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Port innovation ecosystem, a symbiosis of capital; a case study of Rotterdam

Abstract

Ports and port cities are at the frontline of three major transitions – energy, digitisation and social - towards a post-industrial society. In their quest to move away towards a zero-emission, zero-waste society, some port cities in the world – including Rotterdam – view the imminent transitions as an opportunity and are explicitly profiling themselves as innovation ecosystems in post-industrial societies. In the current discourse on innovation in port-city ecosystems, the emphasis is very much on start-ups in post-industrial port areas and the conditions to facilitate them, such as governance mechanisms for easy knowledge crossovers. This paper takes a resource-based view and elaborate on an in-depth case study of Rotterdam. It is argued that innovation in port cities consists of visible and invisible symbiosis of capital: natural capital, industrial capital, human capital, cultural capital, social capital and creative capital. An innovation ecosystem does not solely flourish due to its proximity to the port, but also because of the extent to which companies are able to draw resources from this ecosystem, while at the same time sustain and nurture the ecosystem.

Keywords: *port-city, innovation, ecosystem, sustainability, creative capital, human capital, natural capital, social capital, cultural capital.*

1. Introduction

Ports and port cities are at the frontline of major transitions – renewable energy, digitisation, social transition and circularity - towards a post-industrial society. In port cities around the world, there is a renewed interest for ecosystems and an ecosystems services approach towards port and city planning and development. Being in coastal areas, in river deltas, port cities are vulnerable for the effects of global warming and consequential natural disasters (Von Glasow et al., 2013). At the same time, most post-industrial port cities are having to deal with areas where port operations have moved out, requiring new purpose. In the 1980s, port-urban areas were one of the most run-down sections of many cities, but as modern port operations moved away from the city, these abandoned areas had the potential to be transformed into more attractive, and accessible spaces (Hayuth, 1982). Today's post-

industrial port cities in Europe such as London, Hamburg, Rotterdam have turned into magnets for talent. Talented people are attracted by the concentrations of economic activities, universities, career opportunities and buzzing city life. Several policy instruments and programmes are implemented in cities across the world: smart cities, innovation ecosystems, start-up ecosystems. The question is how to turn talent into technology and entrepreneurship into innovation while sustaining the ecosystem.

To answer this question, I look back on the ideas, concepts and theories in the port-city and innovation ecosystem discourse, starting from the capital perspective. I summarise theories and models on the relations between port and city and explore a few perspectives on the 'sources of capital' of the port city, the inherited resources, which have accumulated over the lifespan of the port-city. I argue for an ecosystems approach, that is an open exchange of capital resources and critical for turning knowledge into sustainable innovation. Rotterdam is used as a case study to illustrate the symbiosis of capital resources: an ecosystem wherein companies attract talent, while at the same time sustaining the ecosystem and creating new capital through innovation and business renewal.

This paper is broken down in 6 sections. Section 1 provided the background to the problem and research question. Section 2 describes the theoretical framework for assessing the innovation ecosystem. Section 3 describes the methodology for data collection and visualisation. Section 4 describes the innovation ecosystem in Rotterdam. Subsequently section 5 covers the discussion. The last section 6 is for the conclusions and recommendations.

2. Framework to assess the port city innovation ecosystem

2.1. A capital perspective of the ecosystem

Port and port development have been studied by researchers from several research domains, often taking a monodisciplinary view. In the last decade scholars from different disciplines, including economists, sociologists, environmental scientists and transport geographers have attempted to give a more holistic perspective on port cities as ecosystems. United Nations posits that when companies and governments take an ecosystems approach, it makes them more responsive to new information and changing requirements. This requires an integrated social, environmental and economic perspectives (United Nations Environment Programme, 2020). The ecosystems approach, embedded in the Sustainable Development Goals, distinguishes three hierarchical layers: the economy is built on top of society, whereas society is built upon the biosphere (Stockholm Resilience Centre, 2020). One of the major challenges for ports is how to co-exist with their societies while preserving the natural ecosystems. A nexus approach starts from the realisation that there are strong and multidimensional

interlinkages, and that by a conventional fragmented approach, resources security - water, energy, food – are endangered, which subsequently will deteriorate the coupled human and natural systems (Liu, et al., 2015). A nexus approach to corporate sustainability aims to enhance resilience of the ecosystem by inducing companies to pursue a portfolio of activities, which are aimed to contribute to multiple SDGs through the creation of co-benefits, while minimising trade-offs between the SDGs (Van Zanten & Van Tulder, forthcoming). Ports have to develop green strategies and take responsibility in order to receive the licence to operate from stakeholders who live and work in the proximity of the port (Acciaro, 2015; Aregall, Bergqvist, & Monios, 2018; Lam & Van De Voorde, 2012). Inclusive port development places ports in the centre among governments, businesses and society and requires authorities to collaborate and search for complementary governance constellations that would benefit direct, indirect and even new stakeholders (Jansen, Van Tulder, & Afrianto, 2018). The ecosystem approach is a decisive element herein. The research framework presented in this paper, takes a 'capital' perspective on the ecosystem in the sense that the ecosystem is rich in its natural and human resources, which have accumulated over time. These accumulated visible and invisible sources of capital provide the resources for human and economic activities. Using existing concepts and models from environmental sciences, social sciences (economy, management), geography (urban studies) and sociology, the framework distinguishes six layers, going from tangible to intangible capital: natural capital, industrial (working) capital, human capital, cultural capital, social capital and creative capital. Such integrated perspective is considered fundamental to better understand the resources and relationships used and affected by an organisation. These capitals are stocks of value that are increased, decreased or transformed through the activities and outputs of an organisation (The International Integrated Reporting Council, 2013). The following paragraphs will shed light on each stock of capital in relation to the port-city ecosystem.

