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An Analysis on Implications of Circular Economy Strategy of North West European Seaports

By

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Lastly, through this research study I believe that the implementing circular economy by the governments around the world to be environmentally responsible and as promising business plans for the companies to achieve sustainability would be the next phase of evolution for the people, planet and profits.

Abstract

The ports perceiving the circular economy prospects envisaged to implement it and today they aim to become circular hotspots and incorporate them as their one of the strategies. The purpose of the study is to investigate the concepts of circular economy and perceived impacts in transition of ports as circular hubs through in-depth literature study, to develop a conceptual framework and maturity levels of circular economy implications of the seaports to assess their scope of transition. After framing the maturity levels, the scope of the circular economy at seaports are assessed. Using the multi case study as the research strategy, four seaports in the north west european region are selected and their port documents are analysed with content analysis method with the framed circular levels as the coding categories. Thus, the outcome of the analysis are presented by generating the hierarchical chart of circular levels and mapping their evolution from 2004-2018 through a graph plot. By comparing the results of four seaports it was found that North Sea Ports are more mature in their circular economy transition and would be the possible first circular port in north west europe. Hence this study definitively answers which seaport is more mature as per the framed circular economy levels and assess their path of transition towards becoming a circular hotspot.

Keywords: Circular Economy, Circular Ports, Circular Levels, Maturity Levels, North-western European ports, sustainability, Circular hub

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List of Abbreviations

CA	Content Analysis
CCS	Carbon Capture and Storage
CE	Circular Economy
EC	European Commission
EFIP	The European Federation of Inland Ports
EMF	Ellen MacArthur Foundation
ERFP	European Resource Efficiency Platform
ESPO	European Sea Ports Organisation
EU	European Union
NSP	North Sea Port
NWE	North West European
POAm	Port of Amsterdam
POAn	Port of Antwerp
POR	Port of Rotterdam
SI	Sustainable Infrastructure
WEF	World Economic Forum
WM	Waste Management
RH/S	Residual heat or steam
BC/BP	Bio-clusters/ Bio-Parks
INC	Incubators
PaaS	Products as a Service

1. Introduction

1.1 Background

The Industrial Revolution of the world was categorized into four eras beginning from the 18th century and today we are living in the fourth era. The Nations around the world were evolved and dominated by the industrial economy over 400 years, which at its core is a linear economic model of take, make, dispose principle. As the result of linear economy dominancy there has been a greater contribution towards the unnatural sources of greenhouse gases which had resulted in anthropogenic climate change (Karimpour,2017), exploitation of natural resources which led to perceived risk of resource scarcity due to global demand growth as the world population is on the rise and thereby which resulted in predicting the world's future demand & supply of these resources impossible (Frodermann, 2018a) and huge quantity of waste generation around the globe with negative environmental impacts. Thus, a natural necessity was created for a shift or transition in social, political and economic patterns which led to the ideology that by transforming the present usage of the resources available thereby improving the efficiency of resources and sufficient supply being ensured which would result in protection of biodiversity and sustainable growth for the world population (Frodermann, 2018a). Hence, the concept of Circular economy (CE) resurfaced as the promising approach towards the transition which led to various reports and research by the economic organizations, governments, academic researchers on the impacts of circular transitions and presented over the years.

Industrial Revolution	*Period*		*Energy*	*Storage location*	*Production system*	*Transport Innovation*	*Evolution of the Port*	*communication*
1st	18th – 19th century		Coal	Coal & Iron ore	Mechanical Production	Rail steamship	Steel Industry	Telegraph
2nd	20th century	First Half	Oil & gas	Oil & gas	Mass production-Make to stock	Automobile trucks	Petro-Chemical industry	Telephone
3rd	20th century	Second Half	Oil & gas, nuclear	Consumer goods	Mass customisation-make to order	Jet aircrafts, Very large vessels	Container handling	Telematics-Internet
4th	21st Century		Renewable energy	Biomass, recyclables, renewables	Distributed manufacturing	Autonomous vehicles	Bio-based and circular industries	Internet of Things (IoT)

Figure 1-1: Overview of 400 years of Industrial Revolution, source: adapted from (Jansen, 2015)

The Ellen MacArthur Foundation (EMF) along with Mckinsey company published the first report in 2012, evaluating the potential benefits of CE transition in the World Economic Forum (WEF) (Wautelet, 2018) and the report identified, circular transition would create an opportunity of about the US $630 billion as annual net material cost savings for a subset of European Union (EU) manufacturing sectors (Ellen Macarthur Foundation, 2012). Mckinsey & Company in their report stated that adopting CE principles by European countries would result in the net economic benefit of € 1.8 trillion by 2030 along with environmental and societal benefits (McKinsey & Compnay, 2015). European Commission (2014), presented the study on the scope of CE transition in the priority sectors, value chains, and material flow also identified the barriers for the transition. They also cited that not only economic benefits exist but also the impacts of rising environmental and sustainability pressures of organizations can be reduced through CE (European Commission, 2014). With given the promising solutions even though CE existed since the 19th century, in recent years the governments around the world begun to explore and introduce CE goals, the global conglomerates-initiated CE in their business as a promising solution for the existing dogmas of the Linear economy.

The EMF report triggered the interests of global companies to dwell deep into the possible implications of CE, hence by evolving the organizational resource consumption, the circular economy provides a framework, which influences the companies to re-consider & re-think on the design of their products, process and business models. Thereby, this transition in their business facilitates the amalgamate economic, social and environmental responsibilities in their organization's vision (Frodermann, 2018a). On the other hand, the governments introduced policies to facilitate CE implementation. The rising concerns of exploitation of natural resources made EC to initiate the European Resource Efficiency Platform (ERFP) which aimed to provide a framework for the transition which would enable to achieve a resource-efficient and regenerative circular economy (European Commission, 2012). In 2015, the EU adopted an ambitious action plan package to promote the European country's shift towards CE as a result of achieving global competitiveness, promote sustainable economic growth and generate new employment. They provided 54 measures to close the loop for the products lifecycle[1] and cited five sectors[2] to speed up their circularity shift along their value chain and in their monitoring framework they presented ten key indicators[3] classified in four themes to monitor the CE transition of each country in the EU(European Commission, 2019).

After the 2008 economic crisis, the major cities around the world were facing challenges in the transition towards sustainable development through regenerating economic wealth which they did not achieve but, through the principle of circularity and synergy a sustainable smart city can be possible. To develop, implement and progress the circular economy transition, the potential option was identified as Port cities & Port areas (Girard,2013). The port cities are significant places in stimulating economic strength, competitiveness, human capital. Global appeal & through a synergistic approach combining port's economic, logistics & industrial activities they serve as the immaculate spot for the implementing circular economy activities (Girard,2013).

Figure 1, shows the evolution of the port as the optimal location at each phase of industrial location and in the present century, it had been evolved into an optimal incubator for the bio-based and circular economy (Jansen, 2015). In 2017, the European parliament had many discussions on the environmental aspects of the

[1] European commission (2019), Product life cycle: begins from the production and consumption to waste management and providing a market for secondary raw materials

[2] European commission (2019), five sectors: Plastics, food waste, critical raw materials, construction and demolition, biomass and bio-based materials

[3] Annex 1 presents the ten key indicators.

maritime sector and the Circular Economy (CE) initiatives taken by the major seaports like Antwerp, Rotterdam, and Hamburg and Kyllönen (2017)[4] stated,

"Port serves as matchmakers' and crossing points for all kinds of waste and industrial flows and act as logistical hubs for the import and export of waste materials, which is why they are ideal places to further develop the circular economy" and *"Ports also accommodate industries that are active in the treatment, collection and shipment of waste and stimulate the emergence of innovation circle"* (Kyllönen, 2017)

Along with European Parliament, the European port organizations European Sea Ports Organization (ESPO) & European Federation of Inland Ports (EFIP) stressed out that there is an enormous potential for the ports to make an initiative in the transition towards CE. The Ports are the cross-road for all kinds of waste, industrial flows, transport modes, houses the industrial clusters and its urban proximity identifies as the ideal place to develop the CE transition (Haezendonck and Driessche, 2019). Jansen (2015), explains the circular transition of ports can be approached through entrepreneurs who vision a potential market in the circular economy through innovating in the sectors of renewable like a waste, energy, biomass and extending products life. These kind of startups are housed by the ports through their incubators centre which in turn facilitates employments, launch new business ideas in circularity, promote innovations and add more value to their transition.

De Langen (2018), address ports as the driving force for the new economy in the horizon and state that the key element to facilitate the transition would be governance and for the ports to achieve it they must address their customers, users internal organization needs and involve stakeholders, co-operate with universities in research studies, attract startups and companies indulging in innovations at circular economy and sustainability for ports and maritime sector. Thus ports have to initiate and invest with sustainability and circularity with the hinterland, environment, economy, and society as a priority which would transform them as a prioritized ideal place for circular economy and evolve them as the circular hub in long run (De Langern, 2018).

The potential of circular economy to facilitate sustainable environment made the port cities and the port authorities to shift from the linear economy to circularity, thus larger number of ports around the world took up the concept and envisaged to become a spearhead in circular transition with a clear vision but the scope and speed of circular transition are noted to be highly uncertain (De Langern and Sornn-Friese, 2019). In the constantly evolving economic environment, the ports laid out their vision for long term developments and addressing the complexity of transitions by prioritizing their strategies where the circular economy is one of their top agenda along with smart digitalization, energy transition, and Internet of Things (IoT).

In their vision reports and strategy reports, some of the seaports envisioned to become maritime circular hotspots, but the progress is still slow-paced due to small scale initiatives, dilemmas on circular investments, major dependent on fossil fuels, no indicator to track their progress in transition. As mentioned above there are indicators to track the circularity of each country in the European region but there are no such indications or frameworks to track the progress or assess the scope of circular

[4] Merja Kyllönen is the member of parliament's transport and tourism committee

transition in ports, which are intended to become circular hotspots. If there is such an indicator or determinants to track or map their progress, they can prevent the uncertainties in the circular economy transition, project it as a competitive factor in the region and progress towards their ambitious plan of the circular hub in the future.

1.2 The Impetus for this Research Study

The port is a derived demand, due to trade and economic activity of the country. As explained earlier, government and business organisations to tackle the environment and resource exploitation approach circular economy as a promising solution. The port which is a vertically integrated with the supply chain has to evolve as circular hub to be competitive in their region. Thus, circular economy transition of the port is inevitable but as the problem identified above, there is no such frameworks or indicators to address the transition of a port in circular economy is the backdrop for this research study. Also, the research paper on *"Developing a circular innovation framework for ports"* presented at IAME 2019 conference by Haezendonck & Van den Driessche (2019), laid the inspiration and foundation of this research study.

1.3 Research Question and Objectives

Guided by the above introduction and background on the circular transition of the seaports, the main research question that needed to be answered in this research study is, ***Which North western seaport will be the first mover to evolve as a complete circular hotspot through a paradigm shift from a linear economy to the circular economy?***

In order to answer the main research question, the following sub research questions were framed:

What is the meaning and potential impact of the circular economy (CE) for ports?

What are the environmental policy measures to support the circular transition of seaports?

What are the current sustainability and circular projects implemented in selected seaports, part of their strategic change and what are their perceived impacts?

What are the barriers to the seaports in their transition from linear to circularity?

The objective of the study is to predict which seaport in the north western european region will be the first circular port. This objective is approached in three steps, firstly developing a conceptual framework of the circular economy implications on the seaports, secondly forming the levels of circular transition or maturity to determine the progress of seaports towards the circular shift. The above two steps are achieved through an in-depth literature review on circular economy and their impacts on ports. The last step is to apply the derived level of circular transition or maturity to the selected seaports in north west europe through a qualitative analysis to determine the respective circular transition of each, thus the results of the analysis will answer the main research question of the dissertation.

1.4 Relevance of this Study

This research aims towards developing the framework of the CE implementations on ports which will be the core concept in defining the maturity level of the CE projects at the ports. These maturity levels will identify the evolution of seaports in handling more complex issues. The circular economy being a strategic decision mentioned in all port vision documents, annual reports, etc, this maturity level will be able to identify the circular evolution of the seaports and their ability to deal with complexity which in-turn makes them more competitive in the port business.

This framework defining the maturity levels will be of interests of the focal stakeholders of the port comprising the Government, port users like shipping lines, port service providers like terminal operators, local community and civil societies of the city and non-exhaustive stakeholders such as shareholders of the port, investors, banks, shippers, press & media, NGO and academic institutions. Also, companies focusing on circularity will also be interested in this research.

1.5 Thesis Structure

The research study is structured in six chapters as shown in figure 1-2.

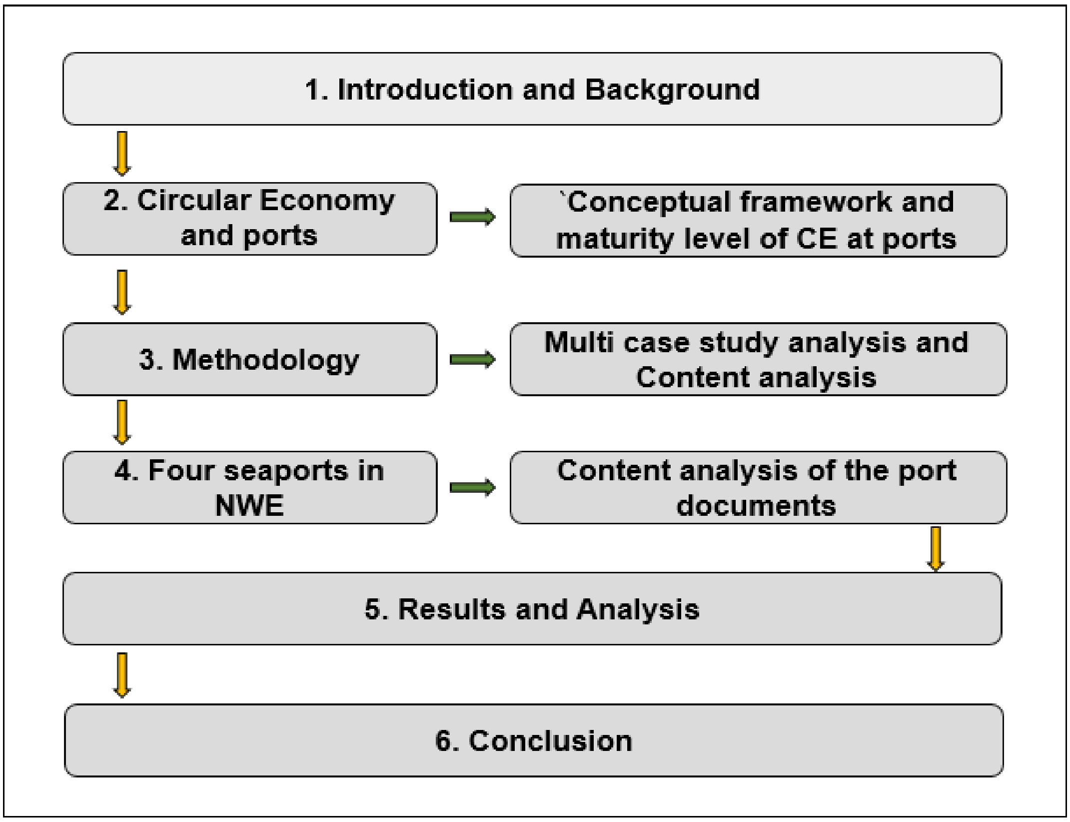

Figure 1-2: Structure of this research study

Chapter 1 Introduces the background of the research focus with impetus for the research study on the circular economy implications over north western European seaports and after which the foundation for the main research question and sub-research questions are drawn and presented.

Chapter 2 presents the theoretical background for this study through an in-depth literature study consisting two parts. Firstly, explaining the concept of the circular economy with its evolution over the years to its current world perspective. Followed by studying the concepts of innovation, business models and sustainability in context of circular economy. In the second part, the available literatures are studied and reviewed up on the impacts of circularity over the ports emerging from the rationality to develop circular economy in ports to the latest circular implications, innovations in ports and discussing their drivers, opportunities and barriers for the transition. Finally, it is concluded with a matrix containing the circular implications found in the literatures. After explaining the theories as mentioned above in two parts, it serves as the core foundation for developing the conceptual framework on the circular implications on seaports and framing the circular maturity level of the seaports, which projects the main contribution of this dissertation.

Chapter 3 will explain the research design of the study with multi case study as the research strategy applied to answer the research question. It begins from explaining the reasons of multi-case study approach and to content analysis being the preferred method for analysing the data. The available type of data for the analysis and a step by step process for the content analysis will be detailed out after studying relevant literatures of content analysis. This chapter is concluded with the limitations of content analysis

Chapter 4 presents the circular projects implicated on the selected seaports. Reasons for selecting the four seaports are discussed in the beginning of the chapter followed by the brief overview of the current circular economy projects at four seaports. Then with the steps defined in previous chapter the content analysis is performed on the por documents and the outcome is tabulated for each seaport with a conclusion.

Chapter 5 is the results and analysis of the outcome in the previous chapter. It present the results of the content analysis performed for each seaport through a matrix consisting the coded nodes representing the circular levels which are arranged in a hierarchy. With this hierarchy chart the circular economy of each port is analysed and their transition is mapped through a graph plot. Finally, all results are compiled and presented in a graph which answers the research question which concludes the chapter.

Chapter 6. will provide the conclusion of this study where the key findings based on the analysis, maturity level and framework will be summarised and how they able to answer the main research question. Limitations of this study and suggestions for further research on the concept of CE implication on ports that have not been explored will be outlined, which could add value to this research.

2. Circular Economy and Ports

2.1 Introduction

After introducing the background of the research study on CE implications on seaports and identifying the research and sub-research question in the previous chapter, next step is to review the literature of the domain of interest (Bhattacherjee, 2012) which establish the theoretical background for this research study. Battacherjee (2012), explains the key purpose of conducting the literature review for three reasons: firstly, to study and observe the present state of knowledge in the area of interest. Secondly, to recognize the key authors, articles, theories, and findings in the area of interest and lastly, to identify the gaps in knowledge in that area of interest. This chapter presents the in-depth reviews on the works of literature on CE and its implications on the ports for the purpose of three key purposes mentioned above. To obtain the literatures the databases of Scopus, Science Direct and Web of science were accessed with the keywords mentioned in table 2-1, which summarise the articles found in 1999-2019/20. Even though the results show of articles above 200 in circular economy and ports, the most relevant articles were found to be very less in this domain while the available literature of circular economy and sustainability are found to be high which is the more researched area.

