases.

Because of this complex nature, the effects will be captured by a spatial example of a future port as well. These scenario ports will show what happens in the port based on the expected effect on the reference growth. For this case there will be a reference port, of course representing reference growth in 2050, to compare the effects of the scenarios with on the spatial level for an average port according to chapter 1 describing the inland port statistics for the Netherlands. Added to the net effects on the shipping industry, the spatial examples will also show the effects on storage and processing in the port. These will also get a 'multiplier', but for those developments there is no reference growth to relate those to as there are relevant studies (DHL, 2012; Deloitte, 2019), but none are giving exact growth estimates towards 2050. Therefore, these estimations will be estimated at the same as the low PBL estimates.

Reduced waste

- ➔ Central CE development
- ➔ Policy based on control of quantity

This scenario follows a future in the lines of policies like 'diftar' and associations or cooperation such as in the 'Plastic Pact NL'. The core goal in this scenario is to reduce waste by means of central governmental policy or agreements on the market level.

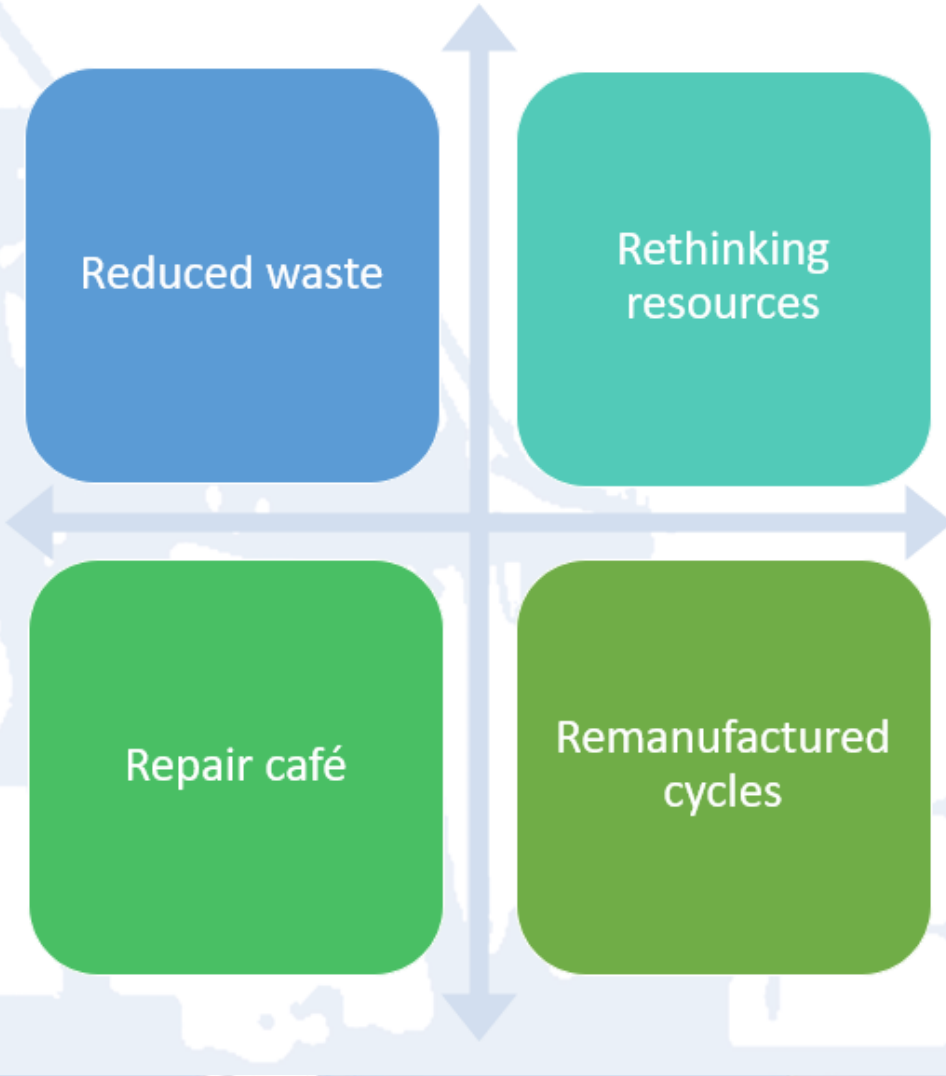
Responsibility at the consumer level is mainly pressed by the government. The 'diftar' model for example is a system in which households are taxed by net rest waste that they produce. All separated streams are free to hand in, so plastics, glass, green waste and textiles. This is a relatively Pigouvian thought, to tax the polluter.

In practice this has yet to be refined, as diftar introduction in municipalities has struck protests and, in some cases, even referenda.

Producers will be either nudged or forced by institutions to use less resources. Whether in the form of a pact like the 'plastic pact' or in the form of laws and regulations on the use of resources.

Consequences for industry

Overall, on the quantity reduction side of the matrix there will be less resources in circulation. That would mean products currently in use will be used longer and thus there would be more refurbishments, reparations and more remanufacturing. On the side of making new products, there might be a larger market for parts, as far as 3d printing would not be able to fill in that gap. In a centralized scenario as this, it would mean there will be supply chains catering to these new demands. These activities could take place in large centres which are specialized in their respective brand or product. Overall, the demand for virgin resources should be reduced as an effect of the measures.



Consequences for the shipping industry

Containers

Containers carry an array of goods, ranging from large machine parts and industrial half-fabricates to, in a lesser extent, consumer goods. However, these consumer goods will be produced less as they are in circulation longer. Assuming the demand for replacement parts does not exceed the demand for new goods, growth in the container shipping market might decline, as less end-user goods will be shipped. However, the reduction in growth in this scenario might be less than in a decentral scenario, as even international supply chains for repairing, refurbishing and remanufacturing might get set up. Overall, growth might be slowed down and the multiplier given to this scenario would be -1. This means a decline of 23.5% compared to the reference point.

Solid bulk

Dry bulk might encounter a situation similar to containers. Less production for end user goods, more parts. Overall, less growth. However, less might resources might be in circulation, optimizing and building recycling networks can gain traction in this scenario as well. So that could also limit the harm to this sector. Therefore, the multiplier given to this scenario would be 0.5. This means, compared to the reference a growth of +4,45%

Liquid bulk[9]

Once again, less demand for manufacturing, less demand for oil. Naphtha as a plastic recycled product might increase in importance in this scenario, as it would enable the industry to make new materials from used plastics. However, overall decline in growth for liquid bulk can be expected. This concludes to a multiplier of -1, meaning a decline of 6.5% compared to the reference.

Consequences for the port

In this scenario smart development and diversification is the answer. Demand for new goods will decline, thus the port might be used less intensively compared to now. Industry would change to remanufacturing and repairing centres, so the industries might change around. In terms of demand for land in the port, this might grow less as the opportunities in this scenario can be incorporated partly in the consumer mail services. Unless innovation places those in the port, the use of the port could become more diverse and attract more diverse industry to the lots.

In terms of spatial planning, some key important elements are the reduction of total land used. That means the port won't use as much land as it would do compared to the reference growth. Decline can be seen in commercial use, container facilities and liquid bulk facilities. Furthermore, there is growing demand for storage (+0,5) and processing (+1,5). Overall, a smaller port is needed compared to the reference growth expectancy.

The effect visible in the reference port is diverse. There is a much smaller facility for liquid bulk to start with, none of the facility is made for circular petrochemicals as well. Then there is the container terminal, which has disappeared in this case and made room for a large-scale storage facility. This was needed to compensate for the loss of economies of scale due to lower consumption levels.

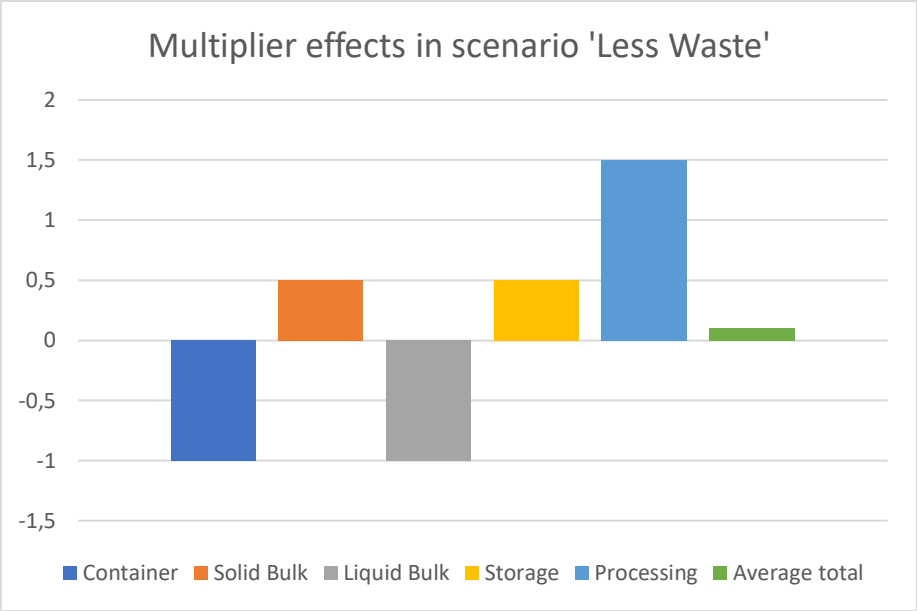
Furthermore, the commercial activity in the port is reduced due to the decrease of consumption expected in this scenario. The municipal waste site remains the same, for it has an important function in recycling all the

[9] Keep in mind that this (and future liquid bulk) is excluding any energy market changes that might take place outside of the specific circular economy case.

consumer goods. The waste incinerator has been replaced by a bioreactor. A circular construction hub has been built in place of one of the retail locations. Furthermore, the scrapyard has decreased a bit in size.