2.1.1 Natural capital of the ecosystem

The natural capital is defined as the stock of renewable and non-renewable resources, such as air, water, land, minerals and forests as well as biodiversity and ecosystem health, that combine to yield a flow of benefits to people (Natural Capital Coalition, 2020). From various disciplines, researchers have shown intrinsic interest in ports. Transport geographers studied the land-use structure and functional use of the port and port city space. Hayuth (1982) saw changes in the port-city interface which were having an impact both in the spatial system as well as in the ecological system. At the end of the 1960s, environmental protest groups which later turned into non-governmental organisations, such as Greenpeace were witnessing the deterioration of the marine ecosystem as a result of industrialisation, overfishing and marine pollution, which triggered scientists to advance knowledge on the externalities on human activities. Driven by profit optimisation, economists would consider them as negative

externalities, thereby leaving the costs and consequences to later generations. Port cities are in a pivotal position. From an ecological perspective, for cities there is no other way for self-sustenance other than to exchange resources and waste with the surrounding land: port cities need other cities and countries to provide for food and building materials (Rees & Wackernagel, 2008). In exchange they are the gateways for society, provide accessibility to markets and home for talent. This notion suggests port cities carry a great responsibility towards society. Being in these coastal zones these large urban and economic centres have the capacity to anticipate, adapt and innovate towards new realities. Von Glasgow et al. (2013) conclude that coastal mega-cities are at the frontline of change in a positive sense: changes (e.g. creating better quality of living) can best be implemented in these megacities, because they are generally more energy efficient, require less transport per capita, and because of these cities can regulate pollution, environmental management, and are places for education and innovation. De Boer et al. (2019) introduced the ecosystem-based port design hierarchy framework. This design framework shifts the focus from offsetting environmental impact to avoiding and reducing environmental impact as an integral part of planning and design. The framework is based on the integrated coastal policy via Building with Nature (Waterman, 2010). Such integrated approach is crucial for the co-existence of ports and port city communities in delta ecosystems and by doing so, it makes these communities resilient and adaptive to the effects of climate change and natural disasters.

2.1.2 Industrial capital and the ecosystem

From an economic perspective, port cities have been ‘staple places’, serving as a location for storage and trading of goods. With trade came capital, which accumulated over the years into prosperous, densely populated agglomerations. Porter’s cluster theory (1990) explains the strength and success of geographic concentrations of industries and economic activities. Competitive advantage in advanced industries is increasingly determined by differential knowledge, skills and rates of innovation which are embodied in skilled people and organisational routines. Port and their cities have physically separated because of scale economies of ocean-oriented operations and industrialisation (Hayuth, 1982; Hoyle, 2000), but the connections between remains important. Innovations and new combinations are more likely within the urban port spaces, because they provide more access to skilled labour, corporate and political decision-making power as well as a variety of complementary – highly knowledge-intensive economic activities (Hall & Jacobs, 2012). The cluster perspective provides a theoretical framework that can usefully be applied to ports (De Langen & Haezendonck, 2012). In principle the cluster theory is a model on competition, but as environmental management, sustainability and corporate social responsibility became more important port authorities engaged in stakeholder management and embraced corporate social responsibility policies. An ecological perspective that emphasises collaboration can make an

important contribution to how we understand and manage the world of organisations (Morgan, 1986). The switch from competition to collaboration is critical for survival in turbulent environments and for firm strategies, which are based on organisational ecology (Trist, 1977). Porter and Kramer coined the concept of shared value (2011) and the ecosystem of shared value (2016): organisations which creating economic value in a way that also creates value for a sustainable society by addressing its needs and challenges, will outperform organisations in ecosystems who don't. Shared value is not about winning or losing, but has a positive sum outcome for both economy, ecology as well as for society. The ecosystem of shared value is based on the idea that societal problems are too complex to solve by single actors and can only be solved by the coordinated efforts of those actors (Kramer & Pfitzer, 2016). To conclude with, the industrial capital perspective on ecosystems regards port cities as clusters of economic activity, which are competing in a global marketplace, however prosper on the basis of collaborative action and shared value creation.

2.1.3 Human capital and the ecosystem

Florida (2003) argued that human capital is crucial for urban-regional growth, which was already noted by Jane Jacobs in The Economy of Cities, 1969, in what is believed her most important work: it is the clustering of human capital, rather than the cluster of companies which leads to economic growth. There is a strong relation between regional income levels and technology, talent and innovation (Florida & Mellander, 2020). But what makes a city 'smart'? Caragliu, Chiara and Nijkamp (2011) define a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance. Cities speed innovation by connecting their smart inhabitants to each other, but cities play an even more crucial role in the developing world: they are gateways between markets and culture and gateways for ideas (Glaeser, 2011). Several countries are aiming to transform themselves into centres or hub of higher learning. For these education hubs, developing human talent is also a way to compete in the global knowledge economy (Lee, 2015). Edvinsson considers the knowledge port complementary to the traditional concept of a port. Instead of the flow of goods, it is about the migration of talent and knowledge. Today's flow of brains is critical (Edvinsson, 2006). The 'brainport' initiative in the Dutch city of Eindhoven is exemplary for the focus on coordinated efforts by governments, businesses and knowledge initiatives in advanced technology innovation (Horlings, 2014). In summary, the human capital perspective on the ecosystem is centred around the bundling of talent and technology into 'smart ports', 'smart cities' also referred to as 'knowledge cities' and 'brain ports'.