		Keywords					
		Circular economy	*Circular economy Concepts*	*Circular economy & Sustainability*	*Circular seaports*	*Circular economy & seaports*	*Sustainable seaport & circular economy*
Database	*Scopus*	4891	896	1058	4	1	1
	Science Direct	21,900	11,803	12,243	262	221	141
	Web of Science	3969	735	920	5	4	2

Table 2-1: Database search of literature with keywords

Finally, based on the reviewed articles, the author develops a framework that forms the core of this research study from which the maturity levels of CE at seaports are developed, thereby which the author aims to answer the research question.

2.2 What is a Circular Economy? – Origin, Concepts, and Principle

The concept of Circular Economy (CE) had evolved with a wider range of schools of thought rather than one definition, over the years. Hence the notion of CE described would be difficult to trace back to a single author (Wautelet, 2018). It had been considered that the environmental economists Pearce, D.W and Turner, R.K in the year 1989 predominantly initiated the concepts of circular economy which was based on previous studies by ecological economist Kenneth Boulding in 1996 (Andersen, 2007; Greyson, 2007; Su *et al.*, 2013; Heshmati, 2015; Murray, Skene and Haynes, 2015; Ghisellini, Cialani and Ulgiati, 2016; Wautelet, 2018). Since the concept of CE had been existing from the 1960s, to date many significant theories developed with CE. Ghisellini et al (2016) and Murray et al (2017) conducted a substantial review of the available literature on CE with a time frame of past two decades and concluded the outcome as the CE origins are predominantly embedded in the three subject areas: Environmental Economics, Ecological Economics and Industrial Ecology (Murray, Skene and Haynes, 2015; Ghisellini, Cialani and Ulgiati, 2016; Wautelet, 2018). From the above literature review, it can be perceived that the origin of the CE concept is under debate.

Murray et al (2017)., identifies the dual meaning of CE in terms of linguistically and descriptively. In the context of linguistic, it means the antonym of Linear Economy and in descriptive terms, it relates to the concept of two cycles: biogeochemical and recycling of products. In their paper, they also recognised that although a wide range of meanings and concepts been linked to CE by the authors, they all have a common standard concept of the cyclical closed-loop system (Murray, Skene and Haynes, 2015). Presently, Ellen Macarthur Foundation (EMF) had considered being a significant contributor towards further development and improvement of the CE concept by fostering modern theories as to the school of thought: Performance economy, cradle to cradle, biomimicry and blue economy (Ghisellini, Cialani and Ulgiati, 2016; Wautelet, 2018). Ghisellini et al (2016) and Su et al (2013) mention the principles of CE as Reduction, Reuse and Recycle which had been termed as 3R in their studies. Charonis (2012), define the CE as a system which is designed in principle to restorative and regenerative, also contemplates CE as an “alternative growth discourse” and not an “alternative to growth discourse” (Charonis, 2012; Ghisellini, Cialani and Ulgiati, 2016).

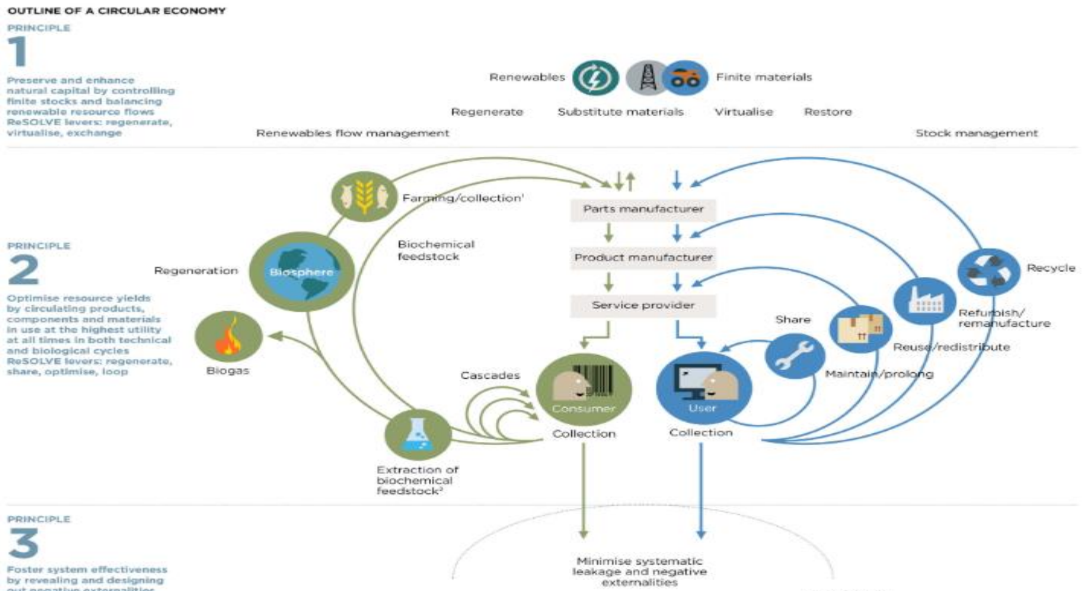

Figure 2-1: Circular Economy System Diagram, Source:(Ellen Macarthur Foundation, 2019b)

Today, Ellen Macarthur Foundation (EMF) had been recognised as the thought engine in the circular economy. The organization was founded and launched in 2010 to escalate the concept of a circular economy and to promote the transition towards it from the linear economy. They were the first organization to present the reports on the benefits of CE and released various other reports researching the potential and impacts of circular transition for governments and companies around the world. To facilitate and innovate CE they launched a platform CE 100 which cluster the various organizations, corporations, innovators to exchange ideas and discuss business cases all around the world, hence the definition provided by EMF had been cited as most relevant to understand the concepts of CE (Frodermann, 2018a).

Thus, EMF (2019), states that *"Circular economy entails gradually developing economic activity from the consumption finite resources and designing waste out of the system and underpinned by a transition to renewable energy sources, the circular model builds economic, natural and social capital"* (Ellen Macarthur Foundation, 2019c). Figure 2-1 is the infographic of circular economy system diagram presented by EMF which shows the three principles of circularity: design out waste from the system and pollution, keep the products and materials in use and regenerate natural system, thus the concept of circular economy is that it is a framework for an economy that is restorative and regenerative by design (Ellen Macarthur Foundation, 2019a). In her exploratory study on circular economy Frodermann (2018), explains that the above definition and infographic of CE based upon the following attributes which are summarised in table 2-2.

The 5 attributes of a circular economy	What does it mean?
Design the waste out of the system	In the above figure, the CE system consists of two cycles: technical & biological cycle (value circles) and products are differentiated as consumables and durables. In the tech-cycle the durable materials are recycled without losing its grade and in the bio-cycle, the consumables are biodegradable and can be utilized as an input or raw material for other resources
Build resilience through diversity	The external shocks impacting the system are prevented by building resilience through diversity
Use the renewables as an energy source	The production should use renewable energy as the source of input
Think in systems	Map the whole process in a systematic view since the association and relationship between the elements are crucial
Think in cascades	The complete biological circle is considered when a biological raw material is being utilized hence an additional value is generated using the waste, which is normally discarded
Use material, not consume it	The ownership of products is retained by the manufacturers & retailers instead of selling the product they provide service through their products to their customers

Table 2-2: The overview of circular economy attributes, source: adapted from (Frodermann, 2018a)

The circular system summarised as, circularity is implemented when the products of the biological or technical circle are manufactured and the former products containing biodegradable nature can be recycled and reused, the latter products are the materials that can sustain in a material loop continuously without losing their grade or nature. Frodermann (2018), perform an extensive literature review on the impacts of the circular economy when it's executed or adopted in an organization or business entities and categorize them as academic and non-academic research studies. She concludes stating that only five academic research studies were available, and the impacts are listed out below in table 2-3.

Author	Methodology	Circularity impacts
(Sinkin, Wright and Burnett, 2008)	Empirical analysis	The overall cost is reduced by achieving low waste inefficiency and pollution of the products thereby resulting in increased profits and firm value
(Park, Sarkis and Wu, 2010)	Empirical analysis	For an organization, the cost is reduced when more recycled materials are used and when the materials present in the loop over a longer period, For the industries, cost reduction is achieved by clustering the procedure of recycling, The company revenue is generated when the used products are resold in the market which gives them positive image and credibility in the business sector
(Geng *et al.*, 2012)	Conceptual study	The companies achieve more coherent use of materials and energy in their system which leads to cost savings, low environmental retribution, revenue generation when the waste is sold from the system and finally they increase their competitive advantage in their business sector.
(Preston, 2012)	Literature review & conceptual study	When CE implemented, the combined consumption of the products leads to the development of a direct relationship between consumer and manufacturer or retailer

(Su *et al.*, 2013)	Literature review	The Chinese companies in the study enhance their competitiveness through a circular economy

Table 2-3: Impacts of Circular economy for organizations, source: adapted from (Frodermann, 2018a)

The above table projects the advantages of circular economy implications over the companies or organizations.

2.3 World Perspective of Circular economy- the 'R' principle

Over the years, circular economy had been attributed into various concepts which paved the way for Performance economy, cradle to cradle, biomimicry, blue economy, sharing economy, resource recovery, waste recycling and separation, eco-industrial parks, industrial symbiosis and regenerative design (Ellen Macarthur Foundation, 2013; Lacy and Rutqvist, 2015; Ghisellini, Cialani and Ulgiati, 2016; Vermeulen, Reike and Witjes, 2018; Wautelet, 2018). However, for the countries to implement the CE, its traditional concept of waste hierarchy '3Rs' (Reduce, Reuse and Recycle) had been the driver for national waste regulations around the world (Antikainen, Lazarevic and Seppälä, 2018; Vermeulen, Reike and Witjes, 2018).

The west european countries such as The Netherlands and Germany framed their waste management policy based on the principle of 3Rs in 1978 and 1986 respectively (Buclet and Godard, 2000; Antikainen, Lazarevic and Seppälä, 2018), however in 1996, Germany spearheaded the implementation of CE by ratifying the law on "closed substance cycle and waste management act" (Heshmati, 2015). In Asia, Japan attempted to implement CE in 1991 by developing a framework for their country's transition into a society focusing on recycling and in 2002, the basic law for creating a recycling based society came into force (Heshmati, 2015; Ghisellini, Cialani and Ulgiati, 2016).

China ascertained that their economic expansion and rapid industrialisation would lead to environment deterioration , thus to address this negative impact in 1999, State Environmental Protection Administration (SEPA) involved significantly to implement circular economy on a large-scale basis (Heshmati, 2015; Frodermann, 2018b). Initially SEPA promoted CE by developing, publishing frameworks, supporting projects on waste recycling but those were not successful due to the insufficient technologies and improper cost management. This led china to perceive that CE is much more than just recycling activities and begin to approach CE in context of restructuring organisation of the industries, developing innovative technologies and refine industrial policies due to which in 2002, the country announced officially that circular economy adopted as an integral part of their development strategy which will boost china's economic expansion at the same time preventing the over utilisation of their natural resources (Frodermann, 2018b).

Ghisellini et al (2016), mention other countries such as Korea, Vietnam and USA adopted their waste management policies based on the 3R's, Australia and New Zealand in the process of evaluating and implementing the CE in their country. Heshmati (2015) and Antikainen et al (2018) exclusively present the circular economy strategies by the european commission and other european countries which is represented in table 2-4.

Organisation/Country	Year	Initiatives
European Commission	2012	*European Resource Efficiency Platform (EREP)- Manifesto and policy recommendations*
European Commission	2014	*Towards a circular economy: a zero-waste programme for europe*
European Commission	2015	*Closing the loop- an EU action plan for the circular economy*
The Netherlands	2016	*A circular economy in the Netherlands by 2050*
Scotland	2016	*Making things last: A Circular economy strategy for Scotland*
Finland	2016	*Leading the cycle – Finnish road map to a circular economy 2016-2025*

Table 2-4: Circular economy strategies in Europe. Source adopted from (Heshmati, 2015; Antikainen, Lazarevic and Seppälä, 2018)

Ghisellini et al (2016), differentiate the implementation of above circular economy initiatives by the countries as top down and bottom up approach China is the only country promoting the circular economy as a top-down national political aim and european countries, USA, Korea, japan and Vietnam adopts a bottom up perspective to implement circularity.

As mentioned above generally the circular economy had been identified to the concept of 3R's principle, however the concept of circular economy had evolved over a period of time from conceptualizing as waste recycling to value retention. (Reike, Vermeulen and Witjes, 2018) Reike et al (2018), explicitly investigate the evolution of circular economy and present number of dimensions for R-Imperatives in context of value retention options available in circular economy.

Based on the timeline of circular economy from existence to its respective conceptualisation in those time line they explain that CE had evolved in three phases, which is shown in figure 2-2. From 1970 to 1990 the concept was about 3R's principle which initiated the governments around the world to implement waste management system based on circular economy and represent as CE 1.0, which is discussed earlier in this section. The second phase is from 1990-2010, the concept had evolved as CE 2.0 in the context of economic expansion without negative environmental impact, a win-win scenario and the last phase is CE 3.0 from 2010, where the circularity principle is considered to be the optimal solution for maximising the value retention in the resource scarcity era due to over exploitation (Reike, Vermeulen and Witjes, 2018).

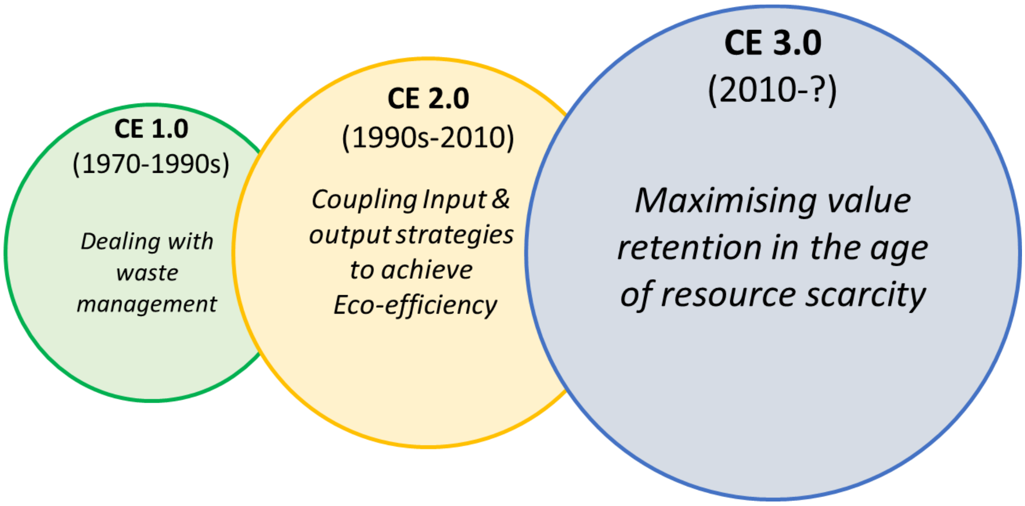

Figure 2-2: Evolution of Circular economy, source adopted from (Reike, Vermeulen and Witjes, 2018)

Vermeulen et al (2018) cite the existence of confusion around the concept of waste hierarchy and the meaning of R's-imperative in value retention, which they also found in the EU and UN policy documents. To overcome this conceptual uncertainty, they performed an exclusive literature study to find the origins of R-imperatives and came up with 38 different re-words (refer annex 2). With these findings they synthesized and presented a final 10R's hierarchy of circular economy value retention options for the consumers and business. Then they map these hierarchy as per the product lifecycle: 'produce and use' and 'concept and design' and group the 10R's into three loops, represented below in table 2-5.

Loops	R- Hierarchy	Value retention option
Short	R0	Refuse
	R1	Reduce
	R2	Resell/ Re-use
	R3	Repair
Medium Long	R4	Refurbish
	R5	Remanufacture
	R6	Repurpose
Long	R7	Recycle Materials
	R8	Recover (energy)
	R9	Re-mine

Table 2-5: R hierarchy and its value retention options, source: (Vermeulen, Reike and Witjes, 2018)

R0-R3, represents the first four short loops in the mapping process where they are associated with the customer, commercial and non-commercial actors who play a role in extending the lifespan of the product. The medium long loop R4-R6 form the business activities and 3rd party such as stakeholders associated with it and finally the long loop R7-R9 represent the waste management, process of recovering energy and re-mining activities (Reike, Vermeulen and Witjes, 2018). The above process of synthesizing and classifying the R-imperatives of circular economy present a clear view of the conceptualisation of circular economy which can be used by the policy makers, business entities, organisations for implementing the circular economy.

2.4 Innovation and Circular business models

The world economy drives on the linearity principle and with the new evolved concepts of the circular economy, the transition phase had been initiated. Companies, governments around the world research on the potential of circularity because the key element for this transition would be Innovation. Sledzik (2013), refers to Joseph Alois Schumpeter as one of the greatest economists of the 20th century for his exclusive contribution towards the concepts of Innovation and entrepreneurship in the economic growth of a nation. As explained by Schumpeter, Innovation is a procedure of industrial mutation, that perpetually revolutionizes the economic structure from inside, results in unremittingly devastating the former one and ceaselessly creating another one (Śledzik, 2013). Schumpeter (1983), classify the innovation into five types which are interpreted in the table 2-6

Type of Innovation	Interpretation
Product Innovation	The evolution of a new product or a new variant of existing product
Process Innovation	Changing the existing procedure of production and developing new methods in the production process
Organization Innovation	Modifying the business model and performance of the company or firm
Market Innovation	Venturing into different markets by developing and introducing new products to the customers
Input Innovation	Exploring and acquiring new alternative sources of raw materials for the production process

Table 2-6: Types of Innovation and their interpretation, source adapted from (Schumpeter, 1983; Śledzik, 2013; Frodermann, 2018)

Frodermann (2018), assess the above types in innovation in terms of circular economy and explains that for a firm to adopt a circular economy the circular framework should be designed in three steps. Firstly, since the CE influence the companies to recycle, reproduce and reuse their products and by doing so an inter-organizational change is required, hence the product, process and organization are the key innovations to implement the circular framework. Secondly, as the definition of CE stated above by EMF the production process required new renewables as energy sources hence the input innovation is included in the framework and lastly, market innovation is included to venture into new markets by introducing circular products. This framework varies depending upon the nature of business and the above types of innovations play a significant role in implementing the circular economy in a business ecosystem.