For easy reference, this is a table with the changes in compared to the reference port:

Reference port	**Less waste port**
Asphalt factory	No change
Container terminal	Replaced by used device bulk storage
Scrapyard	Shrunk in size
Shipyard	Remained the same
Retail	Half remained
Waste incinerator	Replaced by a bioreactor
Metal recycling facility	Shrunk in size
Petrochemical industry	Shrunk in size
Concrete factory	Remained
Municipal waste site	Remained
New addition	Circular construction hub

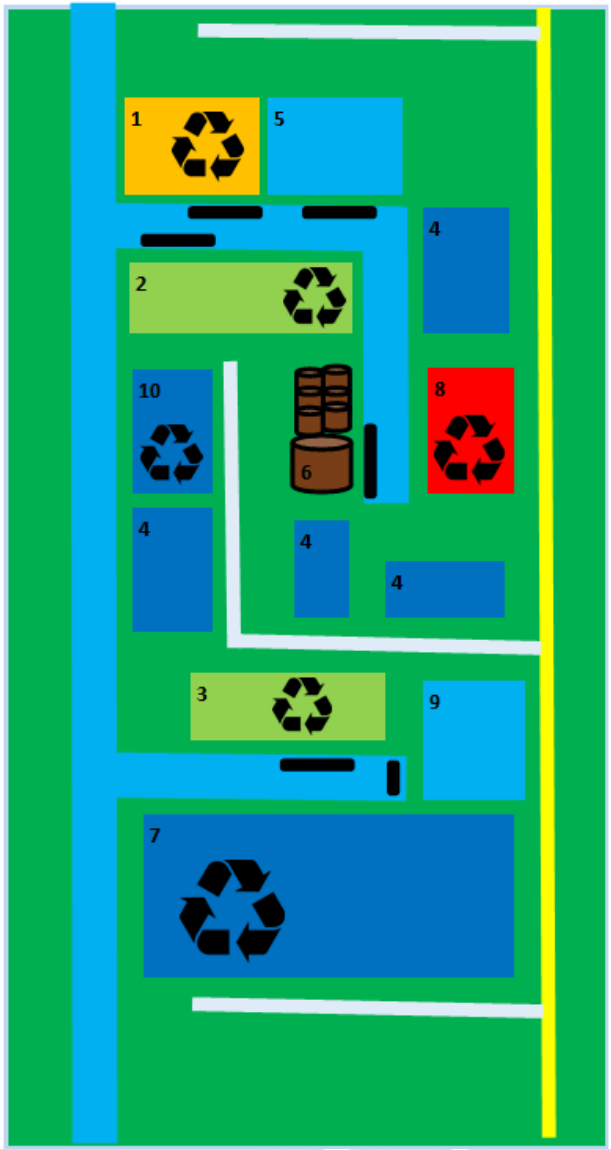


Legend

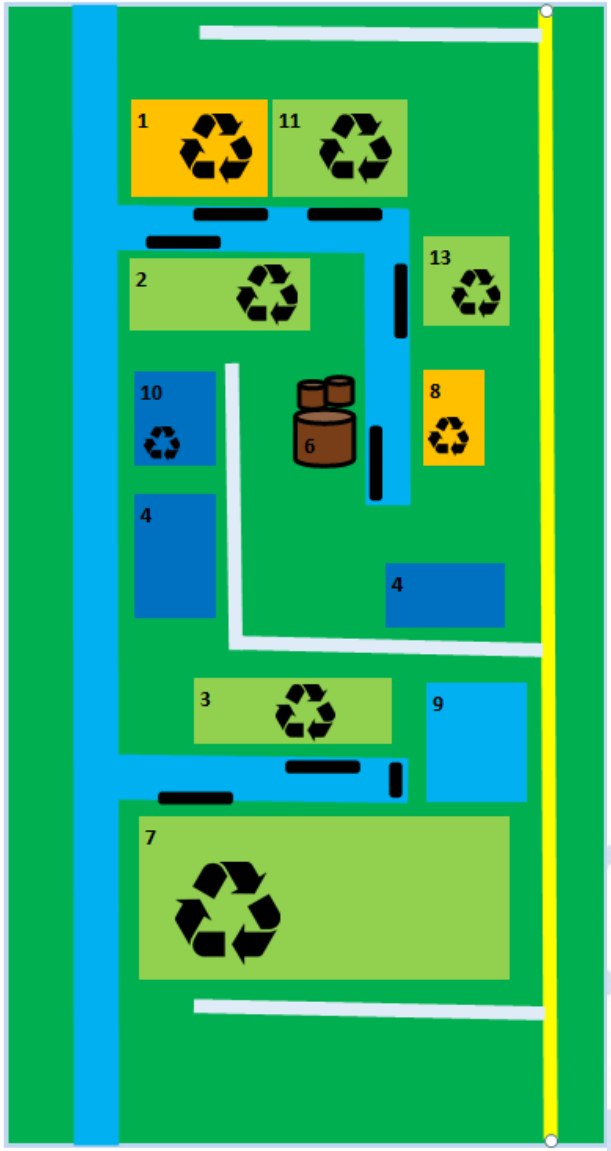
1. Asphalt factory
2. Scrapyard
3. Shipyard
4. Retail
5. Container terminal
6. (Petro-)Chemical storage
7. Municipal waste site
8. Waste incinerator
9. Concrete factory
10. Metal recycling
11. Used devide bluk storage
12. Bioreactor
13. Circular construction hub

Circular activity
Non-port activity
Non-circular port activity
Closed loop circular port activity
In between circularity port activity
Open loop circular (energy) port activity
Active quay (ship)

Reference



Less waste



Rethinking resources

- ➔ Central CE policy development
- ➔ Policy based on improving waste quality

In this scenario, resources are improved upon in order to make recycling more easily possible. Think about the current system in which many types of plastics circulate. Those would be easier to recycle if there were not as many types floating around in our recycle bins. In order to improve on that situation, the number of types of plastics and the quality of those will be regulated in this scenario.

Other improvements in the quality of goods can also play a role, with innovations as biobased component and resource passports for goods. In this scenario, consumerism can continue within the bounds of the new materials and we can continue more incremental changes in the supply chains that exist.

Consequences for industry

If the objects and the cycles of development don't change necessarily, this would mean that industry can carry on its way with incremental changes. Like the plastics aspect, it would have to change the production, but not slow it down. In the biobased field the same would happen. Substituting one for the other means that consumption levels could remain stable along the growth patterns expected. So, the industry overall would see changes in the types of materials used. Furthermore, it would benefit from the overall changes in the economic cycle. The supply would benefit from the resilience to virgin material shortages, except maybe in the field of biobased, which is dependent on harvests, which in turn are threatened by climate change in a way.

Consequences for the shipping industry

Containers

With the assumption that consumption levels can remain the same as they are now, containers could benefit in this scenario. Their development would be dependent on global supply chains and the shocks they endure, such as economic cycles and the occasional pandemic, war or canal blockage. So overall, their growth would be as it is now. Expected multiplier would be 1, so expected growth would be 47.3% as per the reference numbers.

Solid bulk

This market would have more potential than the container market in this scenario, as two factors play a role in this sector. In the first part, recyclable materials are of better quality and will be used as now and recycled more often and in better conditions. This could allow for less risk in those recycle streams, making shipment easier. So recyclable materials and their recycled products could see growth in this market.

The other aspect playing a role in this scenario would be biobased. Wood, grains and other produce for these production chains would be bulk as well, so that would add to the pressure on this market. Overall, this sector could see more growth than currently forecasted. The multiplier that follows this conclusion is 2, leading to an expected reference growth of 29,8%.

Liquid bulk

As in the other scenario, purely looking at production, this would decrease the demand for virgin materials, this decreases the production potential in this market, making it see less growth than expected. Naphtha once again the uncertain factor, as it is an interesting potential in a scenario where plastics can be recycled well into new plastics, but whether naphtha would play a large role in this is uncertain.

Other not names green chemical businesses could have more potential in this scenario, as they are biobased and thus responsible to use from an environmental perspective. This could correspond with a multiplier of 1, giving this sector an expected reference growth of 6,5%.

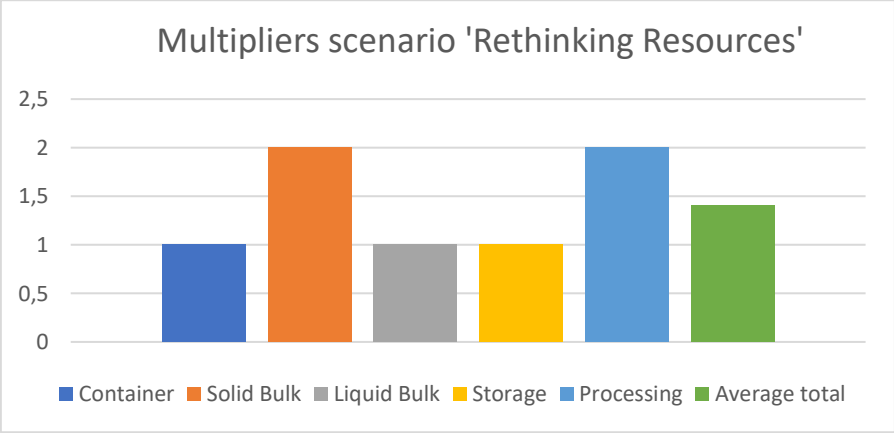
Consequences for the port

Overall, demand for use of the port will grow in this scenario. Container markets will continue to expand and solid bulk growth will increase. Overall, it puts stress on the spatial dimension, as more space in the port will be demanded, but scarcity will also be high. Parallel to the current situation, port authorities will need to be selective on who they let on to their ports to do business there and non-essential services that complement the port will be taken further into the dry industrial areas. Overall, the challenge is to keep the port within a focus. Gain local economies of scale and cluster activities and try not to diversify a single port too much.

Demand for physical labour would increase as industry is expected to increase as well (+2), which is difficult now, but will remain so in the future. If technological changes cannot keep up with the demand for this labour, it might cause shortages and hold back the expected growth partially.

Overall, when it comes to the reference port, it changes as well. Some changes are akin to those of the reference port, like for example, a smaller scrapyard and the waste incinerator replaced by a bioreactor. Other changes for this port do differ a lot more. Demand for storage is expected to be growing as well, more than in the less waste port because of a higher level of both recycling and consumption leading to high storage demand growth (+1).

Reference port	Rethinking Resources
Asphalt factory	No change
Container terminal	Grows in size
Scrapyard	Shrunk in size
Shipyard	Grows in size
Retail	Phased out of the port
Waste incinerator	Replaced by a bioreactor
Metal recycling facility	Grows in size, more circular
Petrochemical industry	Grows in size, more circular
Concrete factory	Grows in size, more circular
Municipal waste site	Remained, more circular
New addition	Circular construction hub
New addition	Biobased materials hub