2.1.4 Social capital and the ecosystem

Several scholars have attempted to examine the way social capital affects the functioning of economic activity. Social capital stands for the ability of actors to secure benefits by virtue of membership in social networks or other social structures (Portes, 2009). Coleman (1988) distinguishes three forms: social capital creates obligations and expectations between group members, it has the capability to acquire and share information faster and easier, and thirdly, it sets norms and sanctions, which can enhance or hamper positive achievements by individuals. Social capital develops over a long period of time and is often anchored in institutions. Places with dense ties and high levels of traditional social capital provide advantages to insiders and thus promote stability, while places with looser networks and weaker ties are more open to newcomers and thus promote novel combinations of resources and ideas (Richard Florida, 2011).In contrast to open social networks, a closed aspect of social capital also has a downside: a closed group of actors could develop into a stronghold against other outside (groups of) actors, which subsequently could lead to upheaval between social groups. These could be worker's unions against employers' associations, supporters' groups of football clubs or closed-knit old boys' networks. Good governance creates strong and positive social capital (Avent, 2016). Even when there are strong stakeholder groups, the ability to accommodate conflicts is the product of good governance (de Langen, 2006). This makes social capital – in contrary to human capital - difficult to exchange and hard to share outside of the network. What it also implies is that performance tends to generate better returns in an environment where various forms of cooperation ensure a willingness to invest in the strengthening of the social group. Another difference between with human capital is that social capital is a public good, which is created when individual actors deliberately choose to invest – as volunteers, donors or sponsor - in the group or network for the greater good, without asking a direct return. This makes social capital often a by-product of other activities (Coleman, 1988). Why does social capital matter to cities? The social capital of the city comprises the networks and the horizontal and vertical connections that are present within professional groups and associations and that, as such, act as lubricants between institutions. Successful port cities know how to effectively utilise this capital, and in such a way that social problems are minimised. Moreover, sustainable port cities manage to bring prosperity while also maintaining balance with the ecosystem.

2.1.5 Cultural capital and the ecosystem

Cultural capital has been used by numerous studies over a span of four decades, starting with Bourdieu (1986). According to Bourdieu, cultural capital manifests itself in 3 ways: in the body and mind of a person (e.g. 'Ich bin Berliner'), in an objectified form of status - photos, paintings, books, instruments, machines, etc.) and in an institutionalised form, when culture

is widely recognised or confirmed, for example, by a scientific institution or publication. Throsby redefined the concept of cultural capital using it to stress the value of culture in economy. (Kisida, Greene, & Bowen, 2014; Throsby, 1999). He argued for a fourth type of capital for economic analysis, namely cultural capital. Cultural capital is the stock of cultural value embodied in a tangible or intangible asset, which in turn give rise to a flow of goods and services over time. The concept of cultural capital enables culture to be perceived as a resource - one that is accessible to people or not, or is scarcely available, may even lead to monopolisation or can be transmitted from one generation to the next (Lareau & Elliot B, 2003). Cultural capital reflects the nonmaterial benefits people obtain from ecosystems. This could be cultural diversity, spiritual and religious values, knowledge systems, educational values, inspiration, aesthetic values, social relations, sense of place, cultural heritage values (Daniel et al., 2012). Recreation activities and (eco-)tourism can turn these cultural assets into cultural services and thus generate economic value. By promoting and capitalising on a specific culture and identify of port cities, this allows residents to develop a sense of pride and flourish (AIVP, 2019).

2.1.6 Creative capital and the ecosystem

Creative capital denotes the ability of economic actors to generate scientific, technological and artistic innovation on the basis of relational assets which are socially produced within a city or urban region (Kratke, 2011). It is an arsenal of creative thinkers whose ideas can be turned into valuable products and services (Florida & Goodnight 2005). The creative workforce includes those employed in a wide variety of industries beyond the creative industries, including computing, engineering, architecture, science, education, arts and multimedia (McWilliam & Dawson, 2008). More importantly, companies cluster in order to draw from concentrations of talented people who power innovation and economic growth. The ability to rapidly mobilise talent from such a concentration of people is a tremendous source of competitive advantage for companies in our time-driven economy of the creative age (Florida, 2011). Driving forces for the knowledge city are conceptualised by Edvinsson (2006). These drivers are universities, society entrepreneurship, knowledge cafes/cathedrals (meeting places), diversity, strange attractors (marketing, branding) and ICT and multimedia infrastructure. Knowledge cities, smart cities, innovation, entrepreneurship and creative class are thus closely related with each other. Where Porter's cluster model reflected the conditions, the entrepreneurship ecosystem framework considers entrepreneurship as the output of the ecosystem. An healthy ecosystem is characterised by the ability to produce, support and nourish high-growth entrepreneurship (Song, 2019). In more recent years port cities have implemented policies to attract the creative class, especially in those areas where port operations activities had retreated and created open spaces indoors and outdoors. Several cities, such as Montreal and Rotterdam have embraced the concept of entrepreneurial

ecosystems, thereby attracting startups and incubator centres surrounding universities (Witte, Slack, Keesman, Jugie, & Wiegmans, 2018). There is also a downside to bringing talent, technology and innovation together in dedicated areas. Urban and economic theory suggests that a key contributor to innovation is the ability to bring together a diverse array of skilled and talented people with different backgrounds, but it could also imply more segregation between and within cities where income, education and job occupations is left behind. Recent research by Florida & Mellander (2020) suggest that metropolitan areas which become hubs for talent and technology are more innovative, but become more spatially sorted and segregated. This in turn may restrict the capacity for inclusive growth and innovation.