The business models of the firms play a significant role in the implementation of the circularity framework for the transition towards a circular economy. Thus, for a firm to be successful in a circular economy their circular business models must be designed consciously in the context of their organizational potentiality and assets, functional capability in the evolution of technology and exploring the opportunities in their existing market sector (Tonelli and Cristoni, 2018). Lacy and Rutqvist (2015) identify five circular business models: circular supply chain, recovery and recycling, product life extension, sharing platform and product as a service, which are presented in figure 2-3.

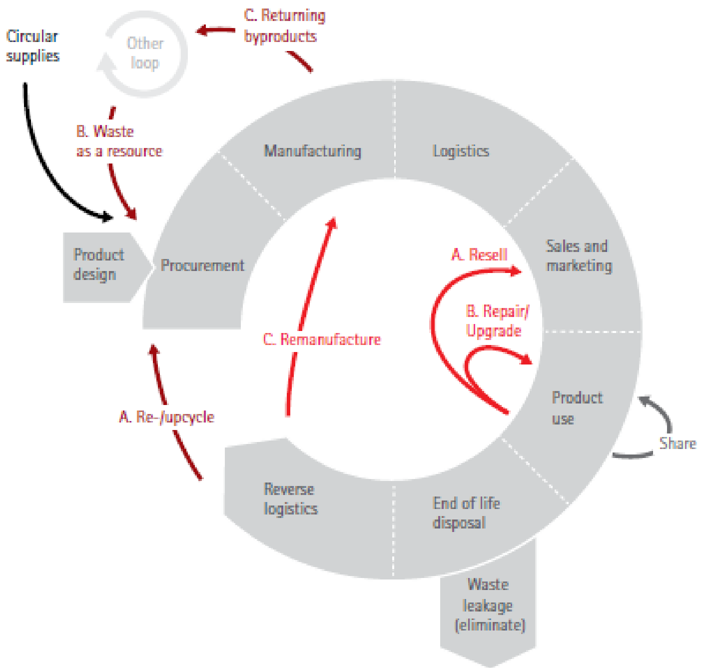

Figure 2-3: The five circular business models, source: (Lacy et al., 2014)

Circular Business model	Overview
Circular Supply chain	This business model completely based on renewables, recyclables or bio-degradable as the key sources substituting fossil fuels. The renewable energy is considered as vital resource input for the circular materials value chain. Thus, the objective of this business model is to completely replace the linear resource model thereby reducing the usage of scarcity resources, resulting in eliminating the waste.
Recovery and recycling	Every product or material has a life cycle and this business model is based upon the product's lifecycle. These products at the end of their lifecycle are supplied into bio or technical cycle based upon the nature of the product (fig 2-1) to be recycled and to recover the resource from the waste. Companies around the world generate a huge quantity of waste and also they have to spend to dispose of those wastes, through this business model the waste is converted into value through recycling and upcycling.

	This business model is achieved by using new technologies, through forming a synergy between the companies, sharing the services, by-products, merging the closed-loop and opting cradle to cradle (C2C) designs. Hence the concept of waste is being eliminated and it is converted into valuable raw material.
Product life extension	This business model aims to extend the product's timeline through building them to last, refurbishing periodically, take-back/ trade-in/ buy-back to remarket, provide up-gradation, refilling and repair it. Hence the manufacturers need to design the products in such a way that its life can be extended by the above methods. Thus, in this business model, the revenue is generated for the business by providing products with longer life rather than manufacturing products in huge volumes and stacking them up.
Sharing platform	This circular business model provides a platform to promote or facilitate the renting, swapping, lending, sharing, gifting or bartering of the resources to connect the product owners with the individuals or firms, due to which collaboration is formed between them. This sharing platform allows multiple users to use similar resources or products thereby reducing the demand for it. The main objective of this business model is to increase the utilization of the product through sharing which would result in reducing the underutilization
Products as a service (PaaS)	In the PaaS business model, the manufacturer or retailer of the product retains the ownership and sells the service by providing the products by pay for use, leasing, renting or performance agreement system. In the PaaS model, the manufacturers provide the physical products or services to prolong their utilization which is achieved through design, maintenance, re-use, remanufacturing and recycling.

Table 2-7: Overview of five circular business model, source: adapted from (Lacy and Rutqvist, 2015)

The above discussed five business circular business models facilitate the transition towards a circular economy in an organization. With these business models, companies can recognize consumer behaviours in a resource-constrained environment, thereby gaining a competitive advantage. Choosing the correct business model and strategy to execute them is the key to the transition into a circular economy (Lacy and Rutqvist, 2015).

The above sections from 2.2 to 2.4 present the first part of the theoretical background which explains the principles and concepts of circular economy. the second part on the impacts of circular economy on the ports are explained below.

2.5 Impacts of Circular Economy on Ports

This section of the chapter presents the review of the literature available in the domain of Circular Economy (CE) and Ports, which will lay the background for developing the framework and defining the maturity levels of Ports in CE implications. The available works of literature were searched using the keywords: *"CE and Seaports", "Circular Seaports", "Ports and CE"* in the databases of Scopus, Science Direct and Web of Science with a time frame of 20 years (1999-2019/2020). The results of the search strings are presented in figure 2-4.

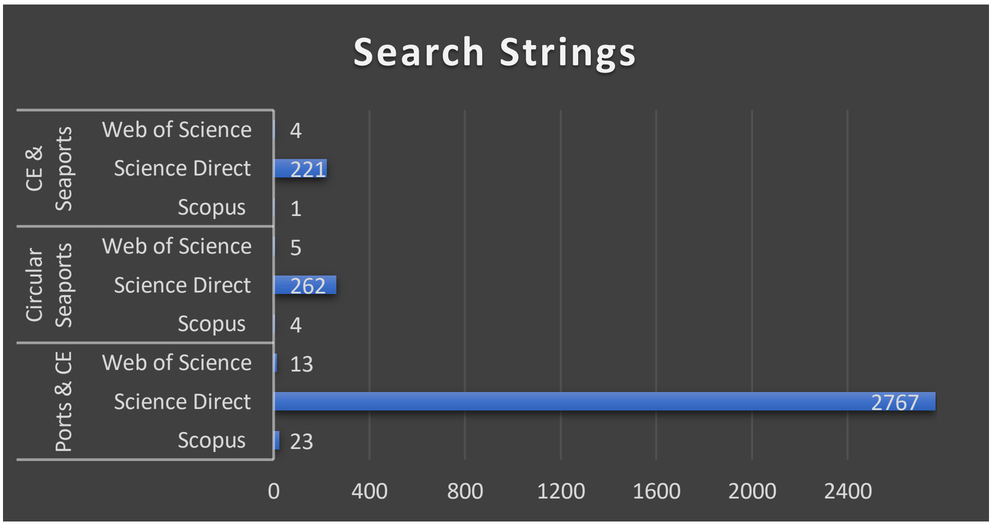

Figure 2-4: Search Strings- Number of literature available in the search database from 1999- 2019/2020

It can be observed from the above figure, that there are very few numbers of academic literatures available in the domain of Ports and Circular economy. It can be noted that Science direct listed out, 221 to 2767 literatures with different keywords but however, very few were relevant literatures related to this study.

2.5.1 CE implications on the ports

De Langen & Sornn-Friese (2019), had written an exclusive chapter on Ports and Circular Economy (CE) in which they had explored the effects of CE transition on the ports by analysing the volume of commodities handled in US ports and opportunities for logistics and industrial sectors through the case studies of Dutch ports in transition. This article is one of the key literatures for this research to develop the framework and maturity levels of circularity which will be presented in the next section. They also identify that although the path of transition being explicit, the scope and pace of the

CE transition on ports is highly uncertain (De Langern and Sornn-Friese, 2019). In their study, first they study the transition of US ports by analysing their port cargo volumes and they came up with four key outcomes: handling of immense non-renewable cargo volume, imports and exports of non-fossil cargoes being linear, key ingredient of bioenergy being exported more (agricultural commodities) and difficulty in assessing the statistics of recyclable in total export and import of US (De Langern and Sornn-Friese, 2019). Their second part of the study is the case study analysis on 5 Dutch seaports- Port of Amsterdam, Rotterdam, Zeeland, Groningen, Moerdijk to examine the opportunities created in transition. Table 2-8 summarises the key circular activities of ports from the literature.

Seaports	***Path of transition***
Zeeland	Exchange of heat energy & utilities through clustering, Bio-park Terneuzen, attracting bio-based & CE investments-offshore wind parks, matching supply & demand products through software platforms
Amsterdam	Sustainable energy, municipal waste recycling, Green Mills-manufacturing bio-gas, electricity, fertilizer & steam, investments on bio glycerine, Prodock-incubator for startups & pilot plans, clean capital- venture to develop CE activities, production of aromatics, fatty acids, phosphate from wastes, attracting and providing land for bio-based & Circular activities
Rotterdam	Bio-diesel plant, manufacturing methanol, biorefinery for W2C, Plant One initiative- bio-based chemicals
Moerdijk	energy plant- transforming animal waste to electricity, e-scrap sampling centre – metal recycling, eco-park- attracting bio-based & Circular companies, developing Pyrolysis cluster
Groningen	Chemie Park Delfzijl – Pilot biorefinery, recycling polluted steel scraps, developing offshore wind

Table2-8: Key Circular activities of Dutch seaports, source: (De Langern and Sornn-Friese, 2019)

All these seaports except Rotterdam in a detailed structure refer circularity in their vision documents or strategic plans (De Langern and Sornn-Friese, 2019) and all five seaports aim to evolve circular hotspots in the upcoming future. Their exploratory analysis of the CE transition of ports concludes stating the following: threats to ports by reducing maritime transport, provide opportunities in logistics & industrial activities, redraw the competitive landscapes between ports (cluster synergies), competing over CE activity investments (De Langern and Sornn-Friese, 2019). From their study, a trend of circular activities had been observed which will promote in developing the maturity levels of CE on ports, as mentioned earlier in this section.

Van zwieteren (2016), presented the study on trade-offs of CE business at Netherlands and Vietnam port areas through a case study analysis of the sustainability factor in the exported recyclable plastics. In his study, he had exclusively listed out the CE activities at Dutch seaports by classifying them into two categories based on the CE principle envisaged by EMF, mentioned above in figure 2-1. Bio-based at Port of Amsterdam, Rotterdam & Zeeland and Technosphere at Port of Rotterdam like Circularity centre (CC)- to expand the business and knowledge in CE and 3-D printing, also identifies the startups, knowledge institutions located at Amsterdam and Rotterdam as the incubator for innovation research and development for the circular activities at the port and city (Van Zwieteren, 2016).

Karimpour (2017), developed a circular economy model for the Copenhagen-Malmo Port (CMP) cruise ship terminal to assess the energy sustainability. The CE model consists of three elements Port Waste Management, Port owned Bio-gas plant and cold ironing provision (shore to ship power supply) which closes the loop, input for the CE model is the waste generated from the cruise ships visiting the port. Thus, the input is fed into the model and output is the clean energy generated and supplied back to ships, to port buildings and the households. The feasibility of this model is assessed through the Cost-benefit analysis method.

Karimpour (2017), in his study, identifies the Circular strategies at 4 ports- bio-based, waste recycling at Port of Amsterdam, Rotterdam. The Hamburg Port Authority (HPA) includes, promoting & familiarising the CE models to their customers through a platform, energy transition to provide sustainable services through CE projects clean energy from biogas plant and providing it in barges and Port of Antwerp includes waste recycling and recovery of energy, virtual knowledge centre to promote innovative ideas and startups, development of onshore power supply. These strategies show a pattern of the shift from fossil fuel to renewable energy, adding value to waste management through CE (Karimpour, 2017)

Sangster (2015) and Carpenter et al (2018), study the resource recovery principle of CE where the waste is reused as a source of input for infrastructure projects. Sangster analyse the project "De Groene Poort", which is about developing the foreshores at the riverbanks of Niewe Waterweg, by reusing the residual materials generated from Port of Rotterdam. Instead of dumping the residual materials such as dredged sands, coarse residues as waste, it is been reused as a commodity for the construction projects there by which the value chain of various companies is connected. Thus resulting in enhancing the CE and biodiversity of the port area through providing sustainable port infrastructures (Sangster, 2015). This was also the same case of Port of Gavle at the Baltic east coast of Sweden, where they developed an entirely new terminal and expanded the port area by utilizing the dredged contaminated materials acquired from deepening their shipping channel to accommodate larger vessels and growing marine traffic. The port's plan to face the rising cargo volumes and sustainable ambition decided to initiate the CE principle of resource recovery to construct a new cargo terminal. This CE approach transformed the port to face sustainable challenges, thereby ensuring the competitiveness of the port through innovation, saving infrastructure cost and lowering environmental impact (Carpenter *et al.*, 2018).

Ballini & Song (2017), in their research paper present an overview of the role played by the ports in CE and summarised the existing circular and bio-based initiatives at the ports mentioned in table 2-9.

Seaports	*circular & bio-based economy clusters*
Antwerp	E-waste & recycling
North Sea port (Zeeland & Ghent)	Bio-park & Bio-refinery
Amsterdam	Recycling
Rotterdam	Renewable energy cluster

Table 2-9: Existing circular and bio-economy clusters at Dutch & Belgium Ports, source: (Ballini and Song, 2017)

Resource recovery, renewable raw materials, extending the service life, sharing economy concept and retaining ownership by providing the products as a service are mentioned as the opportunities for the ports in circular transition in their paper. They also mention space and time required for a circular shift, negative externalities of waste recycling, lack of co-operation among stakeholders as the key challenges faced by the inland ports. Finally, they conclude by stating the ports as an ideal place for developing CE because of existing clusters and synergies with industries in recycling, being a matchmaker and crossing roads for all kinds of material and waste flows, providing logistics for the export and import of waste materials (Ballini and Song, 2017).

Kuipers et al. (2015), termed ports as "*the catalyst* "in the transition process from linear to a circular economy and present an exclusive report on the bio-based and circular economy initiatives of Port of Amsterdam to achieve sustainable competitive advantage. In the report, they list the drivers behind the circular economy as the scarcity of raw materials, innovations, increasing leasing and renting activities, the rise of sharing economy, government policies for transition, waste market opportunities, spatial differences in the manufacturing units, increasing waste and residual flows. For the circular transition innovation play a vital role, new circular products and a new form of circular services are innovated through startups. Thus the seaports utilize this opportunity and provide an innovative environment by incubating these startups and also indulge in R&D with the academic institutions and companies interested in the circular economy (Kuipers *et al.*, 2015).

Scaramelli (2010), does a research case study on the determinants of port competitiveness and present the list of factors to determine the competitiveness after an exclusive literature study. The two determinants relevant to this study are "Hinterland" and "Environment". The land behind the port area where it exports, and imports is the hinterland of the port area and this hinterland connectivity of each port is a prime factor to attract more volumes of cargo into the port. At present, the ports form an integral part of the supply chain and act as the transport node. The supply chain is in a transition towards circular and the drivers of the circular supply chain are profit potential of the firms and societal awareness for sustainability (De Langern and Sornn-Friese, 2019). Thus, the ports evolving as a circular hub position themselves to integrate with circular supply chains to gain competitive advantage among other ports in the region. Haas et al (2015) and De Langern & Sornn-friese (2019), argue that a circular supply chain will be completely sustainable only if the energy utilized in the supply chain were derived from the renewable sources rather than the traditional fossil fuels. The hinterland connectivity of the port also facilitates the waste flows inside the port and recycled material flows out.

Based on the above literature study table 2-10, present the concept matrix of existing circular economy implications on the ports. The concept matrix represents circular economy trends identified from the above reviewed literatures, which are: Waste

Management (WM), Residual Heat/Steam (RH/S), Sustainable Infrastructure (SI), Renewable Energy (RE), Incubators (INC) and Circular Supply Chain (CSC).

		Circular Economic implications						
		WM	**RH/S**	**SI**	**BC/BP**	**RE**	**INC**	**CSC**
Literature Articles	*De Langern & Sornn-Friese, (2019)*	X	X		X	X	X	X
	Van Zwietern, (2016)	X			X		X	
	Karimpour, (2017)	X				X		
	Sangster (2015)			X				
	Carpenter et al., (2018)			X				
	Ballini & song (2017)	X			X	X		
	Kuipers et al (2015)	X	X		X	X	X	
	(Williams, 2019)	X	X			X		
	(Ezzat, 2016)					X		

Table 2-10: concept matrix of CE implications on ports from the literature study, source: Author's compilation

The authors recognised in the concept matrix had explicitly referred the following ports for their CE implications, presented below in table 2-11.

Authors	Literature Articles	Ports
De Langern & Sornn-Friese, (2019)	*Ports and the Circular Economy*	Zeeland Seaports, Port of Amsterdam, Rotterdam, Moerdijk and Groningen
Van Zwietern, (2016)	*The circular economy in the port area of the Netherland and Vietnam : A case study on the sustainability of the export of recyclable plastics to Vietnam*	Zeeland Seaports, Port of Amsterdam, Rotterdam, Moerdijk, Groningen and Vietnamese ports
Karimpour, (2017)	*Circular economy modelling to accelerate the transition of ports into self-sustainable ports : a case study in Copenhagen-Malmö Port (CMP)*	Port of Antwerp, Amsterdam, Rotterdam and CMP
Sangster (2015)	*Sustainable Port Infrastructure- An interdisciplinary design study of nature friendly banks made of residual material to enhance biodiversity in a port.*	Port of Rotterdam
Carpenter et al., (2018)	*Securing a port's future through Circular Economy: Experiences from the Port of Gävle in contributing to sustainability*	Zeeland Seaports, Port of Amsterdam, Rotterdam, Antwerp, Bristol and Gävle

Ballini & song (2017)	*The Role of Port Cities in Circular Economies : Cases from Europe*	Zeeland Seaports, Ghent Port, Port of Amsterdam, Rotterdam and Antwerp
Kuipers et al (2015)	*The Amsterdam port is running (green) through Towards sustainable competitive advantage by focusing on the biobased and circular economy*	Port of Amsterdam
Williams (2019)	*The Circular Regeneration of a Seaport*	Stockholm Royal Seaport (SRSP)
Ezzat (2016)	*Sustainable Development of Seaport Cities Through Circular Economy: a Comparative Study With Implications To Suez Canal Corridor Project'*	Port of Rotterdam and Ningbo Port

Table 2-11: list of seaports engaged in circular economy from the literature study, Source: Author's compilation

From the above table it is clearly conceived that the ports of Amsterdam, Rotterdam, Antwerp, Groningen, Moerdijk, Zeeland seaports and Ghent Port are exclusively involved in the circular transition at the north west european region

2.6 The Framework and Maturity Levels of Circular Economy Implications on Sea Ports

A conceptual framework was developed since, it allows to link the principal concepts, previous research studies and key theories thereby enabling the researcher to approach the research context in a systematic ideology (Peshkin, 1993). The framework projects the researcher's perception on how the research question would be explored (Dickson, Adu-Agyem and Emad Kamil, 2018). Thus, based on the literature reviews explained above on the concepts, principles of CE and its impacts on the seaports, a conceptual framework of circular economy implications on seaports was developed. This framework lays the background for developing and defining the circularity maturity levels of the ports.