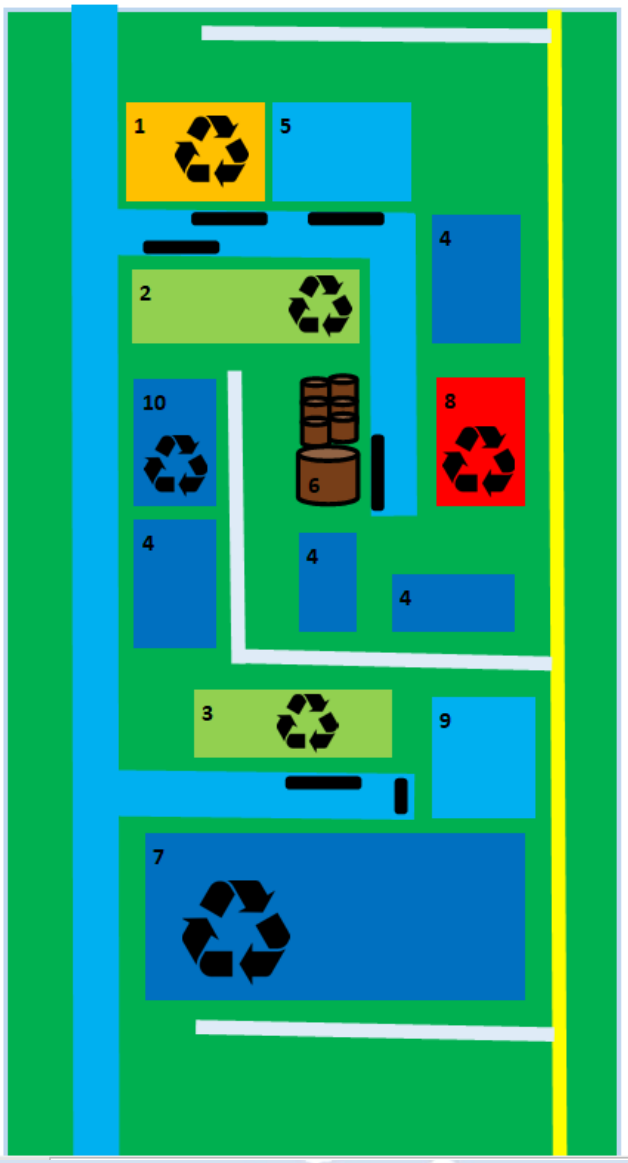


Legend

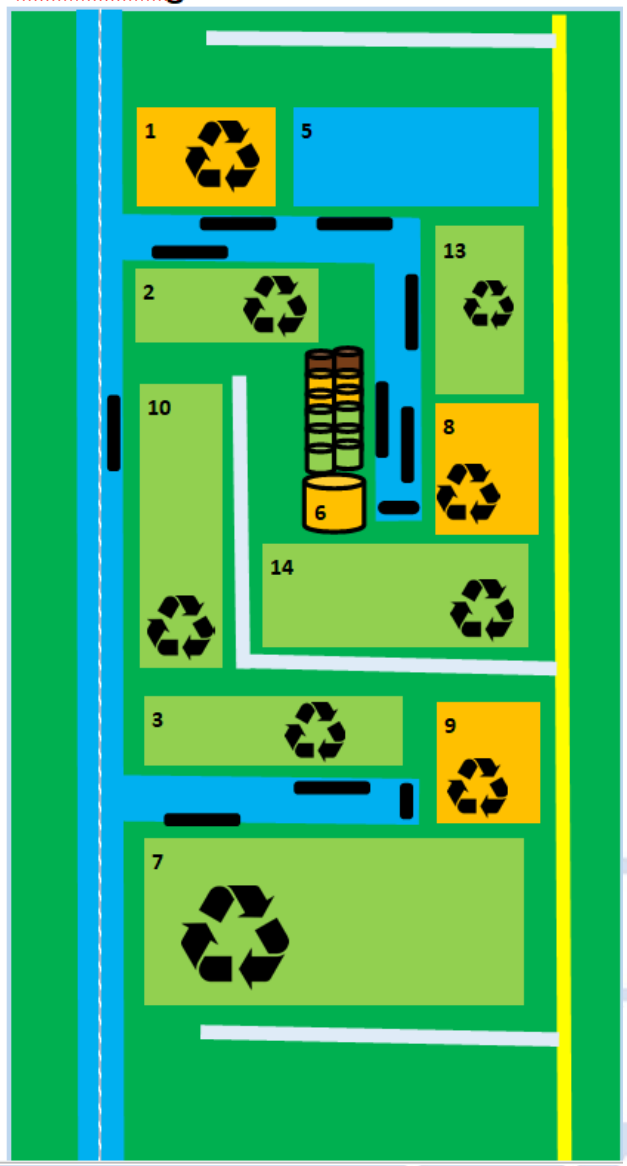
1. Asphalt factory
2. Scrapyard
3. Shipyard
4. Retail
5. Container terminal
6. (Petro-)Chemical storage
7. Municipal waste site
8. Waste incinerator
9. Concrete factory
10. Metal recycling
11. Used devide bluk storage
12. Bioreactor
13. Circular construction hub
14. Biobased materials hub

Circular activity
Non-port activity
Non-circular port activity
Closed loop circular port activity
In between circularity port activity
Open loop circular (energy) port activity
Active quay (ship)

Reference



Rethinking resources



Repair café

- ➔ Decentral CE policy development
- ➔ Policy based on improving waste quantity

This scenario implies more local initiatives which are focussed on repairing, remanufacturing and refurbishing. Thinking of repair cafés and local phone shops which locally deal with issues at hand. This side of the matrix has less economies of scale, but it provides opportunity for interregional and business network-based solutions.

Responsibility will be at local governmental level and consumers might face slightly different regulations depending on their location. Less materials will be in circulation and more local re-use will be encouraged.

Consequences for industry

In this scenario industry will again be producing less. Parts and repair/refurbish and remanufacture will gain traction, but less centralized. Regional centres might get set up for repairing their respective product, but with less scale they might be less efficient than in the less waste scenario. More local expertise centres will see the light. Overall, demand would decline.

Consequences for the shipping industry

Containers

First of all, with more decentral approaches, the market for container transport would decline, as it is less used for those international supply chains as we know them now. Interregional container shipments might increase, but given the premise of having less materials in circulation, it will not compensate for the decline in overall demand in this market. So, less growth compared to the expected growth. The multiplier for this scenario is -1,5, translating to a decrease of 70.95% compared to the reference numbers.

Solid bulk

Comparable to the less waste scenario, less production and less materials in circulation means a decline in growth in this market as well. Given the decentral manner of organising the circular economy in this scenario, it might even mean more of a decline in growth as it will not have to support (inter)national supply chains as much as in the central scenarios. Therefore, this scenario has a low multiplier for solid bulk, as it has for containers. -1 in this case, leading to an expected decrease in market growth of 14.9% compared to the reference.

Liquid bulk

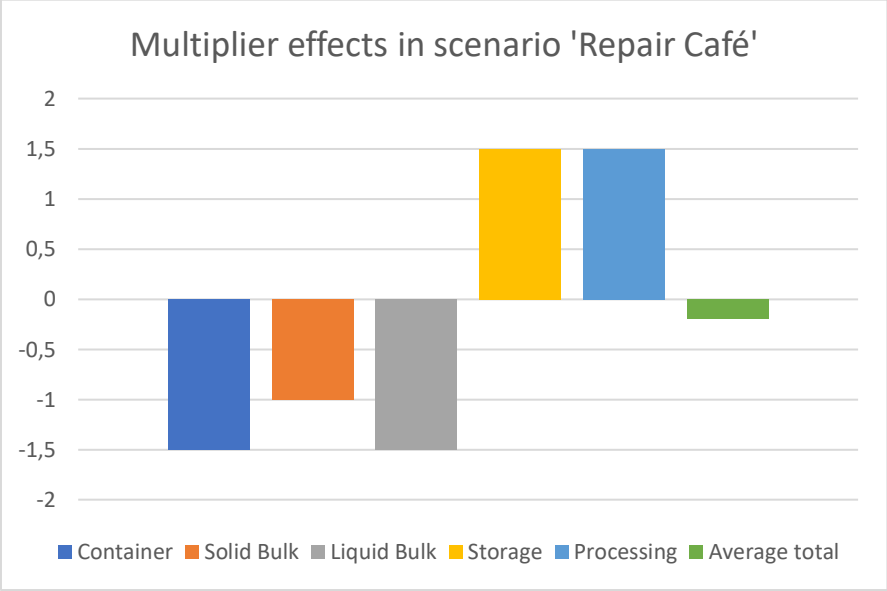
Less production means less demand for oil, naphtha's might be an exception. But due to the more decentral approach in this scenario, it might mean less potential for the naphtha market as well, since more materials will be (re)used in their current network or area. Overall, negative developments due to this combination of results is -1.5, leading to an expected decline of 9.75% compared to the reference.

Consequences for the port

Less intensive use of the port means more local initiatives can take use of the port. Current business could shrink compared to their size now, making the port a more diverse and innovative ecosystem. Overall, it would be comparable with the less waste scenario, but with slightly less industrial growth (+1.5) and businesses with a smaller scale because of the effects of lower economic growth and international trade overall expected in this scenario. However, there are opportunities for more storage (+1.5) and by virtue of more storage also opportunities of ad hoc shipping demand derived from that.

Of course, the reference port and the scenario port differ in this scenario as well. These are the most notable:

Reference port	Repair Café
Asphalt factory	No change
Container terminal	Replaced by used device bulk storage
Scrapyard	Shrunk in size
Shipyard	Shrunk in size
Retail	Halved due to less production and consumption
Waste incinerator	Replaced by a bioreactor
Metal recycling facility	Shrunk in size
Petrochemical industry	Shrunk in size
Concrete factory	Shrunk
Municipal waste site	Shrunk, more circular
New addition	Circular construction hub

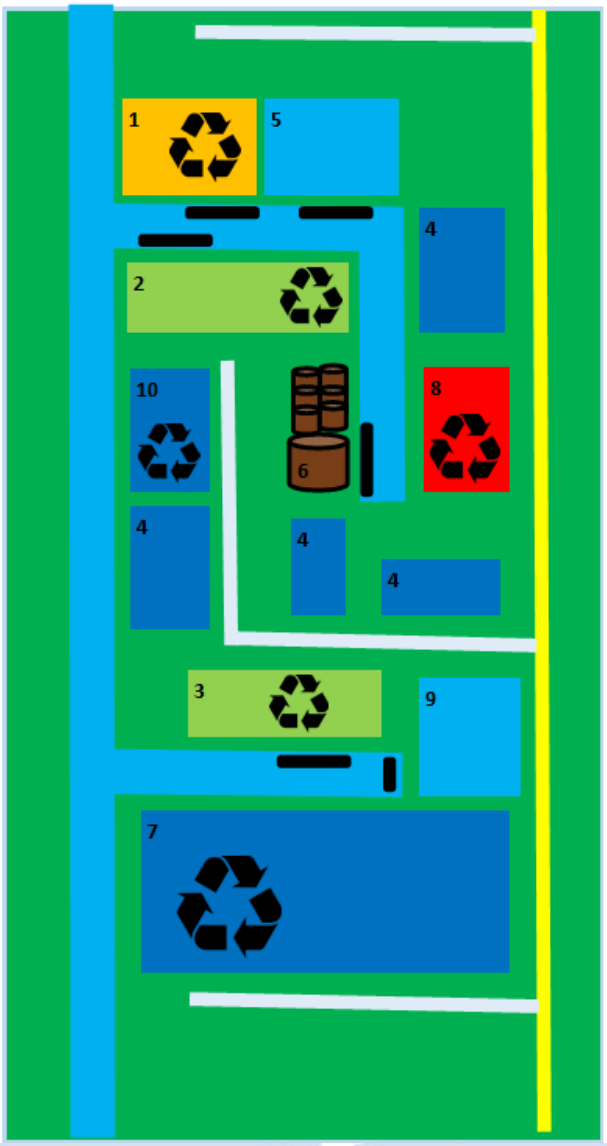


Legend

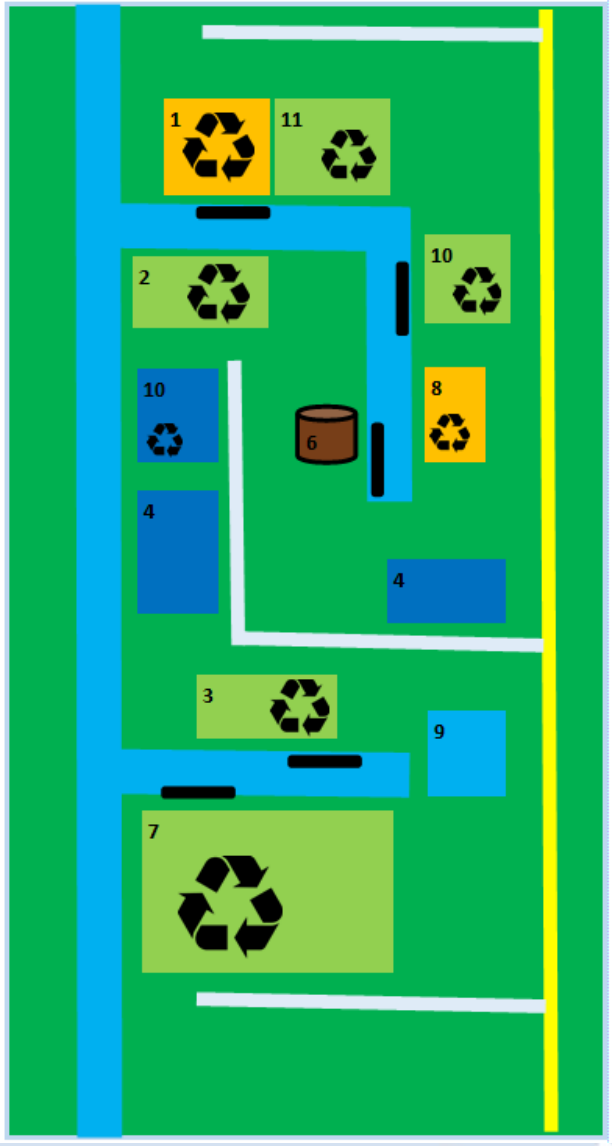
1. Asphalt factory
2. Scrapyard
3. Shipyard
4. Retail
5. Container terminal
6. (Petro-)Chemical storage
7. Municipal waste site
8. Waste incinerator
9. Concrete factory
10. Metal recycling
11. Used devide bluk storage
12. Bioreactor
13. Circular construction hub

Circular activity
Non-port activity
Non-circular port activity
Closed loop circular port activity
In between circularity port activity
Open loop circular (energy) port activity
Active quay (ship)

Reference



Repair Café



Remanufactured cycles

- ➔ Decentral CE policy development
- ➔ Policy based on improving waste quality

In this scenario, local initiatives can be used to create new items which can be recycled better and made more sustainable. One example could be something like the fairphone. This is a fairtrade phone, made from recycled materials. Local recycling, production and consumption will replace the global supply chains.