3. Methodology, data collection and mapping

In this study a qualitative data collection method is chosen for assessing the ecosystems approach. There is a need for information about the physical reality in which human life and work take place in port city regions and a need to move from abstract towards spatial visualisations (Hein & Van Mil, 2019). I have chosen for a method which blends the two approaches into one visualisation, using metro maps. The qualitative information was collected through inferential reasoning (Seel, 2012) and complemented with qualitative interviews have been visualised in structured summaries of information, which are called metro maps (Shahaf, Guestrin, & Horvitz, 2012). Such method helps people to have an overview of the complete ecosystem, which will then appear to be a knowledge landscape, where the complex network of entities is displayed, including the links and intersections. The visualisation allows users to easily make interpretations of the information at a holistic level, and interact with the model and make additions, adjustments while also making mental connections for themselves. For a metro map to provide for the holistic understanding, three criteria should be traded off: coherence, coverage and connectivity (Seel, 2012). Coherence relates to the objective for the metro map to be as complete as possible, while distinguishing between main institutions such as universities and smaller education facilities and partnerships which are worthwhile displaying. Coverage is another challenge. The map needs to be as complete as possible in telling ‘the story’ of the innovation ecosystem, e.g. one map for human capital and cultural capital, the message from the visualisation does not come to front. For this reason, the trade-off is to make separate metro maps. The connectivity is the third element to consider. For credibility we must show those connections the audience knows about yet adding too many connections would create a diffuse picture. Although there are software programmes and algorithms that allow for automatic generation of metro maps, the tool used in this study is Microsoft Visio. The advantage is the instant adjustments (compared to a computed model), thereby making it easier to add new labels. Disadvantage is the manual work is requiring developing the metro map for every new layer or every other city. Interviews with innovation experts, education directors and programme managers were

used to validate the output of the metro map modelling exercise. Subsequently, adjustments were done until a saturation level was reached.

4. Research findings

4.1 Mapping human capital of Rotterdam

The map in **Figure *1*** is built up of three components: 1) districts of complementary knowledge intensive activities, 2) an institutional hierarchy of knowledge intensive activities and 3) a placeholder (Jansen, Haveninnovatie-ecosysteem verpakt in metrokaart, 2019). Knowledge intensive activities are plotted as districts. The institutes per district have the same colours: education (black), research (light blue), innovation campus (dark blue), maritime offshore and safety training (yellow) and green (simulator centre). The hierarchy is such that it distinguished institutes from faculties, departments and specific field labs, laboratories and of knowledge activities of a smaller scale. The river Meuse which flows through the city of Rotterdam is the placeholder, which give the nodes and stations a geographic position on the map. Scales differ with reality; however, the location supports the mind in comprehending the ecosystem. A deliberate decision was made to only depict those institutions where knowledge-intensive activities related to education and research take place and where companies and educational institutions come together at innovation campuses, simulator centres and start-up incubators. In-house company R&D centres and training have not been included on the map.

The main nodes in the ecosystem are knowledge institutions such as Erasmus University Rotterdam, which was founded in 1913 by businessmen as a school of commerce. Delft University of Technology was founded in 1842 under King Willem II when there was a need to train more civil engineers and mechanical engineers to support the Netherlands in catching up with the industrial revolution. The Shipping and Transport College (STC) under its current name was established in 1990, but the maritime academy was established by the municipality in 1833, which provided fresh cadets for the merchant marine. Because of national education reforms, higher nautical studies were split in a maritime academy for vocational studies at the STC, while the maritime studies on a bachelor's level merged in the newly established higher education institution called Rotterdam University of Applied Sciences (founded in 1988). Other important knowledge institutes in the ecosystem are TNO (1932), Deltares, founded as Delft Hydraulics in 1927, merged in 2008) and Maritime Research Institute (1932). These nodes can boast a rich tradition and form the pillars on which the innovation ecosystem has been built.