Ghisellini et al (2016), summarised the worldwide CE implementation in context of Micro, Meso, and Macro, however Carpenter et al., (2018) classified port's circular initiatives as, micro level - when a firm involve in recycle and reusing the waste generated in port zone, meso level – when a symbiotic relationship exist between the companies in port region and macro level- when the port involve in exchange of secondary resources inter-regionally.

The above grouping was the backdrop of the framework presented in figure 2-5. Instead of levels the author consider the implementation as micro CE representing the port, meso CE representing the port cluster and macro CE portraying the port city. This perspective developed to understand the impact of CE at each level and their dynamics between each level instead of classifying them because of the ambiguity existing in classification. The conceptual framework depicts the synergistic relationship of port, its cluster and port city instead of classifying or categorising them which can be explained by an example, the energy recovered from waste in the port serves all the three levels.

The inner circle projects the seaport and it implies the CE initiatives initiated at the port zone. The middle circle represents the port cluster and their CE implications, and the outer circle represents the port city which facilitates CE implications in the seaport and port cluster by providing a favourable climate for the circular business and investments. There by, the port will be in the path of evolving into circular hub, which in turn drives the city in their ambitious plans in transforming into circular city.

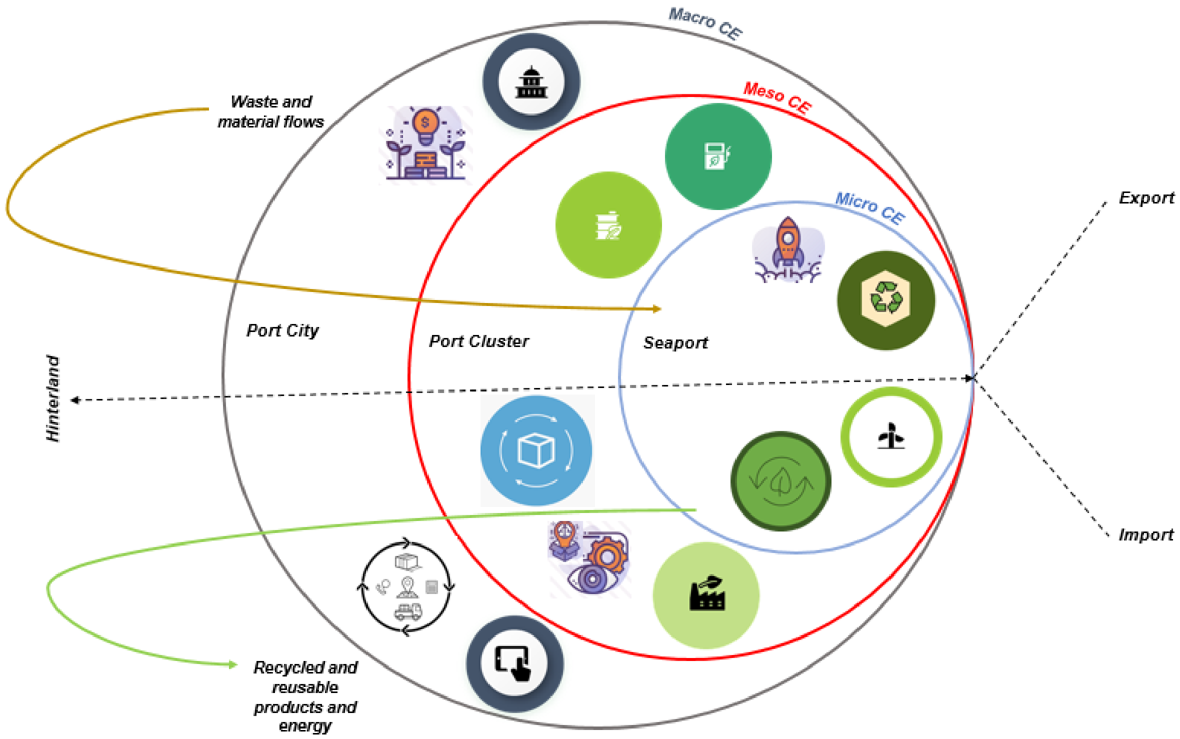

Figure 2-5: Conceptual framework of CE implications at three levels, source: Visualised by the author from the literature review

In the above picture, the inner circle consists the circular initiatives by the seaport such as recycling activities, renewable energy implications such as wind, solar, bio-energy, resource recovering activities like using dredged sands for construction of port projects instead of dumping them as waste, construction of sustainable port infrastructures and facilitating the transition by providing platforms for the innovations through setting up incubators, setting up R&D with academic institutions and investments. The port cluster circle consists of all the manufacturing, refineries, petrochemical companies, etc situated in the port region. All these companies are moving towards the circular economy through implementing innovation with the right circular business model discusses above. The port city provides a business environment and policies to facilitate the transition in the economy thereby stimulating the circular economy in seaport and port clusters. The above explanation on circular initiatives were derived from the table 2-10, the concept matrix which mapped the circular trends from the literature.

Based on the concept matrix and conceptual framework the following maturity levels was framed which are shown in figure 2-6.

The level 1, is the waste management where the ports recycle the inflowing wastes in their zone which was mentioned early in the literatures of De Langern & Sornn-Friese (2019), Van Zwietern (2016), Karimpour (2017), Ballini & song (2017), Kuipers et al (2015) and Williams (2019). Each port has its waste management plan framed as per the national policies and now they have been updated as per the circular policies.

Level 2 represents the sustainable infrastructure where the port constructs its port building, quay walls, dock areas, etc using sustainable materials, circular materials like the dredged sands as explained by Sangster (2015) and Carpenter et al., (2018).

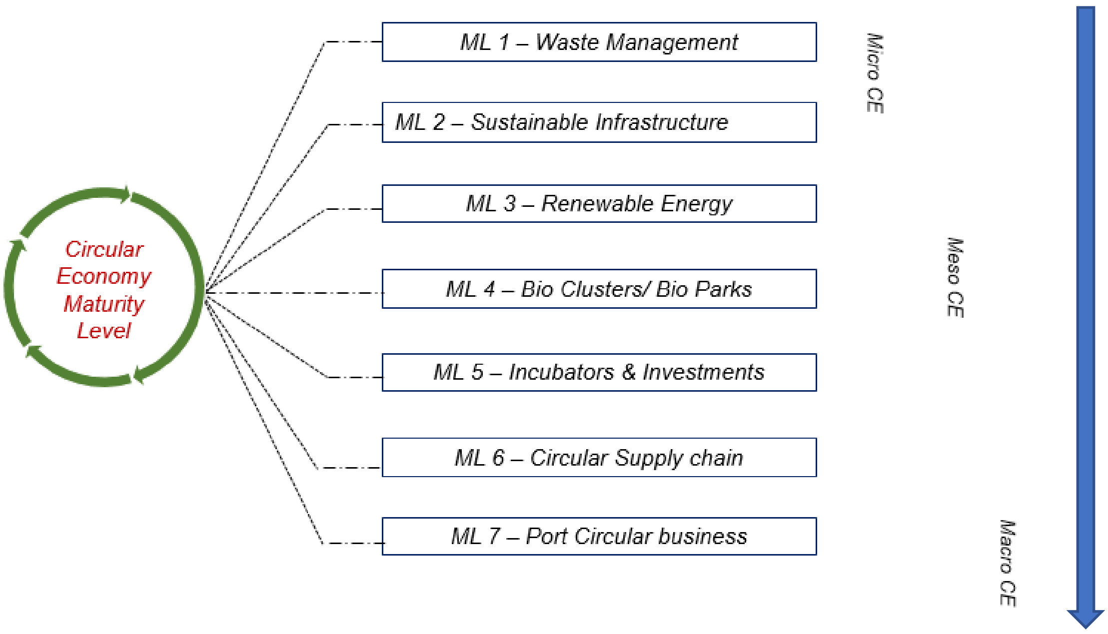

Figure 2-6: Circular economy transition level or maturity level of seaports, source: visualized by author

It can be noted from the literature mentioned above all the seaports are in energy transition and implementing the renewable energy sources in the port area for their consumption, also for their clusters and city. The renewable energy sources such as wind, solar, residual heat/steam and bioenergy were mentioned exclusively in the literatures of De Langern & Sornn-Friese (2019), Karimpour (2017), Ballini & song (2017), Kuipers et al (2015), Williams (2019), Ezzat (2016) and this forms the circular level 3 for the seaport.

All the seaports are housing industrial clusters which are also in transition and predominantly the bio-economy of the clusters was noted in the studies, hence the circular projects initiated in the cluster region of the port form level 4 as referred in reviewed literatures of De Langern & Sornn-Friese (2019), Ballini & song (2017) and Kuipers et al (2015).

As innovation is the key aspect for facilitating the transition which was discussed under Innovation and business models at section 2.4, the initiatives such as setting up incubators to facilitate innovations and start-ups in the port region discussed by De

Langern & Sornn-Friese (2019), Kuipers et al (2015) and Van Zwietern (2016), represents the maturity level 5.

When the port integrates with circular supply chain it will be matured by reaching level 6 and to evolve as a complete circular hub the seaport must reach the maturity level 7 of port circular business.

2.7 Chapter conclusion

This chapter form the core of this research study. The first part 2.2,2.3 and 2.4 discuss the origin, principle and concepts of circular economy followed by the implementation of circular principles by the countries and its evolution R- hierarchy where the concept of 10R's are discussed. Also, the importance of innovation and types of available circular business models are presented. In the second part 2.5, the impacts of circular economy are discussed with their opportunities and barriers discussed and which is concluded by a concept matrix tabulating the circularity trends found in the relevant literatures. Based on these two parts the conceptual framework and circular maturity level of the seaports are framed, which is the main objective of this research study. The chapter also mention the less available of research studies and journals relating to circular economy and seaport, which is a limitation in this study.

3. Methodology

3.1 Introduction

This chapter explains the methodology and the method utilized for the analysis in this research study and to answer the research question. The methodology for this research study is the qualitative analysis with the content analysis being the method used for the analysis. Saunders et al. (2009) explain the meaning of two terms “Methodology” and “Method”, where the term “Methodology” meant the underlying theory based on which the research must be carried out which is Qualitative in this study and the latter refers to the strategy (Procedure & Techniques) used to collect and analyse the data (Saunders, Lewis and Thornhill, 2009; Scaramelli, 2010) which is being the Content Analysis in this study. The analysis of qualitative data such as text data from the reports, magazines, interviews, transcripts, documents, etc. termed as qualitative analysis (Bhattacherjee, 2012b). The qualitative approach over the research study, to a greater degree, depends on three factors- analytic & integrative skills, self-knowledge of the social context of where the data being collected. Thus, the prominence of qualitative analysis lies in making sense or understanding of the phenomenon instead of explaining or predicting. Different strategies are being employed for this kind of approach like grounded theory, phenomenology, ethnography, content analysis, hermeneutic analysis, etc.(Bengtsson, 2016). Our analysis strategy adopted in this research to answer the main research question is the content analysis method.

3.2 Multiple case study analysis

The research strategy for this dissertation is multiple case study. There are no rules or formulas for decisions to select the case study as a research method, fundamentally it depends on the research question (Yin, 2014). Our research question is to determine or predict which seaport being the first mover and the scope being the north west european region. Thus, eventually this pose for selecting multiple seaports which are in circular transition for the analysis thus decided upon multiple case study. The limitation of the multiple case study is that its time consuming (Gustafsson, 2017).

3.3 Content Analysis

As mentioned earlier in Chapter 1, Content analysis (CA) is the method used in this research to analyse the qualitative data.CA is a research method, which uses a set of procedures to make valid inferences from the textual data (Weber, 1990). A wide range of definitions exist for CA, Shapiro & Markoff (1997) reviewed six major definitions available in the social sciences and they proposed an encompassing minimal definition- " any methodological measurement applied to text or other symbolic materials" (Shapiro and Markoff, 1997; Duriau, Reger and Pfarrer, 2007). This definition of CA provides us with an acceptable ideal grounding to examine our data which will be done in this chapter in the forthcoming paragraphs.

3.3.1 Principles, Assumptions, and Advantages of Content Analysis

The key principle is that the core value of CA as a method for the research study recognizing the significance of the language in human cognition (Trager, Whorf and Carroll, 2006; Duriau, Reger and Pfarrer, 2007; Sapir, 2008; Jansen, 2019). There are two key assumptions made in this method, firstly the analysis performed on the collected data let the researcher to understand other people's cognitive schemas (Woodrum, 1984; Jr., 1993; Ginsberg and Huff, 2006; Duriau, Reger and Pfarrer, 2007) and secondly, it had been assumed that the group of words reveal the underlying themes & co-occurrence of the keywords formulated by the researcher can be interrupted as the reflecting association between the underlying concepts (Weber, 1990; Ginsberg and Huff, 2006; Duriau, Reger and Pfarrer, 2007). The output or the basic result after performing the CA is the word frequency, it is considered to be the indicator of cognitive centrality (Ginsberg and Huff, 2006; Duriau, Reger and Pfarrer, 2007; Jansen, 2019). Weber (1990) explore the advantages of CA method, this analysis can be performed over the textual data of human communication and the theme of the communication forms the central aspect of social interests, the textual data e.g. documents of various kind exist over a longer period of time thus the themes, indicators, trends generated from such sources of documents serve reliability to the analysis. Thus it allows the researcher to understand the deeper meaning associated with the organizational documents such as annual reports, strategy documents, vision documents, etc which provide analytical flexibility in the research process (Duriau, Reger and Pfarrer, 2007). CA is also considered to be a safe method since the researcher can fix the flaws by correcting the codes associated with the theme (Woodrum, 1984). Thus, these advantages of CA precedence over other methods and it was considered to be the better method in this research process. Write more!

3.3.2 Overview of the steps involved in content analysis

Weber (1990), states that there are no pre-defined steps to perform the CA, but it should be suitable for the selected domain of interest that the researcher wants to perform the analysis. Hence to define the steps, previous research studies on CA where reviewed to perceive the method. Table3-1 was drawn after reviewing the relevant articles of content analysis. Thus, five steps were drawn, and the analysis of this research study will follow these defined steps to analyse textual data of port reports sourced to answer the research question, which is presented in the next section. The explanation of each step as follows:

Step 1- The Planning Phase

Before performing the content analysis (CA), the researcher has to define and decide on five key criteria which are: the aim of the research, the sample, and unit of analysis, methods for data collection, method of analysing the data and practical implications. they are decided in the planning phase. These five decisions define the impact on the quality of the research study. Bengtsson (2016), explains that the researcher should have a clear vision on the aim of the analysis on the selected interest area and should also decide how the research analysis should be performed, either descriptive or exploratory based on the inductive or deductive reasoning.

Step 2- Data Collection

In this phase the researcher involved in the data collection process. Content analysis is done on the textual data of the researcher's area of interest. The selection of the data is the researcher's decision based on what he had decided to examine. Jansen (2019), list out the following as some of the textual data used for the analysis: trade magazines, publicly available documents, notes from the interviews, annual reports of the companies, open-ended questions in the survey, mission statements of the firms, business cases, transcribed videotapes, databases, other field data, etc. Jansen (2019), explains that there are three critical sampling decisions: the source from where the data had been extracted, the type of document and choosing the specific texts from the selected document. These three sampling decisions are based upon the purpose of research, methodological approach, and availability of information.

Step 3- Coding, the 8 steps

After collecting the data, the next step is the coding process where the researcher should design and implement coding schemes. Weber (1990), explains the process involved in generating and implementing the coding schemes in 8 steps which had been mentioned in table 3-1.

- The researcher must define the recording units, which is the basic and foremost decision in defining the basic unit of the text to be examined. There are six commonly used recoding units: word one, word sense, sentence, themes, paragraph, and whole text.
- The second step involves defining the categories to which the recoding unit are grouped, and this is decided by the researcher based on two basic criteria: should the categories be mutually exclusive or not? how narrow or broad the categories should be?
- After defining the record unit and category, the third step is to check them by coding a sample of text. This is done to check if there is any ambiguity that exists and if so, can be corrected in the above two steps.
- The fourth step is to check the accuracy or reliability of the coded sample text which had done in the previous step. This step is to check the accuracy i.e. whether textual data are coded correctly by the software and if human coders used the reliability is checked.
- If there is low reliability or error had been found in the procedure of coding the sample text, the defined coding rules must be revised by the researcher or the software used must be rechecked and corrected
- In step six, the researcher decides that if the required accuracy or reliability had not been achieved he revisits step 3 and this cycle is repeated until the researcher is satisfied with the level of accuracy and reliability of the software or human coders used in the process.
- When the researcher is satisfied with the accuracy and reliability level of the sample coded texts, in this step the selected full text is coded with the defined coding rules
- The final step is to assess the achieved accuracy and reliability of the coded text. This is done because when it involves the human coders, they tend to commit more mistakes due to fatigue or their interpretation of the coding rule may differ which might lead to greater unreliability. If the coding process were done by the software, the results should be checked to make sure the applied coding rules were correct.

PLANNING PHASE
Aim Sample & Unit of Analysis Method of data collection Method of Analysis Practical Implications
DATA COLLECTION
Sources from which the data is collected, sampling decisions
CODING- the 8 steps
➢ Define the recording unit ➢ Define the coding categories ➢ Test the coding on a sample of text ➢ Assessment of the accuracy & reliability of sample coding ➢ Revise the coding rules ➢ Return to step 3 if sufficient reliability not achieved and repeat it ➢ Code all the textual data ➢ Assessment of achieved reliability or accuracy
ANALYSIS OF THE CONTENT
With the coding scheme defined, all the collected textual data are analysed either using human coders or software.
INTERPRETATION OF RESULTS

Table 3-1: Steps involved in content analysis, source: Author own version, adapted from (Weber, 1990; Bengtsson, 2016; Jansen, 2019)

Step 4- Analysis of the content

In this phase, the researcher uses the coding schemes which had been explained in the previous step to study the content of the selected textual data to answer the aim of the researcher.