Consequences for industry

Overall, consumption and production could remain the same, but smaller in scale and more locally based. Local does not have to mean just for one or two provinces, but maybe on a more national level. Less long-distance transport and more near-sourcing means overall a healthy local industry.

Consequences for the shipping industry

Containers.

Less intensive global supply chains would require less shipping. Although it would probably not be as little as in the repair café scenario, because in this scenario there is more opportunity for alternative materials and improved recycled materials as compared to the repair café scenario. However, due to opportunities in biobased alternatives and less restrictions on production and consumption as compared to the less waste scenario, the multiplier for this scenario comes down to -0.5, meaning a decrease of 23.65% compared to the reference growth.

Solid bulk

As with containers, the decline of global supply chains would mean less potential for global solid bulk transport. Even with the possibility of recycling happening more, it would be on a more local scale. Thus, less bulk to be transported longer distance. Unless the inland shipping profitability could come at lower quantities, this would mean less interlocal shipments, thus less growth in solid bulk. Although, like with containers, still less decline than in the repair café scenario. Overall, the multiplier for the solid bulk in this scenario is estimated at -0.5, meaning a decrease of 7.45% compared to the reference.

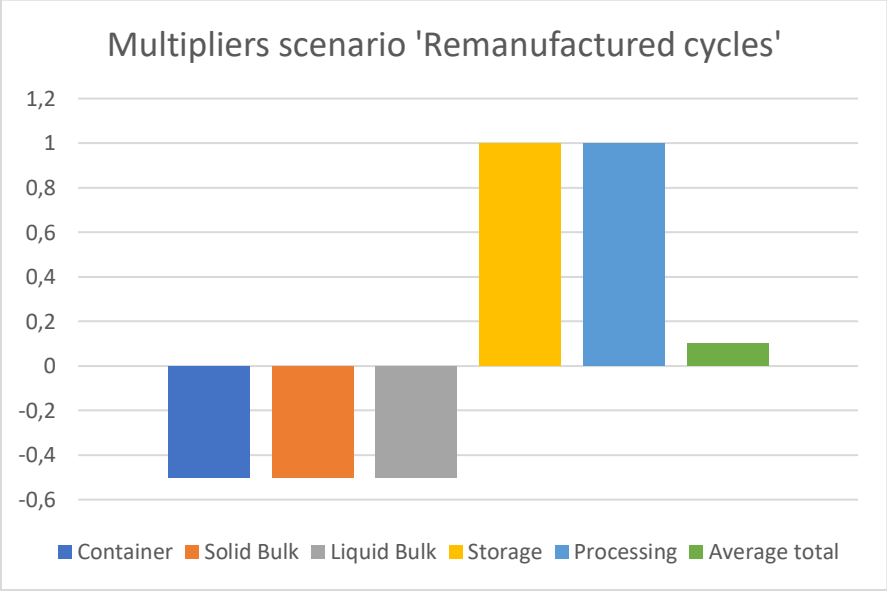
Liquid bulk

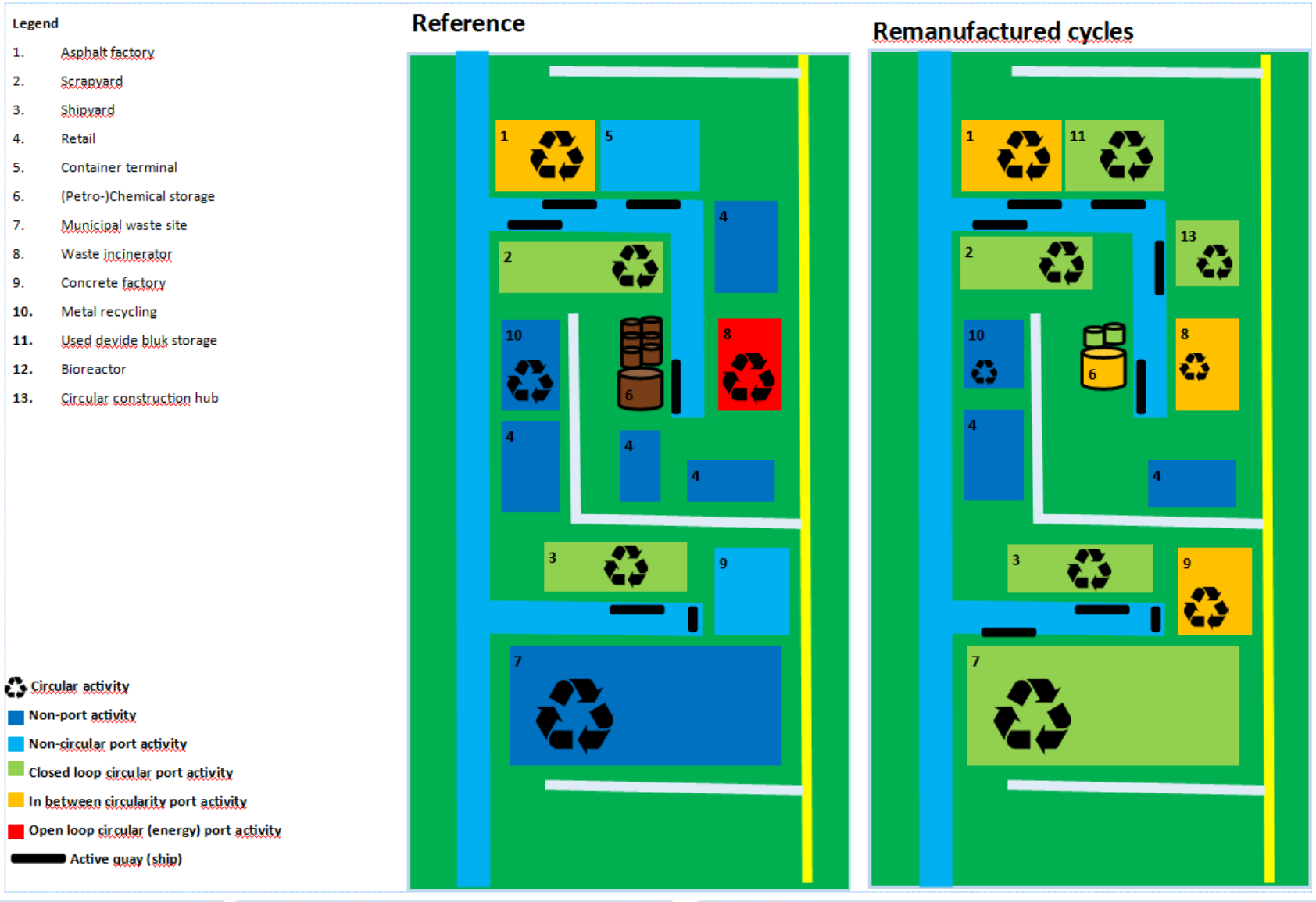
Liquid bulk follows the same as most scenarios. Less production and less dependency on fossil (fuel) resources for production likely will result in less growth in transport of liquid bulk in this scenario. In this scenario there is less opportunity for green chemicals to counteract this compared to the rethinking resources scenario. Therefore, the expected multiplier here is -0.5. This translated to a decrease of 3.25% compared to the expected reference growth.

Consequences for the port

The port will see a decline in use on relatively large scale. Therefore, it could be used by a more diverse group of businesses. Overall, the effect would be in between the less waste and repair café. The port could see a decrease in activity with local and interregional opportunity and a slight grow in biobased cargo, but less growth than it has expected currently. Indirectly the same as for the repair café scenario, opportunities arise to build storage facilities (+1) and utilise those when there is an ad hoc opportunity to ship a bulk load of a certain good in the regional storage for processing (+1) or exchange.

Reference port	Remanufactured cycles
Asphalt factory	No change
Container terminal	Replaced by used device bulk storage
Scrapyard	Shrunk in size
Shipyard	Shrunk in size
Retail	Halved due to less production and consumption
Waste incinerator	Replaced by a bioreactor
Metal recycling facility	Shrunk in size
Petrochemical industry	Shrunk in size, more circular
Concrete factory	Shrunk, more circular
Municipal waste site	Shrunk, more circular
New addition	Circular construction hub