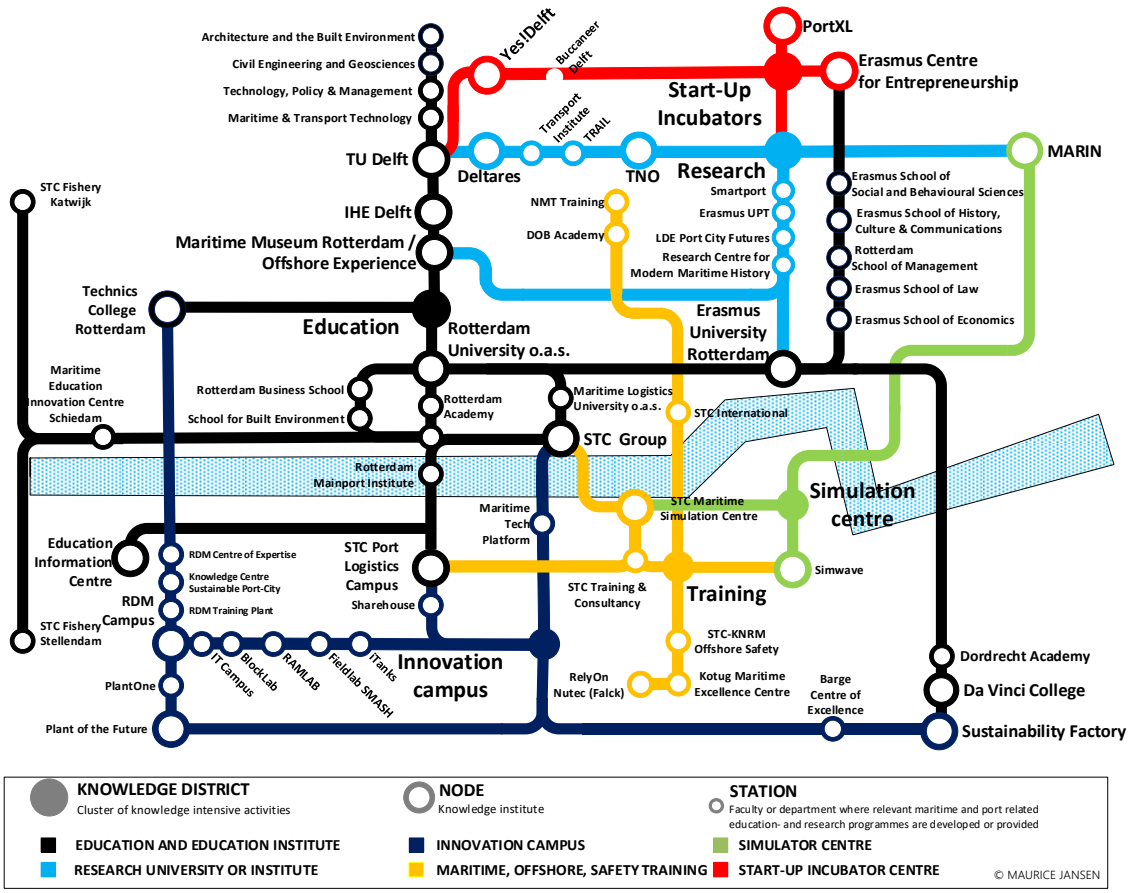

Figure 1: Human capital map of port city Rotterdam
Source: author's own

In more recent years, there have been partnerships between institutions, mainly driven by making optimal use of the maritime education and training infrastructure. A striking example is the institutional cooperation between STC and Rotterdam University of Applied Sciences under the name Rotterdam Mainport Institute, which initially was only centred around the higher nautical studies (BSc degree), but was extended in 2012 to shipbuilding, logistics engineering and chemical technology. A more recent example of institutional cooperation is the PortCityFutures programme, an initiative between Leiden University, Delft University of Technology and Erasmus University Rotterdam. Other partnerships between education institutes happen in so called centres of excellence aiming to exchange knowledge between education institutes and business. Examples of these kind of partnerships are Maritime Tech Platform, Sharehouse and Plant of the Future. These centres of excellence are public-private partnerships where joint investments are done in state-of-the-art training facilities and education programmes. These facilities are used for both initial education programmes as well as to support life-long-learning programmes within companies. Maritime training

simulators have always been part of maritime education, although not as sophisticated as today's equipment. Since the mid-1990s there was a growing need for training and certification of professionals, which opened a new business model for institutes. Especially STC saw this opportunity and started offering its education and training services to the private sector, which also accelerated the growth and sophistication of the maritime simulator park.

In more recent years innovation district started to emerge in the ecosystem, with focus in RDM's former shipyard at Heijplaat and in the M4H former harbour area. After the final closure of RDM shipyards, the quays, buildings and workshops were given a new purpose as part of the 'Stadshavens' redevelopment programme by the city and port authorities of Rotterdam. The RDM Campus was inaugurated in 2008, and since then the area has turned into an innovation district, home to start-ups and technical vocational education. The area hosts communities of practice, in which university students and business practitioners meet to design, develop and test new concepts and prototypes, such as aquadrones, and electric vehicles for city mobility and logistics. Strong dynamics have also developed around TU Delft and Erasmus University Rotterdam. Yes!Delft has been in existence since 2005 and is on par with the best start-up incubator centres in the world (UBI Global, 2019). Erasmus Centre for Entrepreneurship opened its doors in 2013 in the Science Towers, located in Merwe Vierhavens, a port area in transition towards a mixed port and urban use.

Also featured on the map are the Educational Information Centre (EIC) and the Maritime Museum Rotterdam. The EIC is included because the centre – which recently marked its 25th anniversary – has played an important role in introducing the port to younger generations over the years. By doing so, the EIC has made countless young inhabitants of Rotterdam aware of the possibilities of a career in the port and maritime sector. The Maritime Museum is important because it provides a platform for storytelling of the maritime present and past to a wider audience who is often unfamiliar with, thus connecting generations with each other. The Offshore Experience exhibition at the museum has been developed in close cooperation of and with co-finance of the maritime and offshore industry. Nowadays technical education is done at the museum as well, using the offshore experience as a classroom.

Rotterdam has seven almost complete maritime and port-related learning trajectories, which comprise 58 educational courses in total, fourteen of which at the master's level, nine at the bachelor's level, one associate degree, 34 vocational courses and two pre-vocational courses.