Step 5- Interpretation of results

As explained above the key principle or the core of performing the CA on textual data is to understand the deeper meaning or the theme of the text. These coded texts are categorized accordingly by the researcher to analyse qualitatively or quantitatively to find which theme had more frequently and in what context and how they are related to the research aim (Bhattacherjee, 2012b). Jansen (2019); Ginsberg et al (2006); Duriau et al (2007) state that the common output or the result of CA is the word frequency of themes. Weber (1990), explains that the results can be interpreted in four ways: word frequency list, keyword in context list (KWCL) and concordances, retrievals from the coded text and category counts. All these interpretations explain the underlying theme or the deep meaning of the text the researcher seeks to find. Based on the aim of the research, the researcher can decide in what way he want to analyse the results to answer his purpose of the research.

3.3.3 Limitations of Content Analysis

Bhattacherjee (2012), recognizes the limitations of CA as restriction of a coding process to the available information in the text and sampling bias The usual criticism on performing the CA is that the method doesn't have any set of systematic procedures, which would allow other researchers to replicate it (Bhattacherjee, 2012b). Weber (1990), identifies reliability and validity of the text's classification arising due to the ambiguity of the meaning of words, the definition of the categories and coding rules as the main limitations of the content analysis method.

3.4 Chapter conclusion

The chapter provides the reasons for the multiple case study approach and the method of content analysis are explained in detail. Since there were no defined steps for performing a content analysis, relevant literatures of content analysis were analysed and the steps were defined, also the limitations are mentioned.

4. Maturity Level of Circularity at four seaports

4.1 Introduction

Previous chapter explained the methodology and the method of analysis of this research study. This chapter implement the methods explained in the previous chapters to analyse the port documents to answer the research question. The following section implement the CA procedures and steps explained above to analyse the significant textual data of the selected four seaports to answer the main research question of this study.

4.1.1 Content Analysis of the Port Documents – Planning Phase

The main aim of this textual analysis is to predict, ***which north western seaport would be the first mover to evolve as a complete circular hotspot through a paradigm shift from linear economy to circular economy?*** the research question. To predict this the author had approached with multi case study of four North western European seaports (NEW), which are already in transition phase with lot of circular developments and initiatives in the port and in their clusters. For this analysis the following assumption had been made: the seaport with higher maturity level of CE initiatives would be the possible first mover to become circular hub. The maturity levels of CE explained in the section 2.6 under chapter 2 is the underlying conceptual ideology for the predictions, hence the assumptions made. In this planning phase, the next decisions were made regarding the data collection and unit of analysis. The annual reports and sustainable reports of the selected seaports were considered and "*sentence*" as the unit of analysis. The official websites were the source of data collection. Since this was an exploratory deductive reasoning, a hypothesis is formulated to answer the research question.

Based on the theoretical foundation of our literature study, it was assumed that the port ability to address the complexity of circularity would be more mature in CE transition and on this basis the maturity levels were drawn, hence we test the hypothesis as *the port with more mature CE initiatives or developments would be the possible first mover*. For performing the content analysis in this research study Nvivo version 12 software is used.

4.1.2 Data collection

As decided in the previous phase the annual reports and sustainability report of the port were the textual data for this analysis since, the annual report of the port projects the present condition of the port, their growth, financial results, investments and their future strategy, vision for the developments and sustainability report present their sustainable achievements, progress and ambitious plan for their vision. Practical implications were present since only few annual reports were available in their official websites, hence the respective department of the port authority were contacted to obtain the port document. The annual reports were collected with a time frame of 15 years (2004-2018), figure 4-1 represent the catalogue of collected annual reports. 75% of the reports were acquired, where Port of Antwerp (POAn) and Port of Rotterdam (POR) and Zeeland seaports annual reports collected were the maximum, For POAn, four sustainable reports form 2010 – 2017 which are being issued by the port authority for every two years were collected, remaining ports only their annual report were used.

Figure 4-1: Annual reports catalogue from 2004-2018 for four seaports

4.1.3 Design and Implementation of coding scheme

As the first step the sentences in the textual data were decided to be the recording units. Next the coding categories or classifications were considered based on the maturity levels explained in section 2.6 under chapter 2, each code will be having sub coding categories based on the ports.

Coding Categories
Waste Management
Sustainable Infrastructure
Energy Management
Port Clusters
3I- Innovation, Incubator & Investments
Circular Supply chain
Port Circular business

Table 4-1: Classification of codes

For some of the above-mentioned coding categories, few sub coding categories were made, since those themes were mentioned in the annual reports more specifically. These sub codes depend for each port which will be mentioned in the results and analysis of each ports. Each coding category represent the circular maturity level framed in figure 2-6. Under waste management the theme of waste representing the circular level 1 was coded in the port documents. The code sustainable infrastructure is the circular level 2 and themes involving in construction using recycled materials, dredged sands etc were coded under this. The circular level 3, is the energy management which refer to the environmental and energy policies of the port. Based on the initiatives of the port under this category sub codes such as renewable energy, onshore power, residual heat was made.

The code port cluster refer the bio-clusters of each port and related themes were coded under this. This code of port clusters refer the circular level 4 which is the circular initiatives in port cluster. The next code 3I, represent sub-codes three themes namely Innovation, Incubator and Investments, representing the next circular level 5. Under the circular supply chin the port initiatives in sustainable supply chain was coded and as per the port circular business any reforms for changing the core port business model was coded. The last two codes represent circular maturity level 6 and 7 respectively.

4.2 The Four seaports in North western Europe

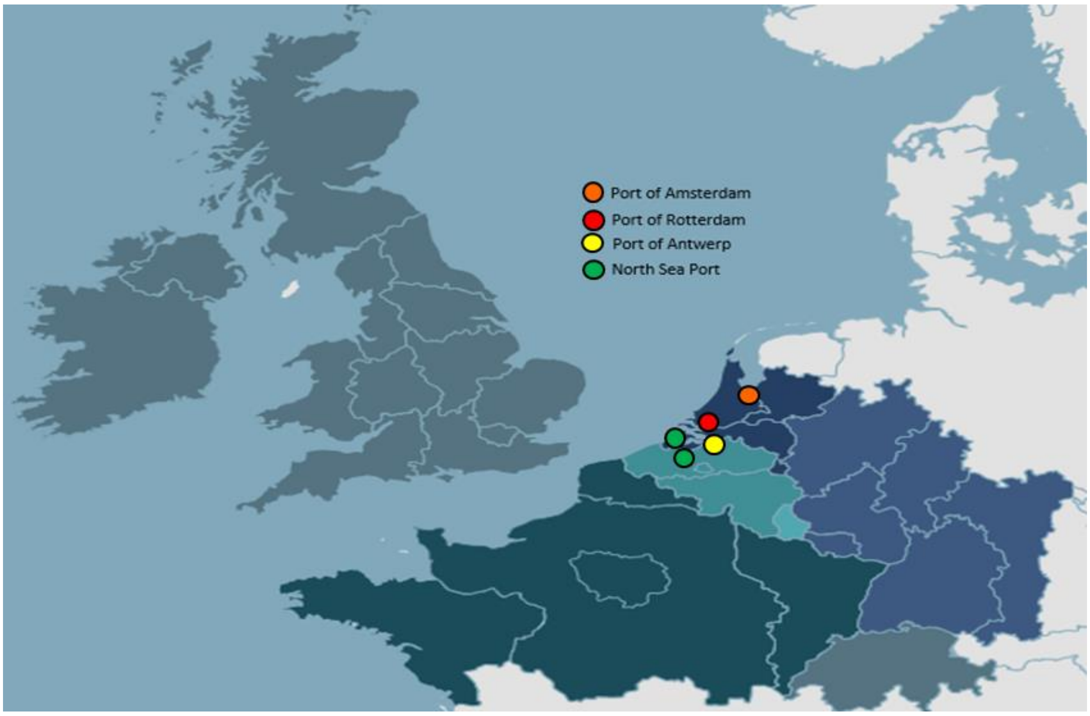

Figure 4-2: The Four seaports in North western Europe, source (Interreg North-West Europe, 2019)

The above figure represents the four seaports in NEW region, conscious decisions were made for the selection of the following seaports: Port of Amsterdam (POAm), Port of Rotterdam (POR), North Sea Port (NSP) and Port of Antwerp (POAn). Three Dutch seaports were chosen since the country is the frontrunner towards the transition into CE with their ambitious target to become a complete circular by 2050 (Government of Netherlands, 2016) and as per Eurostat (2017) in EU, The Netherlands is one of the country handling largest volumes of the goods in their ports (Eurostat, 2017). With their logistics and manufacturing clusters, The POR is the biggest and busiest port in the western European region followed by the ports in Antwerp, Hamburg and Amsterdam respectively (Port of Amsterdam, 2018; UNCTAD, 2018).

Moreover, the CE transition of the selected four seaports had been discussed exclusively in all literatures relating to impacts of CE in the ports in section 2.5, refer table 2-11 under chapter 2. Thus, the selected seaports would be a valuable and relevant decisions for the analysis to answer the main research question of this.

4.3 Content Analysis of the Port Documents

4.3.1 Port of Amsterdam

The seaport located at the Dutch capital city, clearly states its aim as to evolve into a circular hotspot of the European region. To spearhead this transition, they had mentioned circular economy and energy transition as the focal strategy in their vision 2030 document. The six clusters (energy, food, agribulk /minerals & recycling, general cargo & logistics, cruise, maritime services & real estate) of the Amsterdam port region represents the core economic activity of the port and through developing innovation at the intersection of these port clusters they promote the bio-based and circular economy transition (Port of Amsterdam, 2017b). Figure 4-3 shows the established circular companies at the port region which are being categorised into seven clusters[5].

Figure 4-3: Established Circular companies in the Port of Amsterdam, source (Port of Amsterdam, 2019)

In their latest annual report (2018), the port identifies the circular economy as one of the strategic roadmaps. In 2015, the port launched its incubator- The Prodock[6] to provide space for the innovation, new startups, pilot projects in energy transition, circular economy and bio-based, digital technology.

Through this initiative the port had attracted and fostered innovations in the above-mentioned fields and in 2018 they had decided to expand it. The port also decided to construct a new technical coordination centre in 2018 as a circular building to achieve the sustainable infrastructure with BREEAM[7] certification in their premise. The current and future developments of circularity at the port, is one of the major theme discussed among the port authority and their stakeholders (Port of Amsterdam, 2018).

[5] Categorised as city waste cluster and energy production, biorefinery cluster, R&D and Innovation infrastructure, chemical clusters, liquid terminals, logistics infrastructures, building and future developments

[6] De Langen & Sornn-Friese (2019), Prodock is a physical location of 4000 m^2 where the startups test their innovations

[7] (BREEAM-NL, 2019) – Building Research Establishment Environmental Assessment Method, it is an organisation assessing and certifying the sustainability performance of the infrastructures

Table 4-2 presents the results on content analysis of the annual reports of Amsterdam port from 2004-2018. The results are explained and analysed in the next chapter.

ML	Coding Category	Annual Reports	References
1	Waste Management	7	42
2	Sustainable Infrastructure	4	8
3	Energy Management	7	33
	Renewable Energy	6	21
	Wind	7	19
	Solar	5	9
	Bio energy	5	12
4	Port Cluster- Bio & CE	6	31
5	3I		
	Innovation (R&D)	7	35
	Investments	6	15
	Incubator	6	26
6	Circular Supply chain	2	6
7	Port Circular Business	0	0

Table 4-2: Result of Content Analysis of Port of Amsterdam

4.3.2 Port of Rotterdam

The port of Rotterdam is the largest seaport in the European region and in world it is the 10th largest port in terms of cargo handling (Port of Rotterdam, 2018). The port hosts one of the largest complexes of refineries and chemical plants in the world, higher concentration of raw materials and residual flows from the industrial and logistics services, extensive network connections with the hinterland make the port an ideal circular hub for raw materials transition

The vision of the port is, by 2050 its local industrial and logistics activities to be completely circular. To achieve this vision, they adopted four key circular pathways: innovation and scaling up, sorting and recycling, industrial symbiosis and capture & reuse of CO_2. Thus, through this circularity ambition the port want to achieve its energy transition and strengthen its competitive position in the region (Port of Rotterdam, 2019a)

Through a consortium the port authority planned to develop waste-to-chemical plant as first of its kind in the Europe, where valuable chemicals and biofuels are extracted out of non-recyclable waste materials. Ioniqa, a start-up for recycling the bottles made up of Polyethylene terephthalate (PET) into useable chemical raw materials, Rotterdam Additive Manufacture Lab (RAMLAB), first of its kind 3D metal printer on demand for port related sectors through which stocking is avoided, industrial clusters using biomass as raw materials, residual heat generated in the port being reused to heat homes, green houses and offices, Bluecity- breeding ground for innovative companies that work to connect their residual flows, prinses amalaia overpass at maasvlakte constructed using beaumix, a sustainable construction material made from decontaminated residual from waste incinerator plants (Port of Rotterdam, 2019b)

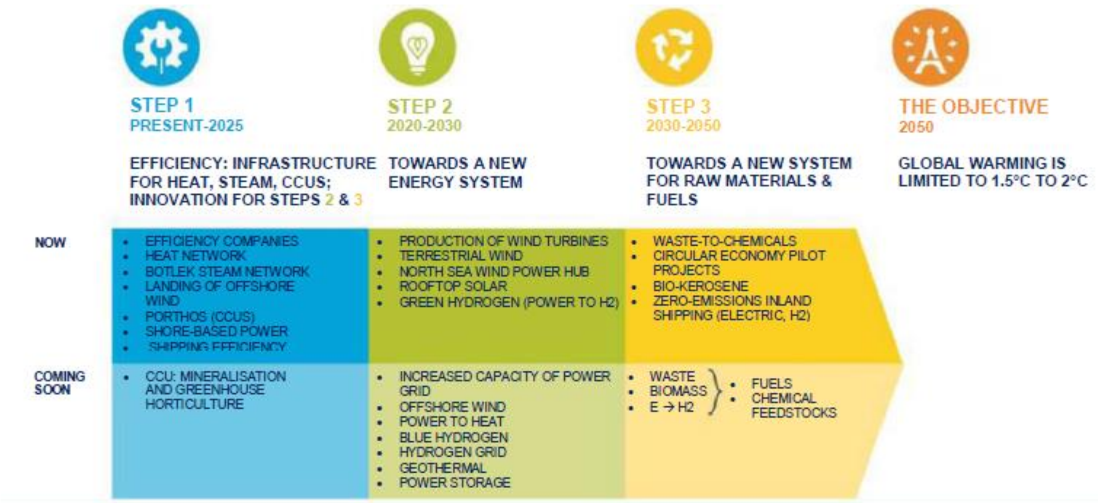

Figure 4-4: Strategic Plan for Energy Transition of Port of Rotterdam for 2050 (Port of Rotterdam, 2019b)

The Table 4-3 present the content analysis of the Rotterdam port annual reports.

ML	Coding Category	Annual Reports	References
1	Waste Management	12	37
	Waste 2 Chemicals	3	14
2	Sustainable Infrastructure	11	27
3	Energy Management	8	54
	Residual Heat/Steam	12	50
	Bio Energy	8	24
	CCS	8	26
	Onshore Power	7	20
	Renewable Energy	8	32
	Wind	8	26
	Solar	6	6
	Bio energy	8	24
4	Port Cluster- Bio & CE	11	74
5	3I		
	Innovation (R&D)	9	56
	Investments	8	29
	Incubator	8	21
6	Circular Supply chain	-	-
7	Port Circular Business	-	-

Table 4-3: Result of Content Analysis of Port of Rotterdam

4.3.3 North Sea Ports

The Dutch port Zeeland[8] and Flemish port Ghent combined together through a cross border merger in the year 2017, to form the North Sea Ports. Zeeland seaports in their strategic masterplan for 2017-2022 mention circular economy as a driver for sustainability which can be achieved through clustering of companies, optimising the energy, consumables and decrease transport needs, thereby which the waste from one company will serve as the raw material for other existing companies in the region (Zeeland Seaports, 2017)

Biopark Terneuzen is a unique and innovative circular initiative by the Zeeland seaports, where it promotes and facilitates the exchange of residual flows exchange of heat, steam, electricity and Co_2 from one company to the others through synergy of those companies in that region, thus the residuals serve as a raw material.

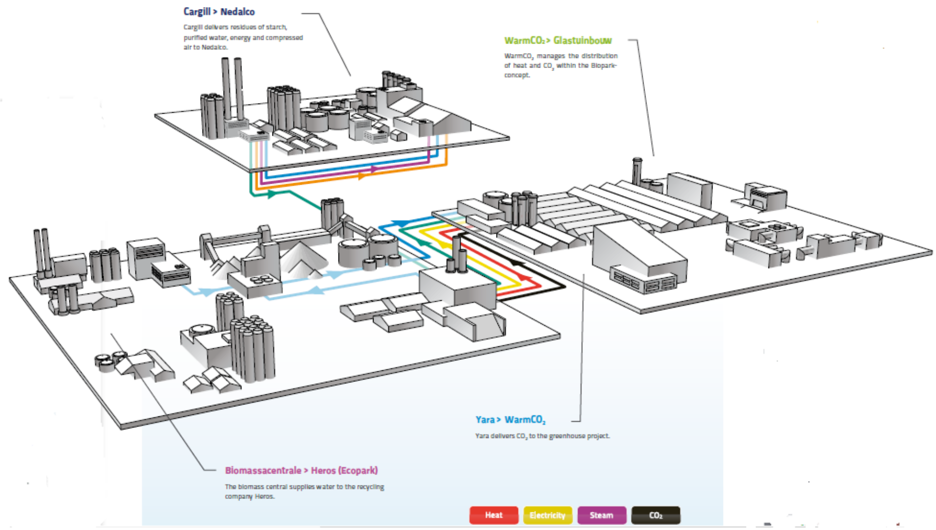

Figure 4-5: Residual flows exchange at Biopark, source (Biopark Terneuzen, 2012)

This led, to the initiative known as Warm Co_2 between the fertilizer factory and the port through which the residual heat and residual Co_2 are being utilized by the greenhouse horticulture companies present in that region. Biopark Terneuzen and Ghent Bio economy valley had built a R&D facility to promote innovation towards bio-based economy. Smart Delta Resources (SDR) is an initiative by the energy companies and industries in the Zeeland region to reduce their energy and raw materials consumption through synergy among them, which is being supported by the NSP. Sloe Heat is a residual heat cogeneration among the port recycling plant, Zeeland refinery and other two companies located in the port region of Vlissingen, Multi Utility Provider (MUP), is an underground pipeline system through which the residual energies are interchanged between the industries in the Ghent-Terneuzen canal region (Invest in Zeeland, 2019). The results from the content analysis on the port annual reports are presented in the table 4-4.