Legend
1. Asphalt factory
2. Scrapyard
3. Shipyard
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5. Container terminal
6. (Petro-)Chemical storage
7. Municipal waste site
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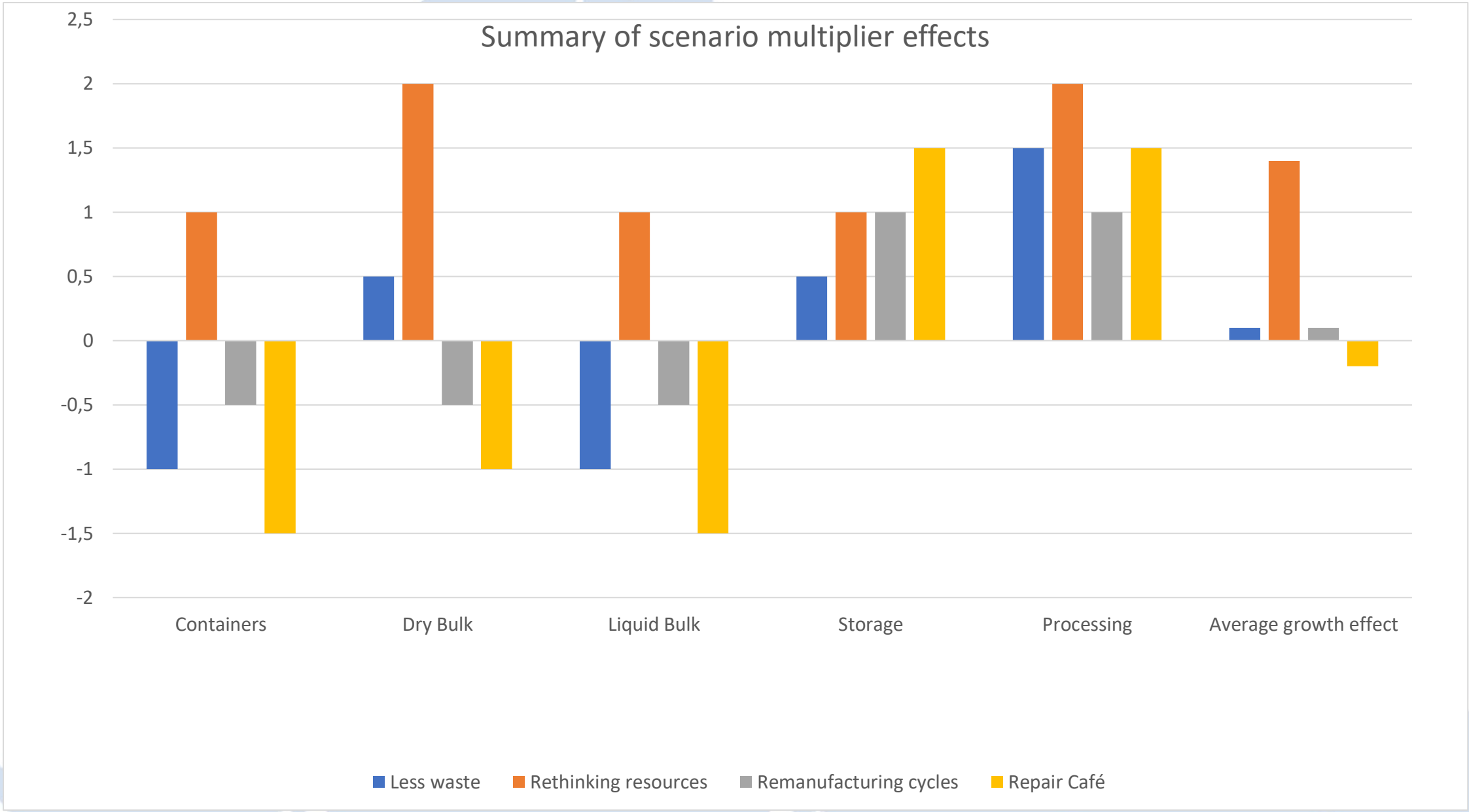
9. Concrete factory
10. Metal recycling
11. Used devide bluk storage
12. Bioreactor
13. Circular construction hub
Circular activity
Non-port activity
Non-circular port activity
Closed loop circular port activity
In between circularity port activity
Open loop circular (energy) port activity
Active quay (ship)
Reference
Remanufactured cycles

Analysis of scenario effects

Overall, the scenarios presented in this chapter have some effects that are generally about the same and some are more different. In order to discuss these patterns, the data on the example ports and the multipliers have to be put next to each other for comparison.

Reference port	Less waste port	Rethinking resources	Repair Café	Remanufactured cycles	Within 'central'	Within 'decentral'	Within 'quality'	Within 'quantity'	General development
Asphalt factory	No change	No change	No change	No change	No change	No change	No change	No change	No change
Container terminal	Replaced by used device bulk storage	Grows in size	Replaced by used device bulk storage	Replaced by used device bulk storage		Replaced by used device bulk storage		Replaced by used device bulk storage	
Scrapyard	Shrunk in size	Shrunk in size	Shrunk in size	Shrunk in size	Shrunk	Shrunk	Shrunk	Shrunk	Shrunk
Shipyard	Remained the same	Grows in size	Shrunk in size	Shrunk in size		Shrunk			
Retail	Half remained	Phased out of the port	Halved due to less production and consumption	Halved due to less production and consumption	Decrease	Decrease	Decrease	Decrease	Decrease
Waste incinerator	Replaced by a bioreactor	Replaced by a bioreactor	Replaced by a bioreactor	Replaced by a bioreactor	Bioreactor	Bioreactor	Bioreactor	Bioreactor	Bioreactor
Metal recycling facility	Shrunk in size	Grows in size, more circular	Shrunk in size	Shrunk in size		Shrunk		Shrunk	
Petrochemical industry	Shrunk in size	Grows in size, more circular	Shrunk in size	Shrunk in size, more circular		Shrunk	More circular		
Concrete factory	Remained	Grows in size, more circular	Shrunk	Shrunk, more circular		Shrunk	More circular		
Municipal waste site	Remained	Remained, more circular	Shrunk, more circular	Shrunk, more circular	Remained	Shrunk	More circular		
New addition	Circular construction hub	Circular construction hub	Circular construction hub	Circular construction hub	Circular construction hub	Circular construction hub	Circular construction hub	Circular construction hub	Circular construction hub
New addition		Biobased materials hub							


Summary of scenario multiplier effects
2,5
2
1,5
1
0,5
0
-0,5
-1
-1,5
-2
Containers
Dry Bulk
Liquid Bulk
Storage
Processing
Average growth effect
Less waste
Rethinking resources
Remanufacturing cycles
Repair Café

The spatial developments

In the table comparing the spatial developments as portrayed in the scenario ports, it becomes clear that there is some overlap within certain critical uncertainties and the effect it has on the way the port is planned in the future.

For example, within the line of centrally organised circular economy it become clear that for this outcome the effects are relatively constant. That should not be surprising, taking into account that the way the waste processing supply chains as they are currently designed can be maintained for a large part. The only relatively unique outcome for this specific part is that municipal waste sites will remain at least the same size. This is likely because for this scenario there is a relative advantage for this facility as it is an element in maintaining some economies of scale in household waste management.

Within the line of decentral organised circular economy, the unique outcomes are found in the fact that many facilities shrink in size. Many decreases are shared with the outcome of the 'quantity' scenarios. This is mainly to be linked to a decrease in (international) trade. For this side of the scenario matrix, it is mainly because of the decrease in economic activity of large-scale players and a decrease in international trade, instead preferring more local economic cycles to be accommodated. This translates well in its only truly unique outcome, namely the shrinking of the size of the shipyard. This could come from a lower international trade, leading to a decrease in the demand for transport by inland waterways. Overall, this could lead to this decrease in the size of the shipyard for this side of the scenario matrix. Furthermore, in these scenarios there is a decrease in petrochemical plants and concrete factory size. This is likely due to the same kind of phenomena as for the shipyards. For the petrochemical is would be because of limited trade, for concrete this is more likely due to the addition of the circular construction hubs, which can play a role in making construction more circular on a decentral level as well, leading to less of a demand for virgin concrete production. Furthermore, municipal waste sites shrink in this half of the scenarios, which might be caused by less economies of scale for municipal waste processors compared to as they are managed now. More waste sources might be processed by specialized local initiatives, which might use different collection methods.

Within the line of the other axis of the matrix, the scenarios on the side of quality have similar effects to the central side of the other axis of the matrix. Quality improvements lead to less of a decrease in production and opportunity for biobased production. Therefore, impact on economic activity is lower compared to the quantity side of this axis. The unique effects of this side of the matrix are the increased circular activity in the concrete factory, petrochemical site and the municipal waste site. This side of the matrix shows a future where the improvements of materials has fostered economic activity and transport in the port.

On the last side of the matrix are the scenarios on the quantity side. These scenarios have more in common with the scenarios on the decentral side. This has in this specific case less to do with international trade, but more with the relatively restrictive policy on production and consumption. It requires smaller and more local circular economy too, so this is complementary with the scenarios on the decentral side, but it is more of an attempt to stop consumerism and to keep materials within the cycle compared to the decentral scenarios. This side of the matrix does not have unique individual effects. Therefore, these cannot be described to effects of the specific line. However, compared to general developments, there is a reduction in metal recycling plant size to be identified. This could be caused by a larger focus on re-use compared to recycle in this side of the matrix in order to prevent loss of material in processing.

Lastly, general developments, these are the developments which are a sure thing in all the scenarios. Firstly, the asphalt factory remains. This is mainly because it has the function of upkeeping the infrastructure, and none of the scenarios expect the concept of roads to disappear. Secondly, the scrapyard shrinks. This can be attributed to either having less to process in the quantity or quality-based policy. Either could lead to less metal to be recycled. Furthermore, retail will find its way out of the port. This could be due to either the effect of the quantity decrease policy, less consumption or because of a lack of space, requiring the port to be more focused on being an industrial transport hub, driving retail back to other areas. Then the waste incinerators being replaced by bioreactors is an effect of more and better recycling, leading to less waste of materials in the future and more demand for organic material processing in the bioreactor plant. Lastly the circular construction hub, which is currently a developing industry in ports.

Multipliers and further referencing on economic growth

The graph on the multipliers shows the relative economic impact for each relevant shipping sector, storage and industry. However, interpretation might be difficult to analyse without putting this into analytical context and some further elaboration on what this could have as net effect compared to either the reference growth as it is referred to in the scenario context parts or compared to historical growth numbers.

For a general view, the effects for the multipliers will be used to showcase the general direction of development. This is mainly because they serve as an applicable indicator to use in individual policy expectations.

Sector	Central scenarios	Decentral scenarios	Quality scenarios	Quantity scenarios	Average for all
Containers	0	-1	0,25	-1,25	-0,5
Dry bulk	1,25	-0,75	0,75	-0,25	0,25
Liquid Bulk	0	-1	0,25	-1,25	-0,5
Storage	0,75	1,25	1	1	1
Processing	1,75	1,25	1,5	1,5	1,5
Total	0,75	-0,05	0,75	-0,05	0,35

Table 6: Average multipliers for the different parts of the scenario matrix

Some visible takeaways from this table are that, like in the effects in the spatial examples, the central scenarios and the quality scenarios show the most overlap in their effects. In the net total effects, they are equal, they differ in a nuanced way between the different sectors. Overall, the main division between these more open and more restricting scenarios as seen in the spatial example hold here as well.

Moving on to the meaning of these numbers. In the start of the scenario chapter there were arbitrary growth numbers established. However, to give some more perspective on what these are in context of the scenarios these numbers will also be compared to the average growth of the sectors as per CBS (2021) statistics. This will be the average growth in the years 2011-2019 for reference. This way it gives an oversight on what these numbers mean compared to the situation in 2021. Storage and bulk will be assumed to have the average of 10% low-expectancy growth of the PBL forecast.