Table 1: education programmes per level and shipping segment

Learning path	Number of pre-vocational programmes	Number of vocational programmes (level 2, 3 and 4)	Number of programmes on Bachelor's level (level 5)	Number of programmes on Master's level (level 6)
Logistics & SCM		11	3 (incl. 1 AD)	3
Nautical studies (incl. inland shipping)		7	1	3
Sea Fishery		3	-	-
Shipbuilding / yachtbuilding		2	3	1
Civil engineering, dredging & offshore		2	-	2
Port logistics		6	1	3
Process industry & Maintenance		3	1	2
Pre-vocational, incl. port track	2	n.v.t.	n.v.t.	n.v.t.
Total number [1] of programmes	2	34	9 (8 BSc, 1 AD)	14
Totaal number of students [2]	800	5,750	2,700	2,000

(1) This does not include the related training courses, such as the woodwork and carpentry college (5) and related technical programmes e.g. automotive (17).
(2) Due to considerable fluctuations in the data files of Dienst Uitvoering Onderwijs (DUO), the Education Executive Agency of the Dutch Ministry of Education, Culture and Science, we have chosen to use the average number of registered students over the years 2015, 2016 and 2017.

The human capital map of the innovation ecosystem and its interpretation explains how authorities and educational institutions have jointly brought new life in desolated port areas. RDM Campus, a transition area on the neighbourhood of Heijplaat has been revitalised into a lively education campus and breeding ground for startups, although its distance from the city necessitates commuting, by waterbus. The Waalhaven South and East sides – also nominated for a transition - have been revived by development of the Port City I and II, reclaimed waterfronts where mainly ship agents and maritime service companies have their offices. Additionally, Shipping and Transport College built and extended the Port Logistics campus on its original and historic location. A slightly different approach is taken for Merwe Vierhavens, but also in this area urban offices, education institutes and startups are blended.

What we can conclude from the visualisations is that institutions form strong anchors for the innovation ecosystem. Port and city authorities have a strong influence how the old port areas are transformed for an urban purpose. Education institutions play an important role to bring life back in terms of students commuting to their school campuses. The consequence of these policy interventions is that education and innovation find root along waterfront areas, but relatively remote from the residential areas. Good public transport facilities are therefore crucial to enable traffic also over water to have high quality physical connections with the city. If innovation and entrepreneurship take place in these areas, what does it mean for the connectivity of other parts of the city with the port?

4.2 Mapping cultural capital of Rotterdam

A third way of visualising the innovation ecosystem of Rotterdam is by plotting cultural capital on the map (Figure 2). The same design principles were used where the districts reflect museums (purple) maritime heritage (dark red), trust/wealth funds (green), festivals (yellow), welfare organisations for seafarers (red) and maritime awareness (light blue). The placeholder is the river Meuse again, but the scale is larger, it includes also the port cities towards the west and south.