[8](Zeeland Seaports, 2019), The Zeeland Seaports comprises of Port of Vlissingen and Terneuzen since 1998

ML	Coding Category	Annual Reports	References
1	Waste Management	19	43
2	Sustainable Infrastructure	18	44
3	Energy Management	17	48
	Residual Heat/Steam	16	40
	Onshore Power	6	9
	Renewable Energy	18	64
4	Port Cluster- Bio Cluster & Bio-Parks	23	101
5	3I		
	Innovation (R&D)	19	66
	Investments	17	45
	Incubator	11	24
6	Circular Supply chain	1	1
7	Port Circular Business	-	-

Table 4-4: Result of Content Analysis of North Sea Port

4.3.4 Port of Antwerp

The port of Antwerp is the second largest container port in Europe, located at 80 kms inland which is contributing towards providing more coherent and sustainable transportation to and from the European hinterlands (Port of Antwerp, 2017).

In 2010, the port of Antwerp setup its sustainability steering group and initiated in the process of mapping and reporting their sustainable initiatives and long-term vision to become a sustainable port, which begin the publication of the port's sustainability report, which was considered to be one of its kind and they issued their report biannually. Totally they have released four sustainability reports from 2012-2017 and the latest report presented their present developments on sustainable transition and future strategies for 2030-2050. The latest report were drafted in context of UN sustainable development goals (SDG)[9] for their transition to a sustainable port and addressed circular economy as one of their strategy (Port of Antwerp, 2017). For the content analysis, 6 annual reports for 2004 -2009 and 4 sustainability reports for 2010-2018 were used as the textual data. Since the sustainability reports were more detailed in their transitions and initiatives related to energy, sustainability, innovations, circular economy relevant for this analysis they were used instead of annual reports. You have to write about the sub codes for each selected maturity level!

ML	Coding Category	Annual & Sustainability Report	References
1	Waste Management	10	71
2	Sustainable Infrastructure	9	25
3	Energy Management	10	57

[9] (United Nations, 2019) The united nations adopted 17 sustainable development goals in 2015, as the foremost plan to build a better world for the people and planet by 2030

	Renewable Energy	10	46
	Residual Heat/Steam	7	24
	Onshore power	4	7
4	Port Cluster- Bio & CE	4	24
5	3I		
	Innovation (R&D)	10	42
	Investments	8	22
	Incubator	7	32
6	Circular Supply chain	-	-
7	Port Circular Business	-	-

Table 4-5: Result of Content Analysis of Port of Antwerp

4.4 Chapter Conclusion

As explained in the Methodology, in this chapter to answer the research question of this dissertation four seaports had been selected in the NW european region for the multi case study. From these four seaports the port documents i.e. the annual report and sustainability report from 2004-2018 were collected and used for executing the content analysis. It begins in presenting the procedures for performing the content analysis on the port documents followed by the brief explanation on the selection of the four seaports in the NW european region. After which the analysis is performed on the secondary data and before tabulating the outcome of the content analysis, a brief description of circular economy strategies is presented for each port. Thereby the results and the analysis are presented in the next chapter

5. Results and Analysis

This chapter presents the result and analysis of the content analysis performed on the port documents of the selected four seaports in the north-western European region, in the previous chapter. The result of each port is represented and analysed by the following:

The Hierarchical Chart: The chart is generated from the outcome of the nodes coded for each port. The colour represents each node, the area occupied by each code and the intensity of colour refers the number of nodes coded per each coding category. In the chart the coding category are organised in a hierarchy from most discussed theme to the least mentioned theme of circular levels in their port documents.

Graph plot of circular maturity level: After analysing the circularity levels or maturity levels for each seaport, the respective level for each year is mapped and presented in a graph plot which shows the developments of the circular economy starting from the waste management to higher-level respectively.

Word Frequency: Word cloud is generated from the coded unit i.e. the coded sentences from the textual data. A representation of frequently occurring words in the coded sentences. This is not taken into consideration as the main result hence it is mentioned in appendix 2.

5.1 Circular Maturity - Level of Port of Amsterdam

The total number of annual reports analysed for Amsterdam Port was seven from 2012-2018. A generic search for the term *"Circular Economy"* was done to check from when the port started discussing the concept and it was in 2013 report the port authority addressed CE explicitly as one of their strategies towards their vision 2030. With the obtained results, tabulated (refer table 4-2) in the previous chapter under section 4.2.1 the hierarchy chart of nodes coded was generated for the Amsterdam port which is represented below figure 5-1.

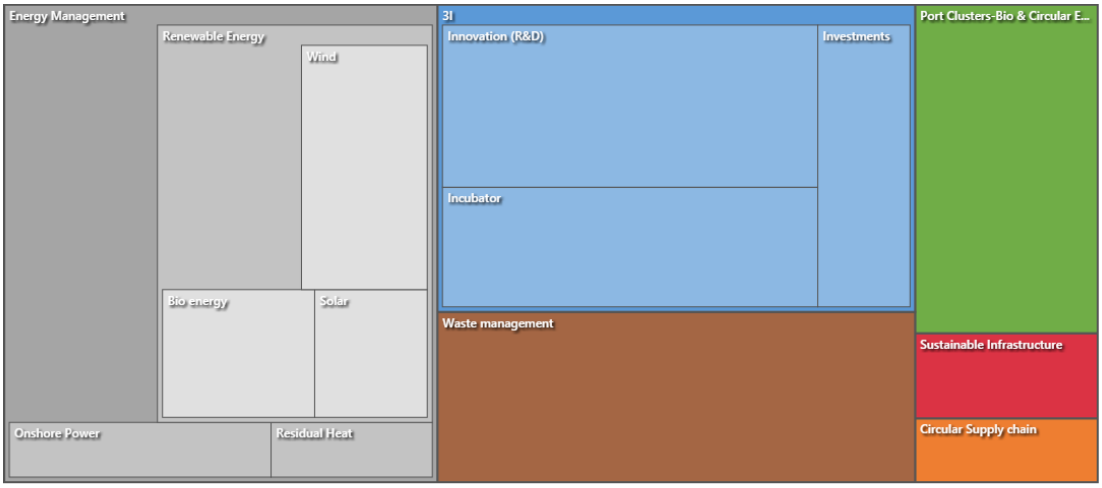

Figure 5-1: Hierarchy Chart of Nodes coded for Port of Amsterdam

As per the total number of coded sentences in table 4-2 per each circular maturity level, they are arranged in an order of highly coded to least coded in figure 5-1, thus the chart represents the hierarchy of the codes. For the coding categories of energy management and 3I, sub-codes were developed to code the sentences in their respective themes, through which a clear view of the discussed circular themes are perceived. The interpretation of the hierarchy chart is explained in the context of the circular maturity levels which are as follows.

Waste Management: The code represents the first level of circular maturity in the seaport. Through their waste management plan, the port supervise the disposals of waste from the ocean-going vessels and cargo residues from the maritime traffic and ensured in recycling rather than dumping in the sea and through collaboration with other companies in the port area they initiated projects in recovering raw materials for reuse from the waste through recycling (Port of Amsterdam, 2012). The companies in the port regions are actively involved in the recycling of household wastes and imports of waste from the UK for recycling cited as the growing opportunity contributing towards the expansion of recycling business clusters which stimulates the circular transition (Port of Amsterdam, 2013).

For promoting the CE in their industrial cluster, the port authority encourages and helps the companies focusing on recycling and reusing projects such as organic materials into biofuels or biochemical products, thus developing the bio-economy too in the port region (Port of Amsterdam, 2014). Thus, the recycling cluster of Amsterdam port developed significantly as a supplier of raw materials for the chemical companies with waste as a new commodity.

To promote CE locally the Port authority along with Amsterdam municipality and other companies initiated a three-year program- "Clean water in and around Amsterdam" to retrieve the floating plastic debris from the inland waters and shore side, recycle and reuse them (Port of Amsterdam, 2016).

In 2017/18 the developments and progress towards the circular and energy transition of the port and its cluster was a major theme of their annual reports. The port aims in 2019 to expand the waste separation process to recover the raw materials from the combined domestic and imported wastes and convert them into clean energy and reusable raw materials (Port of Amsterdam, 2017a). In the chart, the node of waste management is ranked third as per the results in table 4-2.

Sustainable Infrastructure: As per the hierarchy chart above it can be noted that the sustainable infrastructure representing the second circular level is one of the lowest discussed themes in their documents. The circular initiatives under sustainable construction had been exclusively presented in the previous chapter under section 4.3.1

Energy Management: The nodes of the energy management representing the circular level 3 had been positioned as the foremost theme for Port of Amsterdam. The coding category of energy management accommodates three sub-coding categories out of which the renewable energy dominates over onshore power and residual heat. the port adopts wind, solar and bio-energy as the significant renewable forms which are depicted in the above chart and wind occupies more area from which it can be recognised that port's interest in renewables lies with wind energy. About 37 windmills are existing in the port region with 64 MW capacity and its capable of supplying energy to 40,000 households. The port plan to increase capacity to 100 MW by 2021, through which green hydrogen is intended to produce(Zeeland seaports, 2016) on large scale, thereby port transits as a climate-neutral port and circular port (Port of Amsterdam, 2013, 2016, 2018). From 2012, the port involved in developing bioenergy in the port through which they intend to decrease the CO_2 emission in the port area and more recently they started to build a bioenergy plant which utilises the wood waste sourced from the city as raw material to create sustainable energy and heat. solar energy is equally developed in the port zone, so far they have an approximation of 33,000 solar panels. (Port of Amsterdam, 2018).

The above analysis identifies the port circularity level 3 from 2012. In 2018, it was reported that circular economy and energy transition transformed the port as an ideal place for innovation players and existing companies for circular projects, hence it was quoted "*The Circular Economy and Energy transition are increasingly leading to interdependence and integration between traditional port business and game-changers"* (Port of Amsterdam, 2018).

Port Clusters and 3I: These two codes represent the circular level 4 and 5 respectively where the nodes of 3I with sub codes of Innovation, Investments and Incubator is positioned at the second in the above chart. In 2014, the port authority performed seven research projects in the energy transition to develop the circular economy and bio-economy. The port clusters were focused on the bio-economy and approached a circular economy through innovations and investments. The production of bioenergy in the cluster region increased due to the increased recycling activities hence with the strong energy management they moved towards the initial phase of maturity level 4.

From 2015 to 2017 the port focused on strengthening their bio clusters and circular economy initiatives through investing in their incubator Prodock and clean capital to facilitate innovations in circular projects. With their strong bio clusters, the Port of Amsterdam evolved from level 3 to level 4 of circular maturity in 2016 and 2017. With just mentioning the concepts of CE in 2012, the annual reports presented a separate chapter of CE initiatives and their progress and in the 2018 report one of the main themes discussed by the port authority and their stakeholders were their circular transition

Evolving into plastic recycle hub, it made them a circular plastic hub in the country and they also mentioned that the circular transition would lead to lower their raw materials throughput in the upcoming years. The year was full of innovations in circularity, key developments were the rising level of waste recycling, new business initiatives like IGES- a plant is constructed to process the non-recyclable plastics into fuel, production of energy based on biowaste. Thus, with all the circular projects the port increases its added value in the region. The port authority started a study on the expansion of their incubator Prodock, which is the space for innovations and startups. With the above-mentioned circular innovations, the port is in the transition towards the circular level 5 in 2018.

<u>Circular Supply chain</u>: The theme of the sustainable supply chain was coded under this category. Due to the transition of the bio-based and circular economy, new flow of cargoes have emerged but some of the cargo flows originate from certain countries that are socially and environmentally not responsible. Thus, to address this Amsterdam port adopted the responsible supply chain policy in their sustainability agenda and through their document "cargo that carries responsibility-2018" expressed their vision of supply chain and this led the port authority to frame and adopt a policy for circular and sustainable purchasing (Port of Amsterdam, 2018). Thus, the least coded circular supply chain are in their initial stage in the form of port policy.

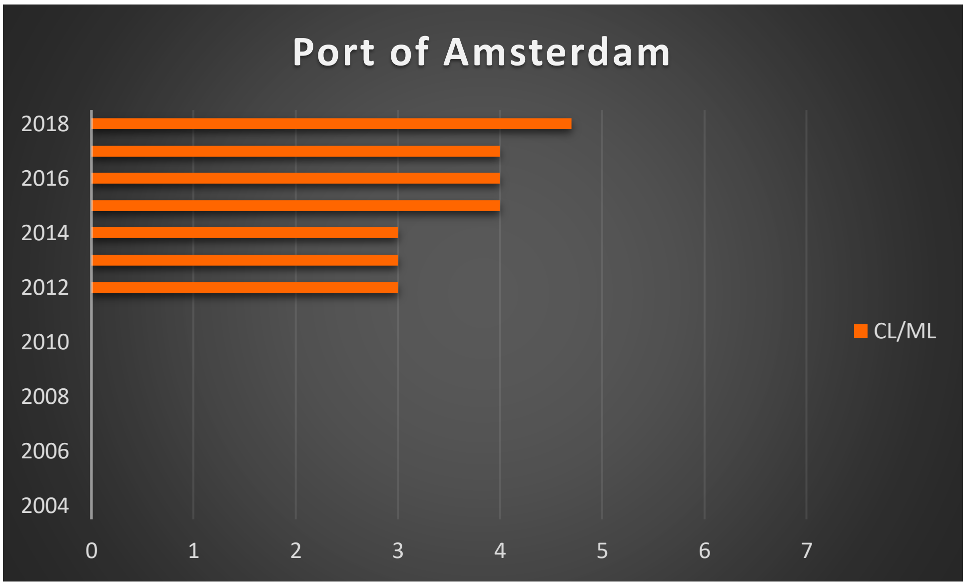

Figure 5-2: Graph plot of circular maturity level at Amsterdam port

With the above interpretation of circular levels as per the results, the evolution of circularity at Port of Amsterdam from 2012 to 2018 is mapped and plotted, refer figure 5-2.

5.2 Circular Maturity - Level of Port of Rotterdam

In the case study of the port of Rotterdam, 12 annual reports were analysed within the period from 2004 - 2018. The generic search for the term *"circular economy"* appeared first in the 2013 report as promising initiatives and new opportunities for future growth. The Hierarchy chart of the nodes coded for the port of Rotterdam was generated as per the output of the content analysis which is tabulated and presented in section 4.3.2 of the previous chapter.

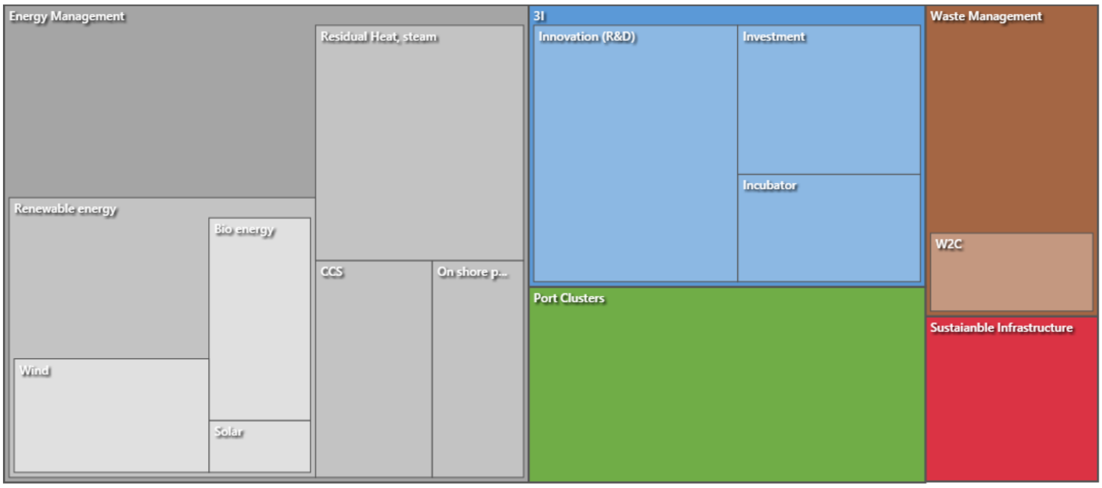

Figure 5-3: Hierarchy Chart of Nodes Coded for Port of Rotterdam.

The analysis of the circularity levels are as follows:

Waste Management: As per the result of the analysis, the theme of waste representing the circular maturity level 1 had been discussed in all annual reports. Under this code, a sub-coding category of W2C also coded to show the evolution of a circular economy from managing waste to creating value out of it. From 2005 to 2010 the port had collected and processed the ship waste through their waste management plan, developed enforcement strategy for shipping waste, engaged with Amsterdam port for inspecting the waste processing plants in the port area and through their shipping waste decree addressed the waste from inland waterways (Port of Rotterdam, 2005, 2008, 2010).

In 2013, the port explored the efficiency of reusing the waste due that led to initiatives such as port waste catch to reduce the plastic waste in the port area and sea and in 2016, through collaboration Rotterdam port decided to develop a waste-2-chemical (W2C) plant to breakdown the plastic waste into a valuable raw material for the chemical companies (Port of Rotterdam, 2016). Recognizing the potential of the circular economy the port expressed to become a plastic hub through developing the pyrolysis cluster in north-western Europe (Port of Rotterdam, 2018). From the hierarchy chart, it can be noticed that this theme is second to last and they promoted circularity in 2005 through recycling but since recent years port are stimulating circularity in waste management through innovations such as W2C and from the colour and size of this subcategory it can be referred as recent initiative.

Sustainable Infrastructure: The circularity level 2 is the least discussed the theme for the Rotterdam port, hence it is placed last in the above chart. The port engaged in circularity through utilising the dredged sands in port infrastructure constructions, instead of dumping them as waste and also they sold it to the third parties (Port of Rotterdam, 2005). The port planned to construct Maasvlakte 2 as the most sustainable port area and incorporated sustainability building practices in their contracts and they decided to assess the sustainability performance of the building through an internal assessment method for buildings provided by the BREEAM-NL (Port of Rotterdam, 2008, 2010). Circular initiatives at port of Rotterdam in the context of infrastructures include reuse of concrete blocks for the construction of hard seawall, reuse of residual materials from old quay walls to construct longitudinal dams to deepen the shores (Port of Rotterdam, 2012, 2014) and more recently construction of Princess Amalia viaduct using beaumix instead of sand obtained from incineration of 230,000 tons of waste (Port of Rotterdam, 2018).