Scenario	Multiplier	Reference growth index	Net growth% compared to 2050 reference	Net avg growth% per year	CBS average growth per year 2011-2019	Delta CBS and scenario	Outcome scenario
Less waste	0,1	110	1	0,033173271	0,334394144	-0,301220874	Negative
-Container	*-1*	*147,3*	*-47,3*	*-2,112548791*	*2,738486948*	*-4,851035739*	*Negative*
-Solid bulk	*0,5*	*114,9*	*7,45*	*0,239805197*	*-1,220670326*	*1,460475524*	*Positive*
-Liquid bulk	*-1*	*106,5*	*-6,5*	*-0,223778408*	*2,310369765*	*-2,534148172*	*Negative*
-Storage	*0,5*	*110*	*5*	*0,162766201*	*0,32*	*-0,157233799*	*Negative*
-Processing	*1,5*	*110*	*15*	*0,466960017*	*0,32*	*0,146960017*	*Positive*
Rethinking resources	1,4	110	14	0,437716065	0,334394144	0,103321921	Positive
-Container	*1*	*147,3*	*47,3*	*1,299373223*	*2,738486948*	*-1,439113725*	*Negative*
-Solid bulk	*2*	*114,9*	*29,8*	*0,873205787*	*-1,220670326*	*2,093876113*	*Positive*
-Liquid bulk	*1*	*106,5*	*6,5*	*0,210136475*	*2,310369765*	*-2,10023329*	*Negative*
-Storage	*1*	*110*	*10*	*0,318205803*	*0,32*	*-0,001794197*	*Neutral*
-Processing	*2*	*110*	*20*	*0,609589*	*0,32*	*0,289589*	*Positive*
Remanufactured cycled	0,1	110	1	0,033173271	0,334394144	-0,301220874	Negative
-Container	*-0,5*	*147,3*	*-23,65*	*-0,895440683*	*2,738486948*	*-3,633927632*	*Negative*
-Solid bulk	*-0,5*	*114,9*	*-7,45*	*-0,257737774*	*-1,220670326*	*0,962932552*	*Positive*
-Liquid bulk	*-0,5*	*106,5*	*-3,25*	*-0,110072223*	*2,310369765*	*-2,420441988*	*Negative*
-Storage	*1*	*110*	*10*	*0,318205803*	*0,32*	*-0,001794197*	*Neutral*
-Processing	*1*	*110*	*10*	*0,318205803*	*0,32*	*-0,001794197*	*Neutral*
Repair café	-0,2	110	-2	-0,067319688	0,334394144	-0,401713832	Negative
-Container	*-1,5*	*147,3*	*-70,95*	*-4,036766932*	*2,738486948*	*-6,775253881*	*Negative*
-Solid bulk	*-1*	*114,9*	*-14,9*	*-0,53636689*	*-1,220670326*	*0,684303436*	*Positive*
-Liquid bulk	*-1,5*	*106,5*	*-9,75*	*-0,341371295*	*2,310369765*	*-2,651741059*	*Negative*
-Storage	*1,5*	*110*	*15*	*0,466960017*	*0,32*	*0,146960017*	*Positive*
-Processing	*1,5*	*110*	*15*	*0,466960017*	*0,32*	*0,146960017*	*Positive*

Scenario	Multiplier	Reference growth index	Net growth% compared to 2050 reference	Net avg growth% per year	CBS average growth	Delta CBS and scenario	Outcome scenario
Central scenarios	0,75	110	7,5	0,241359677	0,334394144	-0,093034468	Negative
-Container	*0*	*147,3*	*0*	*0*	*2,738486948*	*-2,738486948*	*Negative*
-Solid bulk	*1,25*	*114,9*	*18,625*	*0,570947296*	*-1,220670326*	*1,791617623*	*Positive*
-Liquid bulk	*0*	*106,5*	*0*	*0*	*2,310369765*	*-2,310369765*	*Negative*
-Storage	*0,75*	*110*	*7,5*	*0,241359677*	*0,32*	*-0,078640323*	*Negative*
-Processing	*1,75*	*110*	*17,5*	*0,539007941*	*0,32*	*0,219007941*	*Positive*
Decentral scenarios	-0,05	110	-0,5	-0,016707077	0,334394144	-0,351101221	Negative
-Container	*-1*	*147,3*	*-47,3*	*-2,112548791*	*2,738486948*	*-4,851035739*	*Negative*
-Solid bulk	*-0,75*	*114,9*	*-11,175*	*-0,394227688*	*-1,220670326*	*0,826442638*	*Positive*
-Liquid bulk	*-1*	*106,5*	*-6,5*	*-0,223778408*	*2,310369765*	*-2,534148172*	*Negative*
-Storage	*1,25*	*110*	*12,5*	*0,393381842*	*0,32*	*0,073381842*	*Positive*
-Processing	*1,25*	*110*	*12,5*	*0,393381842*	*0,32*	*0,073381842*	*Positive*
Quality scenarios	0,75	110	7,5	0,241359677	0,334394144	-0,093034468	Negative
-Container	*0,25*	*147,3*	*11,825*	*0,373244707*	*2,738486948*	*-2,365242241*	*Negative*
-Solid bulk	*0,75*	*114,9*	*11,175*	*0,35374203*	*-1,220670326*	*1,574412356*	*Positive*
-Liquid bulk	*0,25*	*106,5*	*1,625*	*0,053745711*	*2,310369765*	*-2,256624054*	*Negative*
-Storage	*1*	*110*	*10*	*0,318205803*	*0,32*	*-0,001794197*	*Neutral*
-Processing	*1,5*	*110*	*15*	*0,466960017*	*0,32*	*0,146960017*	*Positive*
Quantity scenarios	-0,05	110	-0,5	-0,016707077	0,334394144	-0,351101221	Negative
-Container	*-1,25*	*147,3*	*-59,125*	*-2,93814386*	*2,738486948*	*-5,676630808*	*Negative*
-Solid bulk	*-0,25*	*114,9*	*-3,725*	*-0,126458328*	*-1,220670326*	*1,094211998*	*Positive*
-Liquid bulk	*-1,25*	*106,5*	*-8,125*	*-0,282072188*	*2,310369765*	*-2,592441953*	*Negative*
-Storage	*1*	*110*	*10*	*0,318205803*	*0,32*	*-0,001794197*	*Neutral*
-Processing	*1,5*	*110*	*15*	*0,466960017*	*0,32*	*0,146960017*	*Positive*

The main message of these tables is that the expected patterns described in the scenarios are supported by the multiplier effect. The most important thing to keep in mind about these numbers is that the reference growth expected is arbitrary. The main result is the multiplier, which in combination with the calculated reference growth is behaving as expected compared to the growth the CBS shows has taken place between 2011 and 2019 in the inland shipping sector.

The same goes for the growth expected within the different combinations of scenarios on a specified side of the scenario matrix. The less restrictive halves of the matrix have the shared first place in having the lowest impact compared to the CBS numbers. In this case that means least negative expected growth. There is no positive net half of the scenario matrix because the effect of the negative scenarios is heavier than the effect of the positive scenarios.

For good reference, the arbitrary growth numbers were dampened by averaging out the numbers of the NEA report with those of the PBL. The numbers taken from these reports were the low expected numbers as well, therefore this could give a negative view of the outcomes. In order to check if the statistics are robust some tests have been done with the numbers. These can be found in appendix E. This has been performed by changing the reference growth by multiplying it by 2, 5 and 10.

This quick and relatively simple robustness test does show that depending on the initial growth the outcome of the scenario in its whole does not change, but it is possible that it does change the outcome for the individual sectors. This means that in the end the robustness test does prove that the multiplier is a useful tool to showcase that the expected outcome of the scenarios is correct.

In short, the multiplier is applicable to the expected growth pattern used in policy making by port authorities. This multiplier then shows the average expected growth per year if used in the same manner as in this paper. Furthermore, it is also possible to calculate the differences between the expected growth for the policy maker and that of the CBS, PBL or NEA.

As much as it is positive that these numbers do confirm what is expected in the scenarios on a more qualitative level, it is important to realise that the reference year for these scenarios is still 2050. It is so far away that half a percent annual growth on top of anything could lead to vastly different results. It would still be recommended to keep track of the relevant middle to middle/long term in mind for the actual developments in the port. This paper likely has a better place in long term vision creation.

Conclusion, recommendations and discussion

Conclusion

Circular economy
- What is the size of the circular economy?
- What drives the circular economy and how will it develop until 2050?
- What are the consequences of this development for inland ports?

Inland ports
- How do inland ports function?
- What are the challenges and threats to inland ports?

External factors
- Which external forces impact inland ports?
- Which external forces impact circular economy?
- What are the critical uncertainties for inland ports related to the development of the circular economy?

Scenario's
- Which scenario's can be developed from the critical uncertainties and developments in inalnd ports and the circular economy?
- What are the consequences for inland ports?
- What advice is fitting for each scenario?

Policy advice
- Which scenario is most likely to develop?
- Which early indicators foreshadow these developments?
- What policy can inland port authorities implement in order to facilitate the coming developments?

Circular economy

The circular economy is a concept in which materials which are being used remain in use through a multitude of processes to save them. From repair to recycle, the goal is to prevent having to use virgin resources. One obstacle on the road is that it has to be cost-effective. Studies have pointed out that financial feasibility is a very important factor for success in circular economical projects. The Dutch national government wants a fully circular economy by 2050, but the question remains if that is within reach.

Developments in the circular economy are plenty. Currently megatons of materials that go to waste and are not recovered. Much of this waste is from businesses, for which the collection and processing is unregulated. Another part of this waste is household waste, this is collected and processed as per the contract the municipality has with collectors of waste.

Inland ports

Regarding inland ports, they are logistical hubs where transhipment, storage and processing takes place. For ease of analysing these ports, a few sectors can be identified to sort the activities in the port by. These are the containers, solid bulk, liquid bulk, special transport and passenger transport. Since passenger transport has no core-business circular economy activities and special shipments are relatively stable and unchanging over time, these are not relevant for analysis in this research.

The remaining sectors are the main units which are analysed in this paper. Furthermore, storage and processing are added to analyse as well, as these play a role in the development of the port and circular economy as well.

There are plenty of policy issues that an inland port in the Netherlands faces today. Spatial planning and environmental/legal issues are at the heart of the current challenges for inland ports . There is a large shortage of space for port development in the spatial planning. For the environmental and legal issues, there are laws and regulations which hinder port development directly by for example restricting the available space for port expansion further, but also indirectly by making shipping of certain goods more difficult. This leads to less flexible port development overall.

External factors

In order to answer the main question of that the effect of the developments in the circular economy will be on inland ports, it is important to know what is driving the two from the inside, but also from the outside. External factors the things that are impossible to control from the inside. That is why it is important to seek out what factors have an impact on the circular economy and the inland ports.

There are a lot of external factors, and they have been grouped in the PESTLE format: Political, economic, social, technological, legal and environmental. This gave a list of about 30 factors which can have impact.

External factors which impact both circular economy and inland ports were examined and distilled to the two critical factors in the scenario matrix. This was done by sorting the factors by uncertainty and impact. Based on those outcomes, there were two trends which were identified. Namely the central/decentral CE development and the focus on quality or quantity-based policy. Based on those critical uncertainties the scenarios were built with the year 2050 as the setting and scenario ports were built in order to showcase the effects on the ports.

Scenarios

The main question of the paper was: How will the development of the circular economy impact inland ports? With the sub-question of what policy would fit these developments? The first will be answered directly, the second in the recommendations.

Per scenario there are different effects of the directions of development of the circular economy. However, some similarities among all scenarios are that waste will be separated more and better, leading to, for example, replacements of waste incinerators by bioreactors. Furthermore, some things might not change, like asphalt factories which will remain important to maintain critical infrastructure. Other activities, like a scrapyard or general retail in the port, might see a decrease in activity due to better materials or decrease in individual use of goods and/or materials. Furthermore, new industries, for example circular construction hubs, could be a part of any port's future.

Furthermore, there are some overlaps per axis of the matrix. Analysis has shown that the central scenarios and the quality scenarios are relatively high in growth and have a more positive outcome compared to the decentral and quantity scenarios. This is mainly because in the central and quality scenarios there is more economic activity like international trade and more production and consumption opportunities. Therefore, these are seen as the relatively unlimiting scenarios, compared to decentral and quantity, which are more limiting. This discrepancy can be seen in the relative growth expectancy in almost all sectors in the scenarios.

Reference growth numbers have also been used to showcase that these scenarios make sense. Overall, multipliers estimated for the scenarios showed expected outcomes for the scenarios, even in robustness tests where the relative growth numbers have been increased.