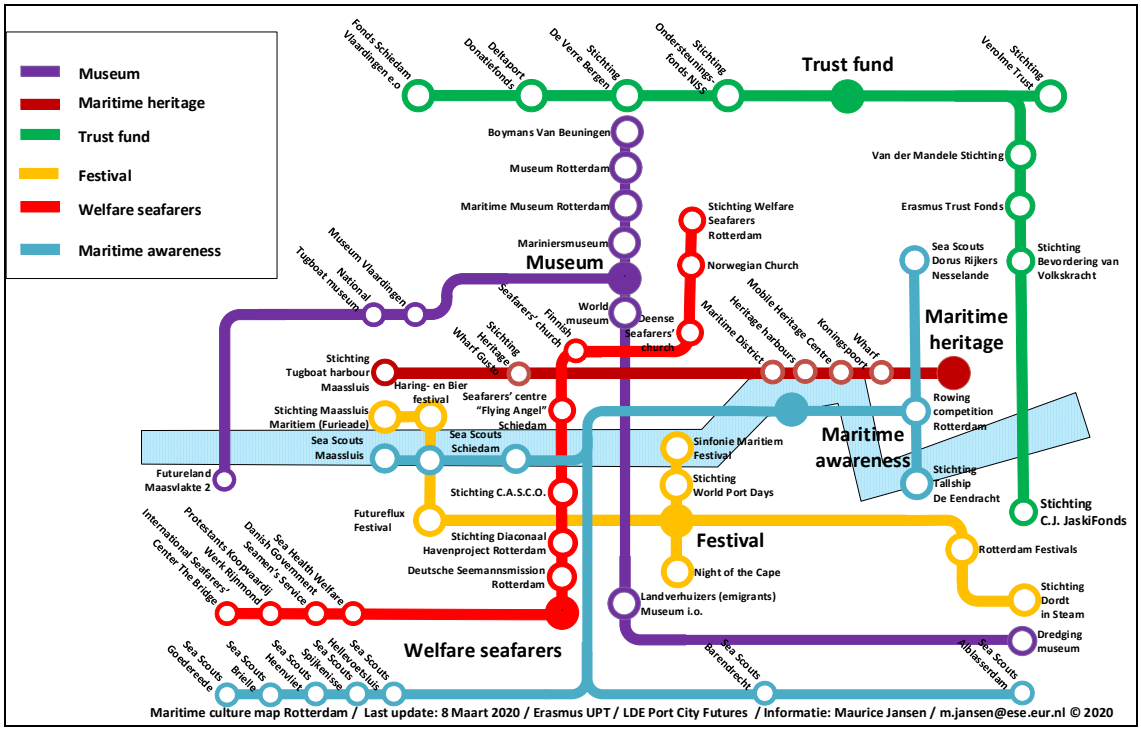

Figure 2: Cultural map Rotterdam
Source: Author's own

When cultural institutions are included on the map, there is a sharp contrast. Most cultural institutions, events, welfare organisations and maritime heritage sites are located on the north bank of the river or in the string of smaller port towns. It was Lodewijk Pincoffs who made the leap to the South side of the riverbank at the end of the 19th century. The docks at Feijenoord were developed at a rapid pace: Koningshaven (vml . Noorderhaven), Spoorweghaven, Binnenhaven and Entrepothaven. The municipality also made two cross-river connections: the rail bridge and the Willems bridge. How this venture ended is one of these peculiar port stories. Pincoffs fled to America and was sentenced in absentia to 8 years in prison for forgery and fraudulent trading. Due to its bankruptcy the port sites came into the hands of the municipality and thus formed the predecessor of the Municipal Port Authority. Due to economies of scale in shipping and advancing industrialisation, the area soon became too small for storage and cargo handling. New harbour basins to the west of the city were needed to cope with growth. The proximity of the port with city on the South bank was short-lived.

Seamen's houses moved away and settled closer to the port operations in Brielle and Hoogvliet. Rotterdam has a rich collection of port-city culture: port paintings in Boymans van Beuningen, ship model, charts and exhibitions, but also cargoships, cranes and lorries are kept in maritime heritage harbours. They tell the story of an illustrious past but are packed together between Coolhaven and Coolsingel. On the Kop van Zuid, maritime heritage got a second life, mainly for commercial purposes: Hotel New York, Pakhuismeesteren, the Entrepot building, Maas Silo and the SS Rotterdam have been converted for the hospitality and leisure industry. Further away from the port in Feijenoord and Ijsselmonde there are few educational and cultural institutions with a port-city connection. The North and South Bank of the two city districts are economically segregated in terms of income levels, education performance and average value of houses. Since 2012 there is a national programme, a taskforce to close the gaps with the rest of the city.

Table 2: Selected key figures, progress report 2018, National Programme Rotterdam-Zuid

Year 2018	Netherlands	G4	Rotterdam	Rotterdam-Zuid
Population	17,181,084	2,372,803	638,712	202,278
Inhabitants < 27 yrs / total population	31%	33%	33%	34%
Non-working working population (% of people 15 – 75 yrs)	7%	11%	13%	16%
Score CITO (last year primary school, 550 is maximum	535,5	534,2	534,1	532,6
% middle or higher educated (% of population)	70%	72%	66%	58%
% youth with start qualification, 18-22 yrs	69,8%	72,9%	69,4%	58,7%
% new dropouts from school (2016-2017)	1.8%	2.8%	3.1%	3.5%
Disposable income (2016)	EUR 28,900	EUR 28,000	EUR 25,600	EUR 22,800
Average value of house (WOZ, 2018)	EUR 230,000	EUR 254,210	EUR 168,053	EUR 124,769

Note: G4 stands for the 4 largest cities in Netherlands: Amsterdam, Rotterdam, Den Haag, Utrecht.

What seems to be missing is the experience, a heart and soul. We find this in festivals, where the locals relive their past for one day per year. Especially in smaller port towns, these local festivals have succeeded in making the connections with the past and present: the Furieade in Maassluis, the Herring and Beer party in Vlaardingen, the Genever Distillers' festival in Schiedam, Dordt on Steam and of course the World Port Days in Rotterdam. These are moments of joy. The Night of the Cape revives notorious days when seamen and red-light district brought lively entertainment. Various charity and welfare trust funds support small and local social projects which are aimed to strengthen social cohesion and stimulate bottom-up initiatives, but it remains difficult for people living in these city districts to catch up.

5. Discussion

Ports and port cities are at the frontline of major transitions – renewable energy, digitisation, social transition and circularity - towards a post-industrial society. For cities to sustain themselves it is important to realise that these cities are dependent on the global system of international trade and vulnerable to the negative consequences of overconsumption and global ecological mismanagement. Being in these coastal zones these large urban and economic centres have the capacity to anticipate, adapt and innovate towards new realities. In this research I examined the sources of capital, which can be utilised to successfully develop innovation ecosystems, while contributing to the urgencies of society. How do port cities turn talent into technology and entrepreneurship into innovation while sustaining the ecosystem?

Using literature from various research disciplines, I argue for an ecosystems approach toward sustainable innovation in port cities. The port city itself cannot be separated from its environment. For a symbiosis to happen the ecosystem needs nurturing, not neglect. The key to turn knowledge into innovation is the open exchange of both tangible and intangible capital resources in the port-city ecosystem. In existing literature there is ample evidence of the cross-linkages between the various sorts of capital. Human capital forms the heart, cultural capital forms the soul, social capital stands for the coherence of the whole and creative capital is the ability to create and innovate. What makes our port city ecosystem framework different is that these sources of capital are inextricable layers of the biosphere and society. Economy, human activity even social networks relate to the physical location, while the people living in these port cities also maintain social connections. These networks of people encompass inherited knowledge and share deeper cultural values. When cities acknowledge the problems and recognise the opportunities the ecosystem approach provides, this would create a sense of purpose and a sense of direction for innovation, and a sense of cooperation rather than conflict between stakeholders. In this article two layers of the ecosystem – the human capital and cultural capital – have been worked out in detail, which brings a general understanding of the symbiosis of these stocks of capital in the port-city ecosystem. Using the logic of the Integrated Reporting framework (The International Integrated Reporting Council, 2013), it can be argued what may happen when ecosystem value is either nurtured or neglected. Knowledge is the connector. The synthesis is reflected in Table 3.