Energy Management: From the above figure 5-3, it can be clearly seen that the port of Rotterdam is in the phase of the energy transition. Thus, the theme of circular level 3, representing the energy management occupies the first position and more area in the hierarchy chart**.** Under this code, there are four sub codes arranged in the order of renewable energy, residual heat/steam, CCS and onshore power accordingly. From 2010-2014, the port evolved into maturity level 3.

In 2008, the port authority looked into the opportunity of new business opportunities for new sustainable forms in the industry through the strengthening of port clusters. In the same year, the developed their own sustainability index to measure the port's progress in achieving sustainability. They based this index on three P's of sustainability and focused on *"Planet"* for which they begin assessing the CO_2 footprint, hence they discussed the project of Carbon Capture and Storage (CCS) project (Port of Rotterdam, 2008). Initially the port phased into circularity maturity level 3, through setting up the steam pipe for transferring the residual heat in 2010 and at the same year the port set up their ambitious target of becoming a CO_2 neutral port and ventured into the projects such as CCS, shore-based power for the ships arriving at ports, usage of biomass, further developments of waste processing units in the port area and residual heat, steam transfers.

In the following years the port invested in renewable energy sources wind, solar and bioenergy, and residual heat, steam transfer was one of the most discussed topics under energy management in their annual reports. The Port of Rotterdam laid their vision report 2030 basis on their energy transition and circular economy is not mentioned explicitly in their report (De Langern and Sornn-Friese, 2019).

In 2018 report the port refer circular economy as inextricably linked to their energy transition where implementing circular principles of recycling, re-use will encourage non-fossil based materials in the port and its cluster thereby achieving a reduction in the greenhouse emission in the region (Port of Rotterdam, 2018, 2019b)

Port Clusters and 3I: From 2015 to 2017 the port is in the circular or maturity level 4 (Port Clusters-Bio & CE). At the same time, the bio-cluster of the port was in constant development and innovation. In 2014, the port recognised CE as one of the concepts for their energy transition and sustainable production thereby they started to recruit bio-based chemical companies, investing in circular projects and facilitated innovation through their collaboration with Yes! Delft, an incubator for startups._After the Paris agreement(United Nations Cliamte Change, 2016), it becomes a central theme in the annual report 2015 of the Rotterdam port.

They placed their ambitious energy transition in lieu of the Paris agreement and in terms of innovation the port authority involved in 3D printing and following years innovations like Waste to chemicals (W2C) were initiated.

Mapping the circularity levels or maturity levels as analysed above from the hierarchy chart they have plotted accordingly and represented in figure 5-6. In the plot graph, the maturity level for three years was not assigned due to the unavailability of annual reports.

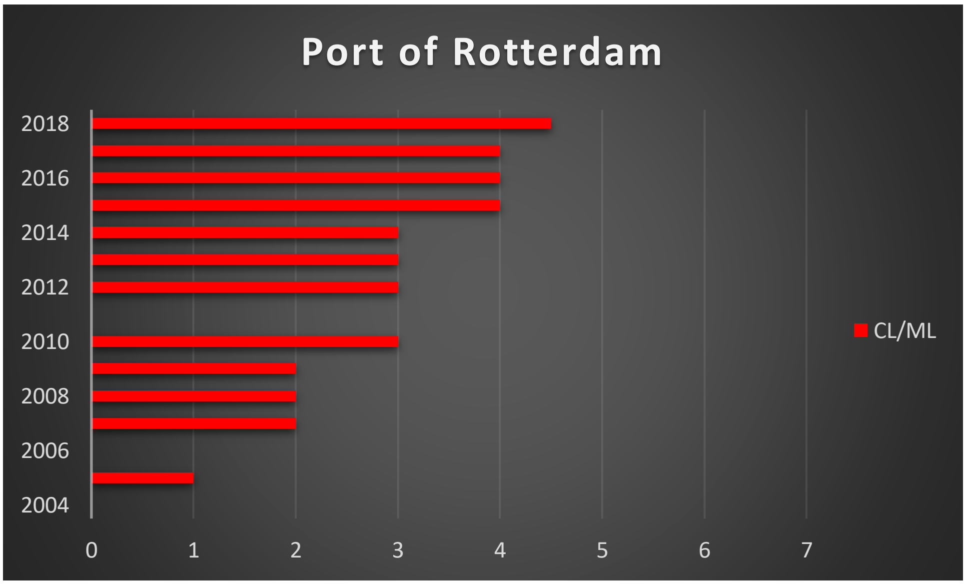

Figure 5-4: Graph plot of the circular maturity level of Rotterdam port

5.3 *Circular Maturity Level of North Sea Port*

As explained in chapter 4, section 4.2.3 North Sea Port (NSP) is a cross border merger between the Zeeland seaport and Ghent port company. For the analysis, a combined total of 23 annual reports of Zeeland seaports (14) and Ghent Port (9) were analysed. The generic search of the term *"Circular Economy*" was repeated and found out to be first mentioned in the 2016 annual report of both seaports.

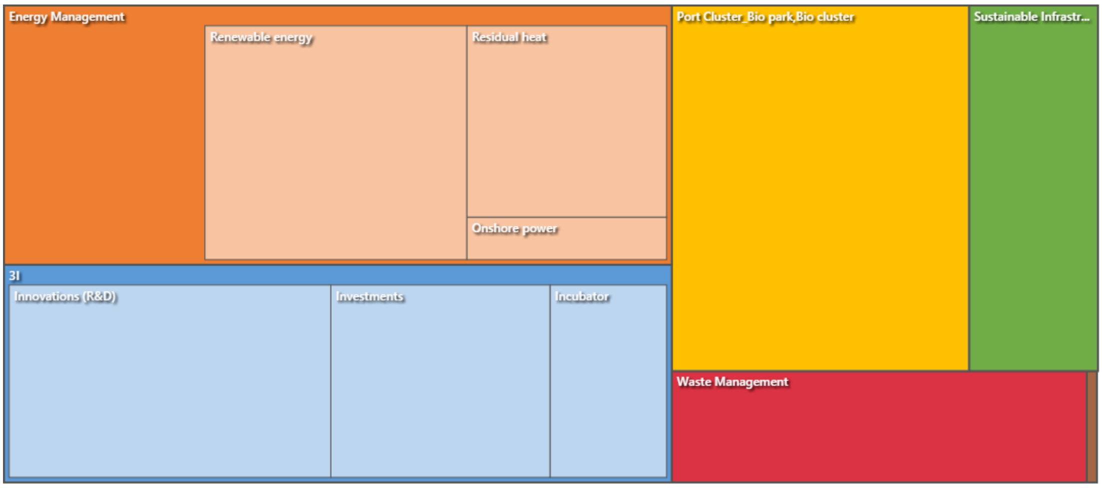

Figure 5-5: Hierarchy chart of coded categories of North Seaports

The above chart is generated from the combined results of Zeeland seaport and Ghent port which is tabulated in the previous chapter in section. The analysis of the above chart in the context of the circularity levels are presented as follows:

Waste Management: The theme of circularity level 1is the least coded which can be deduced from the position of the waste management in the above chart. Zeeland seaports actively engage in waste collection and processing of the ship's waste. In 2004, the delivery of the ship waste was made mandatory in the Dutch ports which initiated the Zeeland seaport to draft their waste plan accordingly and to attract ships to dispose of their wastes they reduced the handling charges of waste by 20%. Thus the ship-related waste increased in the port and they decided to collaborate with other companies to recycle and reuse the waste streams (Zeeland seaports, 2005, 2007).

Realising the environmental benefits, the companies in Biopark Terneuzen begin to use each other's waste as raw materials (Zeeland seaports, 2010), in 2013 the port authority realised the potential of waste to energy plant for supplying steam to the chemical industry located in the port area and to address the plastic waste they joined the green deal plastic to collect, segregate and process the waste (Zeeland seaports, 2013, 2016).

The Ghent port, to utilise the waste streams involved in inventorying the waste streams generated by the companies in their zone, in 2013 and the following year the industries started to use the waste from one factory as a raw material by the other in the cluster (Port of Ghent, 2013, 2014).

The above paragraph summarises the circular initiatives in waste management by the NSP through which they are initially positioned in circular level 1 in 2004 and 2005

Sustainable Infrastructure: Both the seaports had involved in sustainable infrastructure in their port area. In the chart, it is ranked as the second last circular theme as per the coded outcome. The Zeeland seaports collaborated with chemical company Dow Benelux B.V to develop the Value park Terneuzen as a sustainable industrial complex and due to the existing horticulture sector in the region, the port stimulated initiative such as glass garden to develop a large scale greenhouse horticulture area (Zeeland seaports, 2004), later years they developed it.

The port achieved a small-scale circular project through innovation were using the waste streams manufactured bio-asphalt and used them to lay a road in the port area. Through this success the Zeeland seaports involved in laying a small portion of the road between Denmark and Finland using the circular material bio-asphalt (Zeeland seaports, 2015, 2016). In the Flanders region, the Ghent port involved in implemented sustainability in their construction through circularity such as using the dredged sands to increase the height site areas in industrial zone and dock area, instead of discarding the cobblestones from the quay floors they reused it for construction in port area (Port of Ghent, 2008, 2009).

Energy Management: same as the above two Dutch seaports, for NSP the circularity level 3 representing the energy management is positioned first but the area in the hierarchy chart is not as same as above. The code contains three sub-codes of renewable energy which is the highest followed by the residual heat and lastly onshore power. Out of these three, renewable energy and residual heat are more discussed under the theme of energy management in their reports. Under renewable energy for both seaports, wind energy constitutes a greater source.

Zeeland seaports initially carried out a lot of feasibility studies to develop an offshore wind farm. In 2015, 30 wind turbines were erected on the offshore area (Zeeland seaports, 2015) and also carried out studies on developing a solar park in the port region. With the waste generated from their greenhouse, the power station generated green electricity and residual heat for the companies in their port cluster (Zeeland seaports, 2010). For Ghent, port wind turbines are a major source of renewable energy where they installed 13 wind turbines in 2009 and by 2015 they reached 39 wind turbines and aimed in increasing to 63 in the future (Port of Ghent, 2015).

Both the ports with strong bio-clusters produce green electricity using biomass. The potential of residual heat was acknowledged by Zeeland seaports in 2007 through engaging in supplying residual heat and CO_2 from their Biopark to the greenhouse for growing vegetables and in 2008 with the fertilizer company Yara they collaborated to form WARM CO_2, a circular project where the residual heat and CO_2 from Yara is supplied to the greenhouses in the port through underground pipeline and in 2011, development of another circular project Multi Utility Providing (MUP) was also discussed under which the residual power exchanges performed in Zeeland-Flemish canal zone (Zeeland seaports, 2007, 2010, 2011).

At the Ghent port, the residual heat system was developed in their industrial cluster. After 2010, both seaports developed onshore power installations for inland shipping to reduce CO_2 emissions. The above analysis on energy management concludes that NSP entered the circular maturity level 3 from 2007.

<u>Port Cluster and 3I:</u> The bio-cluster of both the seaports are analysed which represents the circular level 4. It is the highest coded category as per the table 4-4 and positioned in the chart after the circular level 3I from which it can be perceived that the theme of bio clusters dominates the other circular themes in both port documents.

In 2006, with the existing Agri-cluster Zeeland seaports looked into an opportunity to develop a bio-park to stimulate sustainable growth through using sustainable raw materials, efficient use of residual materials, reduction of CO_2 and reusing waste streams. This initiative aims to achieve sustainability through clustering or smart linking of the companies in the Biopark (Zeeland seaports, 2006). The year 2007 marked the official start of the Biopark Terneuzen and Valuepark Terneuzen, which clustered through the synergy of companies, logistics and service providers specialised in the chemical sector to achieve sustainable benefits (Zeeland seaports, 2007).

The above mentioned two major projects represent the bio-cluster of the port, in the Biopark the planned to develop greenhouses, biodiesel plants, biomass plants based on the cycle ecosystem thus the waste streams generated are used as smart links between the companies where they utilise the residual values instead of discarding them. WARM CO_2 is a successful project developed in 2010 at the Biopark (Zeeland seaports, 2010) which had been explained in energy management.

On the other side, Ghent port in 2008 decided to adopt more cluster concepts in the port area to control the entire production chain and in the same year they entered the bio-cluster by opening a biodiesel factory (Port of Ghent, 2008), to facilitate the biofuel cluster the port set up a bio base Europe pilot plant for innovations and training centre to educate and support the people for bioindustry. The Ghent port expressed its ambitious goal of evolving as the largest biofuel cluster in Europe by 2020 and actively developed the bio-cluster which made them a pioneer in bioenergy production and logistics in Europe (Port of Ghent, 2009, 2010).

By 2012, the port was responsible for 600,000 tons of biofuels, representing about 90% production in the Flanders region and the port decided to provide land of 100 hectares and 30 hectares for developing the bio-based chemical sector and recycling industries (Port of Ghent, 2012, 2015). From the above-detailed analysis, the NSP is the first seaport port to progress towards circular maturity level 4 in 2008, which is the first port to engage in the bio-based economy and they represent the strongest bio-cluster in north western Europe.

The 3I's coded to represent the fifth circular level of the seaport economy, with sub-codes Innovation being the most coded followed by investment and incubator. All their innovations and investments are largely based to develop the bio cluster of the ports and to achieve sustainability. Zeeland seaport developed a sustainability knowledge centre on the Biopark whereas Ghent port collaborated with Biopark Terneuzen and Ghent bioenergy valley to develop Bio base Europe- pilot plant to stimulate innovations through research and training (Port of Ghent, 2009). For promoting sustainable dredging, Zeeland seaports developed Seaport Innovation project in 2011 and realising the technology evolution they involved in developing a platform, the Smart Delta Resources (SDR) to match supply and demand through energy and commodities exchange which provide a competitive advantage for the companies involved in this platform (Zeeland seaports, 2011, 2017).

Thus, mapping the circular levels from the above analysis, the graph plot is presented for the North Sea ports in figure 5-6.

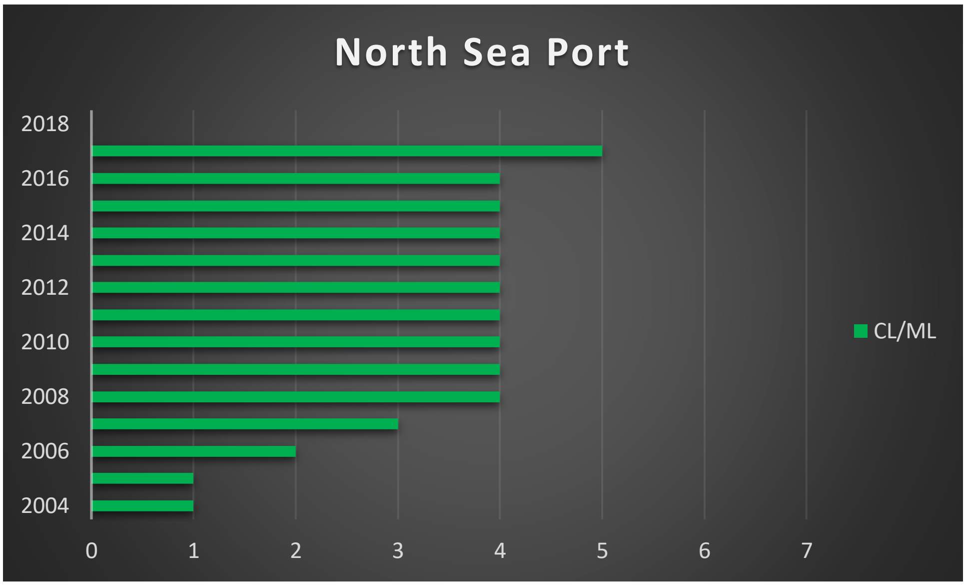

Figure 5-6: Graph plot of the circular maturity level of North Sea Ports

5.4 Circular Maturity Level of Port of Antwerp

As mentioned above for the three seaports, the generic search for the term *"circular economy"* in both annual and sustainability reports was done for the seaport of Antwerp and it appeared in both reports of 2015. The port authority addressed CE in their annual report by inviting the companies specifically involved in circular projects to utilise their available space at Churchill industrial zone (Port of Antwerp, 2015a) and mentioned that the port is evolving into a circular hub due to its recycling activities of critical metals and dangerous waste materials in their sustainability report (Port of Antwerp, 2015b).

The outcome of content analysis had been tabulated in the previous chapter in section 4.3.4 and the result are presented through the hierarchy chart of nodes coded in both reports, refer figure 5-7

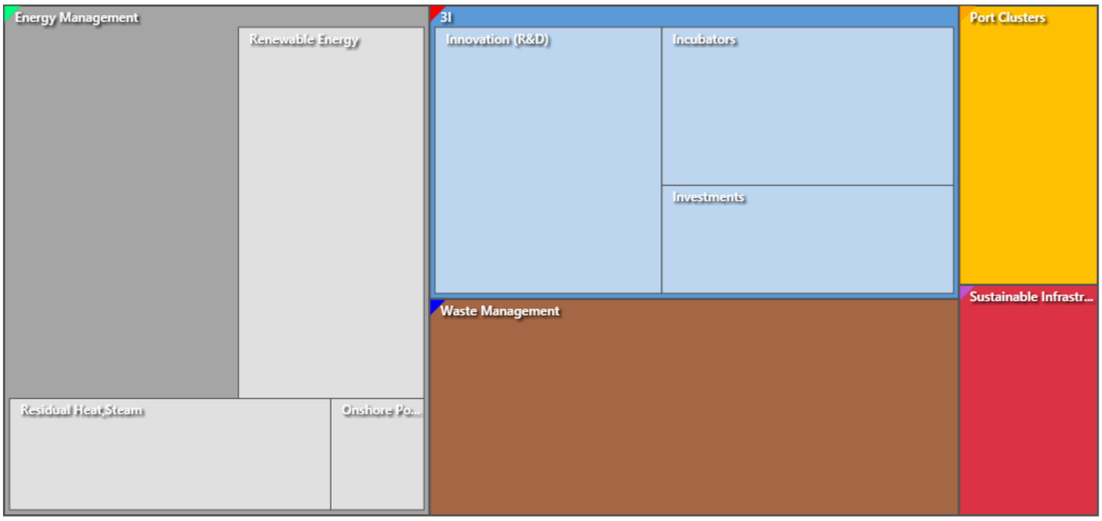

Figure 5-7: Hierarchy Chart of Nodes coded for Port of Antwerp

The summary of each coded category in figure 5-10, representing the circular maturity level are analysed as follows:

Waste Management: The position of waste management in the above chart is as per the number of coded references representing the theme of circular maturity level 1. From the analysed port documents, it can be explicitly identified that one of the strategic theme discussed by the Antwerp port authority is managing the waste flows with active waste management since 1996 (Vermeulen, 2016) and in 2004, the first waste processing system was established (Port of Antwerp, 2004). The waste flow in the port area is classified by port authority based on their sources it's being generated which are from industrial waste, ship waste, litter and floating rubbish (Port of Antwerp, 2012). The industrial waste is monitored by OVAM (Flemish waste management authority) and presents an annual report on the waste generated in the port's industrial cluster. The waste from the port companies are actively recycled and reused, the unrecyclable wastes are incinerated and energy is recovered thus through this circularity one company's waste serve as the raw material for other company (Port of Antwerp, 2015b). The port authority frame a waste management plan for collection and processing of waste from the seagoing ships as per the EU and Flemish regulation for every three years which begun in 2006 and to stimulate the incoming ships to dispose their wastes in the port, the ship operators are encouraged through a refund system where the paid waste collection charges are levied . To manage the waste from inland navigation they provide three waste park or waste centres for the barges to dump both hazardous and non-hazardous waste materials which are collected and sent to the waste processing facilities for recycling (Port of Antwerp, 2015b). The floating rubbish is collected every day by the condors to provide a safe and sustainable port (Vermeulen, 2016).