Less waste

This scenario mean less growth of production and consumption, relatively less growth overall

In terms of policy this would mean the focus has to be on diversifying the port, as that would reduce the risk of lock-in

Rethinking resources

This scenario means high port activity growth

Policy would have to accommodate a specific sector and aim to be selective of which companies get a place near the water

Repair café

This scenario means shrinking growth of activities in the port

Innovation is needed in order to gain perspective for this port, as it is uncertain how the port will deal with loss of economies of scale and loss of consumed and produced goods at once

Remanufacturing cycles

This scenario consists of similar growth to less waste

However, this has more opportunity for new flows of goods, but still has to implement policy to keep a certain level of economies of scale as that will be lost due to the decentral policy on CE.

Policy advice/recommendations

Overall, the opportunities are vastly differing across the scenarios and port authorities will have to implement policy fitting to the developments they either see or expect to take place. Though, it is important keep in mind that even though the scenarios are meant to be showing the difference between the possible futures, in reality the outcome might end up between two or more scenarios.

Firstly, based on the general findings, such as shrinking scrapyard sizes, decreased retail activity in ports, change in waste processing facilities and the rise of new types of circular activities, it is important to play into these developments by making long term policy advices which acknowledge these changes to come. That way a port authority will be prepared to face at least these general outcomes of the scenarios.

Secondly, another important element which shows in all scenarios is the growth in storage demand and in processing plants. Circular economy should be seen as an industry and policy has to accommodate it as such. It is important to take this into account for the near future developments in circular activity in the port.

Furthermore, what a policy advisor wants to take away from this scenario planning study is relative to their position on what the future holds. In this study, there are 3 scenarios which face less growth than expected and one which does have higher growth than expected. It is important to plan ahead for these kind of scenarios, as unexpected low growth of a port might be a costly omission in the policy plans.

Lastly, if a policy maker is willing to make use of the more quantitative parts of this thesis, it is advised to tread carefully. These numbers in this paper are rather arbitrary and should only be used to give a general idea of what the scenarios might have in store. It is useful as a broad guide for long term policy, but for concrete investments it is important to keep the medium to middle-ling term developments in mind as well.

Discussion

General remarks

This research is based on general developments and not on individual ports, despite drawing from their knowledge. That means the policy directions are relatively general as well and might differ in necessity between ports. However, trying to break down the scenarios per sector of activity in the port has worked around that for as much as possible. However, for highly specific questions such as technology and or local issues such as a change in production at the local chemical plant there has to be specific research into those questions to answer them. This research is merely a step up to those papers and will likely serve as a basis for more detailed research on certain inland port cases or specific sectors.

Methods

The main method of this paper is scenario planning. This makes it possible to answer the broad question that was the research question that was presented, but it inherently means that this thesis is also a little bit less concrete compared to, for example, case studies into a specific port issue at hand. This is mainly because scenario planning is a bit of a catch-all tool to be able to write about very uncertain developments and give food for thought to policy makers who might want to learn about what is to come.

That means this thesis could make a great tool to investigate recurring themes in circular activity in inland ports and thus be good for that visionary policy making for the long term, but this is limited in terms of concreteness. First of all because it is a scientific way of narrating a possible set of futures, but secondly because it has limits on its exactness.

To continue on the limits of this method and the elements that it has brought into this paper, there is always the risk of omission of variables in this qualitative research. For example, the internal factors for circular economy. It is nearly impossible to catch all of the developments in this broad concept, mainly due to the vast amount of research into this topic. Now while many studies are linked together, whether via some large-scale players or via cross-referencing, it is impossible to get a hold of every expected development. This was also clear during the interviews, as each interviewee had different views on circular economy, the effects and its implications. This does not only show the versatility of the circular economy and the innovation that comes with it, but also this significant risk for research on circular economy as a relatively unlimited subject.

The same goes for the external factors. As much as it has been attempted to get the most relevant external factors for the subject, chances are that some might not appear on the list. Whether it has a large impact on the study is not certain, but it would be interesting if, in a distant future, these kinds of possible omissions could be prevented as much as possible by large scale data scraping on cross referenced papers on a subject.

The choice for the arbitrary expected growth

What's in a name? Arbitrarily made expected growth numbers. The main issue for this paper is that there are a just a few long-term market exploring datasets or papers which give some insights in the expected demand growth in the inland shipping sector in the Netherlands in 2050. To make some use of the literature available two studies' numbers are combined to create this arbitrary growth number for reference. This could be improved upon in other studies, as this method might be acceptable, but is not ideal.

One last note on growth expectancy, for storage and industry the expected growth has been put equal to the expected growth in the inland shipping industry. Even though picking a number is arbitrary, if possible, this could also be elaborated on further in future research, as circular industry will likely play a role in the medium-term developments for inland ports.

Generalisability

In academics, two things are important, generalisability and replicability. For the latter the mentioning of sources is important. For the first, it is less explicit how this can be guaranteed. First of all, this is likely more of a problem which plagues quantitative research, as they sometimes base their studies on datasets which might be skewed and then later corrected to increase generalisability. But such a thing is more difficult in qualitative methods, as input directly influences output. The ports and people spoken to during the making of this piece have likely steered the outcome in a way which is impossible to prevent as an author. This is why the discussion is important, and the listing of the sources an interviewees, so that future research can attempt to be different in a way that adds more to the work already done.

This paper is the start of many. Therefore, in order to achieve generalisability, it is important to have more research into this subject. A general rule of thumb which counts for all methods of research is the concept of wisdom of the crowds, or more academically metadata. The more data and studies become available the better the view on the subject becomes if one knows how to relate the articles to each other. Then, in maybe five years and after many publications, it would be interesting to 'update' this piece to see what direction developments have taken and to produce an article which more generalisable and maybe even more concrete in its conclusions.

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1: Academic source, available via Erasmus University
2: Link is a direct download, so this will immediately start a download of the file in question

Appendix A: Literature on what drives CE

Drivers	Case	Source
Legal framework, financial support, potential revenue, business development, environmental concerns, strategic concerns, skills and capabilities, global pressure, opportunity for job creation, consumer awareness, communication and collaboration, supply configuration, technological advancement, ICT development	Global, macro	Aloini, Dulmin, Mininno, Stefanini, & Zerbino, 2020
Investment costs, profitability, external financial support, win-win expectations, institutional networks, domestic market structure, commitment of private sector stakeholders, external economic environment, city targets/objectives, laws/regulations, taxes, infrastructure, technology, skills and knowledge, leadership/coordination, awareness of CE, wide appeal, media	Downside-up small size initiatives for CE in Amsterdam & Rotterdam	Russell, Gianoli & Grafakos, 2020
(Lack of) interest/knowledge, paradigm of linear economy, (lack of) collaboration between businesses, (lack of) internal collaboration in businesses, regulatory and legal framework, investment costs, virgin material prices, business case, funding, (lack of) visions, complexity of the incentives, lifecycles of products, technical challenges, standardization, design-based change, leadership, demand, engagement, relationships, systems thinking, responsibility	Building environment	Hart, Adams, Giesekam, Tingley, & Pomponi, 2019

Table 7: Assorted literature on drivers of the circular economy.

Drivers	Regulation	Barriers	Case	Source
Profitability, cost reduction and principle	Strong regulation aids CE progress	Unawareness, cost, lack of expertise or capacity.	Pakistan, automotive industry (micro)	Agyemang et al., 2019
Economic reasons and resource risk management	No significant result		Intra-industry (macro)	Gusmerotti, Testa, Corsini, Pretner, & Iraldo, 2019
Job creation, abide by law, principle	Strong effect	Negative consumer perception of re-use, technological limitations, lack of public awareness	Supply chain drivers and practices (macro, but small sample size!)	Govindan & Hasanagic, 2018
Principle, economy and policy, financial benefits	Strong effect	Policy and institutional risk, financial and economic risk, logistical/infrastructural risk and knowledge risk	Argo - macro	Mehmood, Ahmed, Viza, Bogush, & Ayyub, 2021

Table 8: More broad literature on drivers of circular economy

Appendix B: Interviewed (representatives of) organisations

Nr	On behalf of	Position	Person(s)
1	Inland ports in the province of Friesland (Frisian Ports)	Policy officer of the municipality of Smallingerland	Wim Burgers
2	Municipality of Roermond	Economic policy officer for the municipality of Roermond	Robbert Speksnijder
3	Municipality of Maasgouw	Economic policy officers for the municipality of Maasgouw	Hedzer Kooistra, Serna Widdershoven and Maarten Mertens
4	Port of Amsterdam	Director Energy & Circular	Roon van Maanen
5	Movares	Businessmanager	Bart Bouwens and Sjoerd Keetels
6	Municipality of Kampen	Economic policy officers for the municipality of Kampen	Fred Pals
7	NICE	Director	Alex van Oost
8	Port of Moerdijk	Commercial director and employee	Annette van Ketel en Jayand Baldien
9	Port of Rotterdam	Business manager	Leontien Sneider

10	Rijkswaterstaat	Policy officer	Marijn teernstra
11	Municipality of Sittard-Geleen	Policy officer	Raymond Ubachs
12	Municipality of Meierijstad	Policy officer	Rob Verpoort
13	Groningen Seaports	Business manager circular economy	Heleen van Wijk
14	Municipality of Nijmegen	Accountmanager	Jeroen Jansen
S	NVB	Audience	The general assembly of the NVB
S	NVB	Management	NVB management

Appendix C: impact scoring

Factor	Import and export	Labour supply and demand	Spatial dimmension	Municipal desicion making	Actions in the CE 3.0 model	profitability of CE	Preliminary interviews	Total
Politics	1	0	0	1	1	1	1	5
Public view on public spending	1	0	1	1	1	1	0	5
Decline of demand in western world	1	1	1	1	0	1	0	5
Demand for energy	1	0	1	1	1	1	0	5
Currency uncertainty	1	1	1	0	0	1	0	4
Trust among companies	0	0	0	1	1	1	1	4
Workforce decline	1	1	0	1	1	1	0	5
Spill overs from dem. Change	1	1	0	1	1	1	0	5
Changes in workforce	1	1	0	1	1	1	0	5
Education	1	1	0	1	1	0	0	4
NIMBY	1	0	1	1	1	1	1	6
Strive towards sustainability	1	1	1	1	1	1	1	7
More efficient production	1	1	1	0	1	1	1	6
Small data	1	1	1	1	1	1	1	7
Big data	1	1	1	0	1	1	1	6
More efficient separation	1	1	1	0	1	1	1	6
Environmental legislation	1	0	1	1	1	1	0	5
Economic legislation	1	1	1	1	1	1	0	6
Patents	0	0	0	0	1	1	0	2
Waste transport	0	1	1	1	1	1	0	5
Nitrogen disposition	1	0	1	1	1	0	0	4
Threatened species	0	0	1	1	1	0	0	3
Climate change	0	0	1	1	1	0	1	4