Table 3: Symbiosis of capital in context of the port-city

Capital	Leads to knowledge	Nurture leads to	Neglect leads to
Creative capital	Know what's next	Create the future	Destruct the future
Industrial capital	Know what	Income (sustained)	Unwanted externalities
Natural capital	Know-why here	Sustains	Destructs
Human capital	Know-how	Employment	Unemployment
Social capital	Know who	Talent networks	Old boys network
Cultural capital	Know why	Connected generations	Disconnected generations

Source: author's own

Creative capital forms the top layer of the ecosystem, it flourishes from the nurturing of deeper layers of capital. When cities nurture their talent well, it facilitates creatives and entrepreneurs and creates value through innovation. These creatives know what's the next technology that will come to market. Industrial capital is the established business cluster. Their role is to support creatives as launching customers, mentors and investors. These established companies know what sells in today's markets, not necessarily in tomorrow's markets. The natural capital explains why industry invest here. It is because of favorable location conditions, i.e. good for business and attractive for their employees to live and work. The human capital is the skilled and adaptive workforce. Industry leverage on the know-how of these people, who choose to live and work in the ecosystem because it gives them career opportunities and purpose. Not investing in human capital leads to a disconnect of skills and longer distance to the job market. Eventually it could even lead to a brain drain. The social capital is the sense of belonging, which is especially important for newcomers in the port city ecosystem to root in the ecosystem. Talent networks support newcomers. They can make friends, create a business network and improve the quality of life. Lastly, cultural capital is the most intangible, but is inevitably important. For port cities cultural capital provides the shared identity, shared values. Knowing the history and passing on stories from part times connects generations. Maritime museums play an important role in bridging the distance newcomers, migrants and children may have towards the maritime industry. In table 3 we juxtapose the negative effects when the ecosystem approach is neglected.

Conclusions

This paper contributes to the existing discourse by taking a holistic approach to innovation in port cities, going beyond the metaphor of the ecosystems. Innovation is placed physically in the biosphere of the port city and its region, displaying the different layers of capital in the ecosystem, geographically. This makes our ecosystem approach more than a metaphor. Our framework is providing a sense of place and a sense of direction for innovation ecosystems. A second contribution relates to the visualisation of the research findings. Visualisation itself creates mental connections of a relevant audience, which provokes new insights on what needs to be done. Whereas most of the literature on ecosystems works with either a conceptual model or spatial map, the chosen method makes the step towards a spatial map of the ecosystem. The added value of this illustrative approach lies in the fact that it shows the coherence between knowledge-intensive activities within the ecosystem, both in a geographical sense.

There are also limitations to this study. The ecosystems view on sustainability and innovation of port cities requires deeper understanding. Port cities are pivotal to make transitions happen when stakeholders act collaboratively, rather than maximise individual goals. How stakeholders can create value for themselves and for others considering the scarcity of resources and space in port cities is one of the wicked problems and requires further research. Looking forward into potential future directions the framework in table 3 and visualisation of stocks of capital of the port cities contribute to the understanding interconnections between and within port-city ecosystems. Rotterdam was used as a case study in which we have chosen to reflect on the human capital and cultural capital maps. Further research is required to also visualise the other layers. The interlinkages between the layers of capital require further scientific evidence as well, ideally by comparing the sources of capital of port cities and non-port cities with each other, using the visualisation method, complemented with in-depth interviews with policy makers and actors in the networks. Another research avenue could be to assess the evolution of the creative industry in former port areas and assess their economic activities but also their mission and vision and seek what connections still exist with the port city. To what extent are these economic activities really contributing to the port city innovation ecosystem? A third follow-up is to assess what mechanisms are at play in creating a successful innovation ecosystem. Another interesting question would be how strong the influence of port authorities and municipalities is on the innovation ecosystem. Is their governance persuasive enough for stakeholders to collaborate, co-create and contribute to the SDGs?

In terms of policy recommendations, I have argued for an ecosystems approach to foster innovation in the port city. The case study of Rotterdam illustrates the relative success of

shared investment in human capital. There is an abundance of knowledge institutes which directs young talent in seven different directions into the maritime industry and can compete with other major maritime capitals in the world. However, the case study also shows the risk of economic segregation which was addressed by Florida and Mellander (2020). The cultural and human capital map combined seems to reveal a neglect for the district on the southeast side of the city. Obviously, the transformation of the old port areas into talent hubs may seem a success, it has created a larger distance for people living in areas whom already had a distance to the port and maritime sector. A second policy recommendation is related to the transitions. Looking at these maps and into the future, the question arises as to what the knowledge landscape should ideally look like in ten or fifteen years. What new professions will appear when the port transforms itself into a digital platform and hub of the circular economy? Which technical training courses will have to be reinvented once energy is no longer largely generated from fossil fuels, but from renewable energy sources?

An ecosystem does not solely flourish due to its proximity to the port, but also because of the extent to which companies are able to draw on this ecosystem's resources. This is attributable to its proximity to the port, but especially the symbiosis that people can create when they interact responsibly and openly share their knowledge. By doing so, the port innovation ecosystem will succeed in sustaining a continuous inflow of talented people. That is an inexhaustible asset and a raison d'être for the port city.

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