In the sustainability report (2017), the port authority explained that the circular transition of Antwerp port will be measured through two indicators where the tonnage of waste generated and processed in the port region is one of the indicators and other being employment and added value in the circular economy. the waste management indicator will be reported by OVAM based on the statistics and survey carried out in the port and its industrial cluster at the end of 2019 (Port of Antwerp, 2017). The waste management representing the first maturity level is stimulated by the port authority through their sustainable waste management, encouraging the initiatives for clustering waste flows in the industrial zone, closing the loop through collaboration between the port users (Port of Antwerp, 2009) and supporting their shareholders in their circular projects such as Flanders recycling hub and Antwerp metabolising flow of materials (Port of Antwerp, 2017).

Sustainable Infrastructure: As per the Annual report (2004), the port authority aimed in developing the ecological infrastructure network in the port region by adopting sustainable measures. Due to the expansion of cargo flow, increasing marine traffic and geographical position of the port led to the regular deepening of the Scheldt river. On contrary, the port authority faced a problem of processing and disposing the dredging spoil and to solve it they developed a sustainable project to extract the water from the spoils mechanically which was referred by the port authority as the viable solution for social, urban planning, economic and ecological reasons (Port of Antwerp, 2004). Thus, initiated in setting up a plant known as AMORAS (Antwerp mechanical water extraction and sludge recycling and utilisation) through which the dewatered spoil is obtained which can be used as a raw material for landscape restorations, construction works, and the plant is aimed to operational by 2010 (Port of Antwerp, 2005). In 2010, the design for the new port house was drawn as per the BREEAM assessment method to provide sustainable infrastructure and during the construction sustainable materials were used obtained from the AMORAS project and the building was opened in 2016, which had already mentioned in section 4.3.4 in the previous chapter. Also, the port authority used dredged sands from the Scheldt river for constructing a second sea lock instead of dumping them as waste and for constructing office and warehouses the port opted sustainable choices which also included the use of concrete made with recycled granules as per IRCOW project (Port of Antwerp, 2012). The above initiatives summarise the theme of circular maturity level 2 i.e. sustainable infrastructure and can be noted that it is the lowest coded category as per figure 5-10.

Energy Management: From the hierarchy chart it can be noted that the coding category of energy management representing the circular maturity level 3, being the largest and it contains three sub coding categories of renewable energy, residual heat, and onshore power from which it can perceive the port's transition towards sustainable energy. In the years 2004-2009, port authorities framed their energy policy to address the environmental issues and energy management to lower the carbon economy. They commenced with the aim to reduce the amount of energy consumption by 1% each year (Port of Antwerp, 2005) and during these years the port authority explored and invested in renewable energy thorough wind farm expansion with the vision of supplying green energy to the grid and initiated with two wind turbines and aimed at constructing 38 turbines with 90 MW capacity (Port of Antwerp, 2004), as per their energy policy they set up a multidisciplinary energy working party to assess the investment proposals in energy projects and investigated new possibilities in sustainable energy which led to the development of solar power, shore power, feasibility studies on hydropower and biomass and distribution network of waste heat.

The port authority replaced electric heating by residual heating system for one of their office building in 2008 and the following year they set up the first onshore power supply (OPS) for providing electricity to the ships visiting the port and stated these sustainable energy initiatives will reduce the CO_2 emissions by more than half in the port region. From 2010-2017, there was a significant expansion in the utilisation of renewable energy in the port even though combined heat and power (CHP) capacity dominated in providing sustainable energy. Previously they planned for the wind farm in the right bank and in 2013 the port authority planned to initiate another wind farm expansion project on the left bank to construct 55 turbines to become the largest onshore wind farm in the country (Port of Antwerp, 2010).

Given the largest chemical and petrochemical clusters, feasibility studies were carried out for developing the industrial residual heat system and also other studies were carried out in setting up biomass power plants with the aim of reducing GHG emission by 20% (Port of Antwerp, 2010). In 2015, ECLUSE steam distribution network was set up from which six chemical and logistic companies in the port region utilise the green heat for their production process and this circular initiative aims to cut the fossil fuel heating system of these companies thereby saving 100,000 of CO_2 emission per year and in the same year the port authority expanded OPS for their barges, set up 11 OPS for their tug fleet (Port of Antwerp, 2015b). As per their latest sustainability report (2017), the total installed renewable energy (solar, biogas, biomass and wind) capacity is 200 MW of which wind energy produces 122 MW (Port of Antwerp, 2017).

Port Cluster and 3I: The hierarchy chart ranks the 3I node for the port of Antwerp in the second position which reflects the port's circular innovations. The port has the largest chemical cluster in Europe and from 2006, biodiesel was produced in the port region. The chemical companies and energy companies begin to invest in cogeneration where the residual heat from industry serves as raw material to produce electricity (Port of Antwerp, 2006). One of the prime objectives of the Antwerp port for circular transition was further integration with its chemical cluster and promote innovation with its cluster. For which the port placed developing the pipeline network on its sustainability agenda (Port of Antwerp, 2015b). over the years the companies in the port involved in their own research and developments for circular transition, thus there are 121 companies actively involving in the circular economy and port reported through which there was a significant rise in employment and added value even though investments were less (Port of Antwerp, 2017).

The port set up its digital platform in 2012 where the case studies, research, and ideas were shared for sustainability (Port of Antwerp, 2012). The port involve in circular innovations through collaborating with knowledge institutes and companies involved with it and their circular innovations include researching algae as an alternative raw material which can be used by the chemical cluster of the port, Avantium project involving in bio-plastic, converting waste methane into ammonia, Catalisti- innovation in chemicals and plastics, Gyproc C2C – circular economy for plaster products and Car loop- circular economy for scarp cars (Port of Antwerp, 2017). The above analysis places the ports in circular level 4 from 2013 to 2016 and it approaches the circular level 5 from 2017.

Thus, mapping the above circular levels of the port of Antwerp in respective years, the graph plot of the circular evolution for the port is represented in figure 5-8.

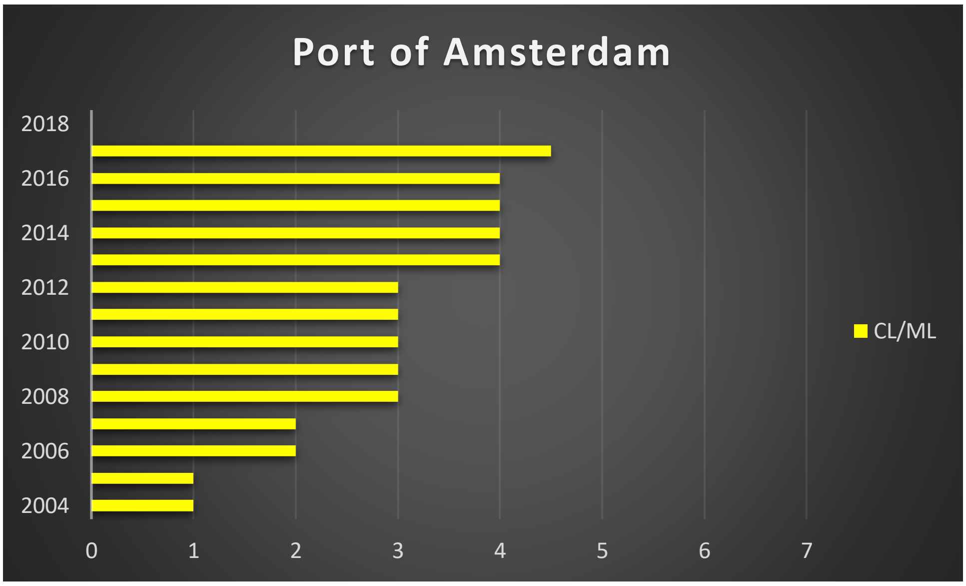

Figure 5-8: Graph plot of the circular maturity level of Port of Antwerp

5.5 Chapter conclusion

From the above analysis and results of the content analysis, this section answers the hypothesis to predict the possible seaport to be the first mover as a circular hub in NW Europe.

By compiling the graph plots generated for each seaport tracking their maturity levels, the figure 5-9 represent the circular level of all four seaports together from 2004 to 2018.

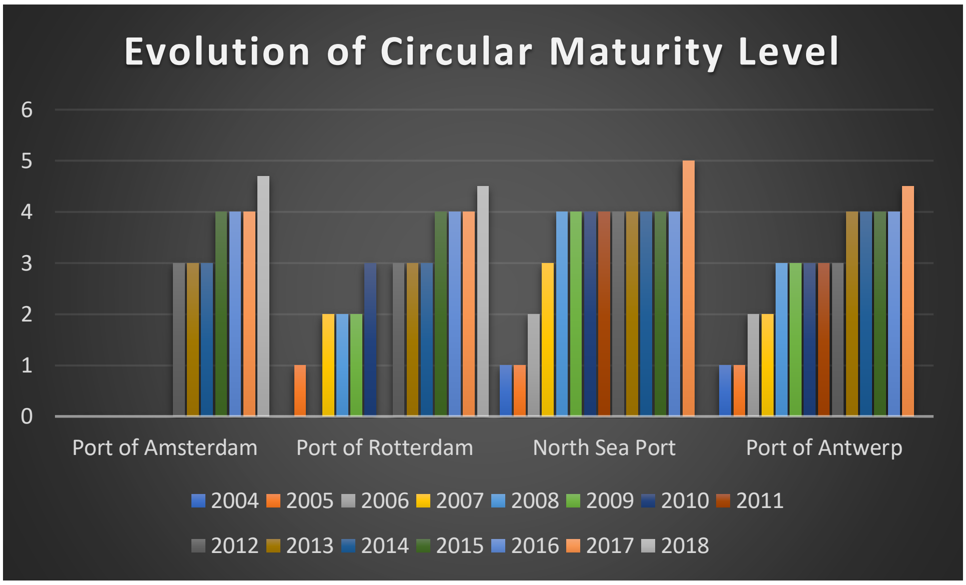

Figure 5-9: Evolution of Circular economy in four seaports of the NW European region.

From the above graph it can be examined that North Sea port is more mature and answers the formulated hypothesis for the content analysis. There by the main research question is answered.

6. Conclusion

This final chapter concludes the research study on the analysis of Circular economy implications at north western seaports. The first chapter presents the background and introduction of the research topic which was followed by the motivation for this study. Then the research question accompanied by sub research questions was presented along with the relevance of this research. With the illustration of the thesis structure, the chapter was concluded.

The second chapter was the literature review of the researcher's domain of interest for this study. This chapter begins with the review of works of literature answering the evolution and concepts of circular economy with its present world perspective. This laid a basic understanding of the circular economy. It was also an important aspect to have a clear view on the relationship and differences between sustainability and circular economy, thus relevant articles were studied and reviewed. Followed by the impacts of the circular economy on the ports were presented and the circularity trends on the ports found in the literature were summarised through a concept matrix. This in-depth literature study laid the theoretical background for developing and explaining the conceptual framework of circular economy implications on the seaports and maturity levels of the circular economy at the seaports. This chapter was concluded stating that very few pieces of literature available on the impacts of the circular economy on seaports.

Chapter three explained the methodology for the research study. It began exploring the reasons and limitations behind the reason for multi-case study analysis. Followed by the explanation on the method of content analysis, where textual data being analysed. Since no defined steps for this analysis, the author studied the relevant literature on concepts of content analysis and derived the five steps for proceeding the textual analysis and the chapter concluded with the limitation of content analysis.

In the fourth chapter, the steps developed previously for content analysis were followed and the port documents were analysed to answer the research question. The reasons for selecting the four seaports were discussed followed by the circular economy implications on those ports were presented. This was followed by chapter five were the results of the analysis conducted in the previous chapter are discussed.

chapter five presents the analysis of the results of the content analysis of the port documents. For each seaport, the results are presented with the hierarchical chart of coding references and word cloud generated from the most frequent words in the coded sentences to understand the themes discussed in their annual reports in the context of the circular economy.

6.1 The Research and Sub research questions

The research question is answered in three steps, firstly through in-depth literature study the conceptual framework is drawn, and circular levels are framed with the relevant explanations under Chapter 2. Secondly, through multiple case study approach four seaports are selected in the north west european region based on their circular transition. From the four seaports the data sourced are the textual documents of the port such as annual report and sustainability report. Under content analysis the framed circular levels are coded as coding categories with the sentences as coding units in, this is done under chapter 4.Lastly, in chapter 5 the results are analysed, and final outcome is that North Sea port is more mature in the region and will be the possible first mover as circular hub. The sub research questions are answered in Chapter 2 and Chapter 5

6.2 Limitations of the study

the outcome of this dissertation proposes North Sea Ports as the possible first mover to evolve as a circular hub in the North western European region, where the assumptions made in framing the circularity levels and in coding categories had to be acknowledged, which could influence the result. The foremost, limitation is the number of relevant literatures in the context of circular economy and ports. Very few academic studies and journals were available related to circularity and ports whereas studies related to circular economy and sustainability, circular supply chain, etc are available more.

The second limitation of the study is the scope and selection of seaports. With 14 seaports in NW European region, only four were selected for the case study since they had been spearheading the circular transition in ports. With a wider range of ports selected from different countries, the framed circular levels from this study can be used to assess their transition in their regional, national and world level which applies to inland ports too.

The final limitation was the textual data used for the content analysis. Annual reports for all and only for port of Antwerp sustainability report were included for the analysis. The process of sourcing the port documents was difficult since they were not available in their port websites and other sources. Respective department of the port authority was approached for collection of data, however, a total of 19 annual reports were not available. Not all annual reports were available in English, the only exception was Port of Antwerp and with other seaports collectively 17 were in Dutch which was translated and used for the analysis.

6.3 Suggestions for further research

Circular economy is a new theory and all the seaports are in transition. The concept is complex and further research should be encouraged under this. One of the limitations of the study is very less number of studies are carried out in this domain. Future research suggestions includes Port circular business models, how port can be competitive with circular business models and the concepts of sustainability and circular economy in context of seaport.

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Appendices

Appendix 1

Themes	***Ten Indicators***
 **Production and consumption**	*Self-sufficiency of raw materials for production in the EU*
	Green public procurement (as an indicator for financing aspects)
	Waste generation (as an indicator for consumption aspects)
	Food waste
 **Waste management**	*Recycling rates (the share of waste which is recycled)*
	Specific waste streams (packaging waste, biowaste, e-waste, etc.)
 **Secondary raw materials**	*Contribution of recycled materials to raw materials demand*
	Trade of recyclable raw materials between the EU Member States and with the rest of the world
 **Competitiveness and innovation**	*Private investments, jobs and gross value added;*
	Patents related to recycling and secondary raw materials as a proxy for innovation

Ten Key indicators to monitor the progress the transition of circular economy of each European country, source: adapted from (Eurostat, 2019)

Appendix 2: Word clouds for the four seaports

Port of Amsterdam

Figure A2-1 : Word cloud of coded categories for Port of Amsterdam

Figure A2-1, represents the word cloud generated from the word frequency of the coded sentences from the report. It can be interpreted that the more frequent words were circular, waste, energy, sustainable

Port of Rotterdam

Figure A2-2, represent the word cloud of the most occurred word such as energy, waste, sustainable infrastructure etc.

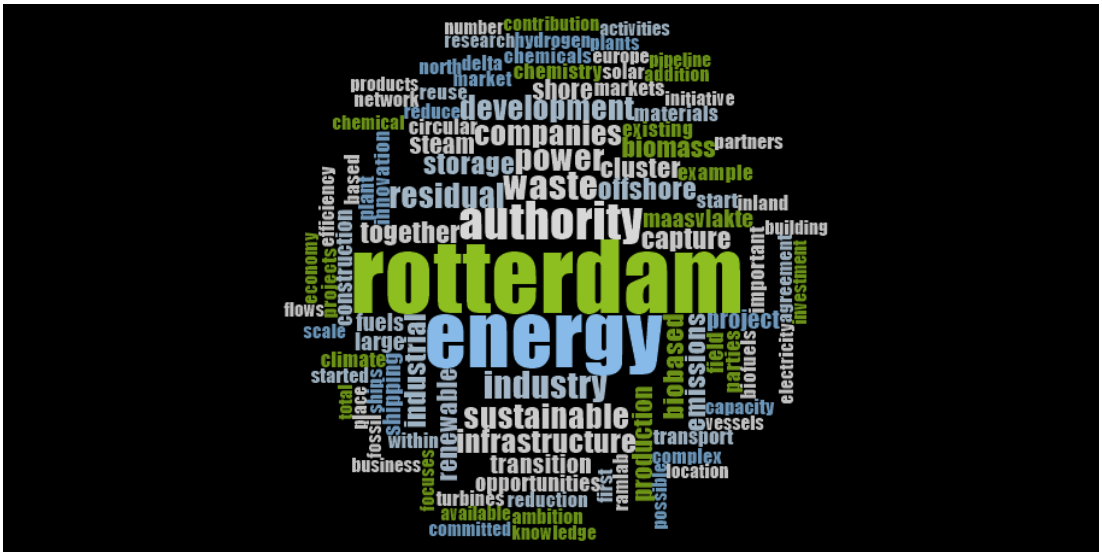

Figure A2-2: Word cloud of coded categories for Port of Rotterdam

North Sea Port

Figure A2-3: Word cloud of coded categories for North Sea Port

Port of Antwerp

Figure A2-4: Word cloud of coded categories for Antwerp Port