Appendix D: Data from [CBS statistics (2021)] for table 7

Binnenvaart; goederenvervoer, vervoerstroom, soort lading									
	Onderwerp	Vervoerd ladinggewicht	Vervoerd ladinggewicht	Vervoerd ladinggewicht	Vervoerd ladinggewicht				
	Soort lading	Totaal	Droge bulk	Natte bulk	Container	Delta totaal	Delta droge bulk	Delta natte bulk	Delta container
Vervoerstromen	Perioden	1 000 ton	1 000 ton	1 000 ton	1 000 ton				
Totaal	2010	346901	207964	99087	39848				
Totaal	2011	351783	209325	100420	42040	1,014073	1,006544	1,013453	1,055009
Totaal	2012	350069	200925	105565	43580	0,995128	0,959871	1,051235	1,036632
Totaal	2013	356062	203810	107677	44577	1,017119	1,014359	1,020007	1,022877
Totaal	2014	366627	213416	106141	47070	1,029672	1,047132	0,985735	1,055926
Totaal	2015	359897	206133	107403	46362	0,981643	0,965874	1,01189	0,984959
Totaal	2016	361365	201367	111404	48595	1,004079	0,976879	1,037252	1,048164
Totaal	2017	365697	201832	112147	51719	1,011988	1,002309	1,006669	1,064286
Totaal	2018	357281	197533	110324	49424	0,976986	0,9787	0,983745	0,955626
Totaal	2019**	357069	185379	121130	50560	0,999407	0,938471	1,097948	1,022985
Totaal	2020**	349006	178284	118819	51903				
Average						1,003344	0,987793	1,023104	1,027385

Appendix E: Robustness tests

2x

Scenario	Multiplier	Reference growth index	Ref growth double	Net growth% compared to 2050 reference	Net avg growth% per yea	CBS average growth	Delta CBS and scenario	Outcome scenario	Robust avg gr p/y%	Robust delta cbs
Less waste	0,1	110	120	1	0,033173271	0,334394144	-0,301220874	Negative	0,066346541	-0,268047603
-Container	-1	147,3	194,6	-47,3	-2,112548791	2,738486948	-4,851035739	Negative	-4,225097581	-6,96358453
-Solid bulk	0,5	114,9	129,8	7,45	0,239805197	-1,220670326	1,460475524	Positive	0,479610395	1,700280721
-Liquid bulk	-1	106,5	113	-6,5	-0,223778408	2,310369765	-2,534148172	Negative	-0,447556815	-2,75792658
-Storage	0,5	110	120	5	0,162766201	0,32	-0,157233799	Negative	0,325532402	0,005532402
-Processing	1,5	110	120	15	0,466960017	0,32	0,146960017	Positive	0,933920035	0,613920035
Rethinking resources	1,4	110	120	14	0,437716065	0,334394144	0,103321921	Positive	0,87543213	0,541037986
-Container	1	147,3	194,6	47,3	1,299373223	2,738486948	-1,439113725	Negative	2,598746447	-0,139740502
-Solid bulk	2	114,9	129,8	29,8	0,873205787	-1,220670326	2,093876113	Positive	1,746411573	2,9670819
-Liquid bulk	1	106,5	113	6,5	0,210136475	2,310369765	-2,10023329	Negative	0,42027295	-1,890096814
-Storage	1	110	120	10	0,318205803	0,32	-0,001794197	Neutral	0,636411605	0,316411605
-Processing	2	110	120	20	0,609589	0,32	0,289589	Positive	1,219178	0,899178
remanufactured cycles	0,1	110	120	1	0,033173271	0,334394144	-0,301220874	Negative	0,066346541	-0,268047603
-Container	-0,5	147,3	194,6	-23,65	-0,895440683	2,738486948	-3,633927632	Negative	-1,790881366	-4,529368315
-Solid bulk	-0,5	114,9	129,8	-7,45	-0,257737774	-1,220670326	0,962932552	Positive	-0,515475549	0,705194778
-Liquid bulk	-0,5	106,5	113	-3,25	-0,110072223	2,310369765	-2,420441988	Negative	-0,220144446	-2,530514211
-Storage	1	110	120	10	0,318205803	0,32	-0,001794197	Neutral	0,636411605	0,316411605
-Processing	1	110	120	10	0,318205803	0,32	-0,001794197	Neutral	0,636411605	0,316411605
Repair café	-0,2	110	120	-2	-0,067319688	0,334394144	-0,401713832	Negative	-0,134639376	-0,46903352
-Container	-1,5	147,3	194,6	-70,95	-4,036766932	2,738486948	-6,775253881	Negative	-8,073533864	-10,81202081
-Solid bulk	-1	114,9	129,8	-14,9	-0,53636689	-1,220670326	0,684303436	Positive	-1,07273378	0,147936547
-Liquid bulk	-1,5	106,5	113	-9,75	-0,341371295	2,310369765	-2,651741059	Negative	-0,682742589	-2,993112354
-Storage	1,5	110	120	15	0,466960017	0,32	0,146960017	Positive	0,933920035	0,613920035
-Processing	1,5	110	120	15	0,466960017	0,32	0,146960017	Positive	0,933920035	0,613920035

5x

Scenario	Multiplier	Reference growth index	Ref growth double	Net growth% compared to 2050 reference	Net avg growth% per yea	CBS average growth	Delta CBS and scenario	Outcome scenario	Robust avg gr p/y%	Robust delta cbs
Less waste	0,1	110	120	1	0,033173271	0,334394144	-0,301220874	Negative	0,165866353	-0,168527791
-Container	-1	147,3	194,6	-47,3	-2,112548791	2,738486948	-4,851035739	Negative	-10,56274395	-13,3012309
-Solid bulk	0,5	114,9	129,8	7,45	0,239805197	-1,220670326	1,460475524	Positive	1,199025987	2,419696314
-Liquid bulk	-1	106,5	113	-6,5	-0,223778408	2,310369765	-2,534148172	Negative	-1,118892038	-3,429261803
-Storage	0,5	110	120	5	0,162766201	0,32	-0,157233799	Negative	0,813831006	0,493831006
-Processing	1,5	110	120	15	0,466960017	0,32	0,146960017	Positive	2,334800087	2,014800087
Rethinking resources	1,4	110	120	14	0,437716065	0,334394144	0,103321921	Positive	2,188580326	1,854186181
-Container	1	147,3	194,6	47,3	1,299373223	2,738486948	-1,439113725	Negative	6,496866117	3,758379168
-Solid bulk	2	114,9	129,8	29,8	0,873205787	-1,220670326	2,093876113	Positive	4,366028934	5,58669926
-Liquid bulk	1	106,5	113	6,5	0,210136475	2,310369765	-2,10023329	Negative	1,050682375	-1,259687389
-Storage	1	110	120	10	0,318205803	0,32	-0,001794197	Neutral	1,591029013	1,271029013
-Processing	2	110	120	20	0,609589	0,32	0,289589	Positive	3,047945	2,727945
remanufactured cycles	0,1	110	120	1	0,033173271	0,334394144	-0,301220874	Negative	0,165866353	-0,168527791
-Container	-0,5	147,3	194,6	-23,65	-0,895440683	2,738486948	-3,633927632	Negative	-4,477203416	-7,215690364
-Solid bulk	-0,5	114,9	129,8	-7,45	-0,257737774	-1,220670326	0,962932552	Positive	-1,288688871	-0,068018545
-Liquid bulk	-0,5	106,5	113	-3,25	-0,110072223	2,310369765	-2,420441988	Negative	-0,550361115	-2,860730879
-Storage	1	110	120	10	0,318205803	0,32	-0,001794197	Neutral	1,591029013	1,271029013
-Processing	1	110	120	10	0,318205803	0,32	-0,001794197	Neutral	1,591029013	1,271029013
Repair café	-0,2	110	120	-2	-0,067319688	0,334394144	-0,401713832	Negative	-0,336598439	-0,670992583
-Container	-1,5	147,3	194,6	-70,95	-4,036766932	2,738486948	-6,775253881	Negative	-20,18383466	-22,92232161
-Solid bulk	-1	114,9	129,8	-14,9	-0,53636689	-1,220670326	0,684303436	Positive	-2,681834449	-1,461164123
-Liquid bulk	-1,5	106,5	113	-9,75	-0,341371295	2,310369765	-2,651741059	Negative	-1,706856473	-4,017226238
-Storage	1,5	110	120	15	0,466960017	0,32	0,146960017	Positive	2,334800087	2,014800087
-Processing	1,5	110	120	15	0,466960017	0,32	0,146960017	Positive	2,334800087	2,014800087

10x

Scenario	Multiplier	Reference growth index	Ref growth double	Net growth% compared to 2050 reference	Net avg growth% per yea	CBS average growth	Delta CBS and scenario	Outcome scenario	Robust avg gr p/y%	Robust delta cbs
Less waste	0,1	110	120	1	0,033173271	0,334394144	-0,301220874	Negative	0,331732706	-0,002661438
-Container	-1	147,3	194,6	-47,3	-2,112548791	2,738486948	-4,851035739	Negative	-21,12548791	-23,86397486
-Solid bulk	0,5	114,9	129,8	7,45	0,239805197	-1,220670326	1,460475524	Positive	2,398051975	3,618722301
-Liquid bulk	-1	106,5	113	-6,5	-0,223778408	2,310369765	-2,534148172	Negative	-2,237784076	-4,548153841
-Storage	0,5	110	120	5	0,162766201	0,32	-0,157233799	Negative	1,627662012	1,307662012
-Processing	1,5	110	120	15	0,466960017	0,32	0,146960017	Positive	4,669600173	4,349600173
Rethinking resources	1,4	110	120	14	0,437716065	0,334394144	0,103321921	Positive	4,377160651	4,042766507
-Container	1	147,3	194,6	47,3	1,299373223	2,738486948	-1,439113725	Negative	12,99373223	10,25524528
-Solid bulk	2	114,9	129,8	29,8	0,873205787	-1,220670326	2,093876113	Positive	8,732057867	9,952728193
-Liquid bulk	1	106,5	113	6,5	0,210136475	2,310369765	-2,10023329	Negative	2,101364751	-0,209005014
-Storage	1	110	120	10	0,318205803	0,32	-0,001794197	Neutral	3,182058026	2,862058026
-Processing	2	110	120	20	0,609589	0,32	0,289589	Positive	6,09589	5,77589
remanufactured cycles	0,1	110	120	1	0,033173271	0,334394144	-0,301220874	Negative	0,331732706	-0,002661438
-Container	-0,5	147,3	194,6	-23,65	-0,895440683	2,738486948	-3,633927632	Negative	-8,954406832	-11,69289378
-Solid bulk	-0,5	114,9	129,8	-7,45	-0,257737774	-1,220670326	0,962932552	Positive	-2,577377743	-1,356707417
-Liquid bulk	-0,5	106,5	113	-3,25	-0,110072223	2,310369765	-2,420441988	Negative	-1,10072223	-3,411091994
-Storage	1	110	120	10	0,318205803	0,32	-0,001794197	Neutral	3,182058026	2,862058026
-Processing	1	110	120	10	0,318205803	0,32	-0,001794197	Neutral	3,182058026	2,862058026
Repair café	-0,2	110	120	-2	-0,067319688	0,334394144	-0,401713832	Negative	-0,673196878	-1,007591023
-Container	-1,5	147,3	194,6	-70,95	-4,036766932	2,738486948	-6,775253881	Negative	-40,36766932	-43,10615627
-Solid bulk	-1	114,9	129,8	-14,9	-0,53636689	-1,220670326	0,684303436	Positive	-5,363668898	-4,142998572
-Liquid bulk	-1,5	106,5	113	-9,75	-0,341371295	2,310369765	-2,651741059	Negative	-3,413712947	-5,724082711
-Storage	1,5	110	120	15	0,466960017	0,32	0,146960017	Positive	4,669600173	4,349600173
-Processing	1,5	110	120	15	0,466960017	0,32	0,146960017	Positive	4,669600173	4,349600173