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Mapping Opportunities for Floating Urban Developments in Port Cities

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Population growth and urbanization mainly take place in vulnerable coastal areas. This article presents a global overview of these areas with both rapid population growth, high flood risk and land requirement for urban expansion. The analysis focuses on port cities since these are cities that in particular could benefit from floating developments. Next, a large scale floating maritime spatial project is presented of the BlueRevolution North Sea. This is a plan for floating urban expansion in front of the coast of the Netherlands.

Keywords: Floating urban development; vulnerability, port cities, flood risk, population growth, land scarcity

INTRODUCTION

Rapid growth of coastal cities in vulnerable delta areas introduces many challenges such as increasing flood risk and reduced land availability and resources availability. In the last decade there has been a rising attention for water management approaches which are not only focused on optimizing the current urban water system, but instead seek to deal with multiple, integrated challenges by establishing and entirely new model of urban development. Examples are Cities of the Future (Novotny and Brown, 2014), Water Sensitive Urban Design (Wong and Brown, 2009) but also Floating Urban Development (De Graaf, 2012; Moon, 2012;) and Floating productive developments (Dal Bo Zanon et al 2017). These are developments that are based on floating foundations and can adapt to changes in the water level autonomously. Since most cities are located in coastal delta areas that are threatened by sea level rise, floating developments (e.g. Figure 1) are gaining more interest. In particular for port cities, floating urban development could be an interesting alternative for land based urban expansion and urban renewal on land. The main reasons are their proximity to water, the availability of sheltered water surfaces, economic activity and abundance of waste heat, CO_2, and nutrients which could function as a source for floating production of food and biofuels. Dal Bo Zanon et al (2017) presented an analysis how floating algae production could address bot global and local land scarcity and how it could contribute to achieve a circular urban metabolism at city level. Earlier research (Roeffen et al., 2013) estimated global land scarcity in 2050 between 13 million and 36 million km^2 and indicated floating production of food and energy as well as floating urban developments as potential strategy to address the land scarcity issue.

This article aims to investigate which port cities could benefit most from floating developments. Three criteria are analysed for this purpose. These are (1) the expected population growth, (2) the expected flood risk and (3) the land requirement for urban growth. The hypothesis explored in this article is that cities that are facing rapid urban expansion, are characterised by high flood risk and also require large amounts of space for their population growth, would be areas with high potential for floating developments. Finally, an innovative large scale floating urban project is presented

which is based on the innovation agendas and policy documents of the topsectors of the Dutch Economy.

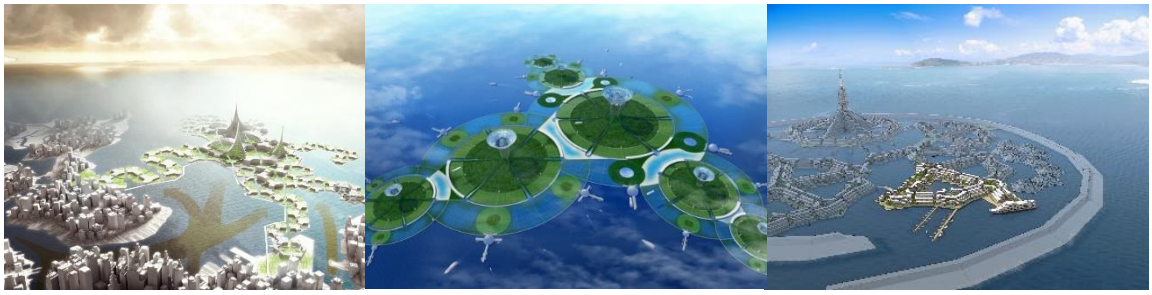

Figure 1: Examples of floating development concepts (DeltaSync, 2013; Shimizu, 2008; Seasteading, 2014)

METHODS

The analysis of Hallegate et al. (2013) was used as a starting point. This study investigates the 136 coastal port cities with more than a million inhabitants in their agglomeration in 2005 (Hanson et al. (2011). The study of Hallegate et al. gives estimations on the mean annual loss (M$) that is expected in these cities in 2050. The expected loss is based on socio economic changes, climate change, land subsidence and adaptation measures. For this study, the scenario with 20 cm sea level rise, land subsidence and adaptation measures with constant probability was chosen. For the global analysis of rapidly population growth, data from the United Nations (2014) on cities larges than 300,000 inhabitants was used. From this data, the 136 coastal port cities were extracted. Data included historical growth figures from 1950 onwards as well as projections of population growth up to 2030. The ranking of the cities was based on the expected population growth in the period 2015-2030.

The global analysis of the land requirement of urban expansion of the coastal port cities was based on research on the expected additional urban extent of cities until 2050. This data was extracted from the Atlas of Urban Expansion (2018). A compiled ranking was made based on the three criteria population growth, flood risk and land requirements.

For the spatial concept of the BlueRevolution case study a literature survey was done of policy documents and innovation agendas of the nine Dutch economic topsectors (Topsectoren, 2016). Moreover, key stakeholders of the Topsector Water were involved in the analysis. From these sources the most relevant initiatives, plans and projects were extracted and incorporated in the spatial context by the research by design method (Biggs and Buchler, 2008).

RESULTS AND DISCUSSION

The first screening result as mapped in Figure 2 provided a first indication where floating urban developments could contribute to reduce the increase in flood risk, and accommodate population growth. In particular for rapidly growing cities in South East Asia floating development seem to have potential.

Figure 2: First screening: rapidly growing cities with high flood risk are indicated in blue, rapidly growing cities without high flood risk are indicated in orange.

The second criteria: expected future flood risk already incorporates urban growth but only as one of various sub criteria. Since urban expansion is directly linked to the option to realize this on land or, alternatively on the water, expected population growth was included in the analysis as one of the three separate criteria. One could argue that the third criteria, land requirement, is partly included in the first criteria: expected population growth. However, cities grow in different ways. They could be focused on expanding by building high rise buildings, suburbs or mainly have expansion in industrial and port activities. Coastal cities with a high space requirements for urban growth are in particular promising application areas for floating developments. Therefore, space requirement was also included in the analysis. Table 1 presents the results of the analysis.

The results in table 1 shows the top 25 cities with most potential for floating developments according to the three criteria. The majority of cities is located in Asia. More cities are coastal than located along a river. China has 7 cities in the top 25. India follows with 5 cities and the USA with 3 cities. There are no cities from Europe, Latin America or Oceania in the top 25.

The results are not surprising since most of the rapidly growing cities in vulnerable lowland areas are located in Asia. Including different criteria and perhaps also different weights of these criteria in the analysis, would probably lead to a different list of cities but the overall picture of geographical distribution of cities with most potential would probably be more or less the same. The presented results should be considered as a first indication of an exploratory analysis. More research is need to further substantiate these findings and critically re-assess them.

Table 1: Ranking of port cities with most potential for floating developments based on the three criteria in this article.

Rank	Port City	Type	Location	Flood risk	Space required	Population growth	Overall score
1	Guangzhou, Guangdong	River	China	1	3	7	11
2	Kolkata (Calcutta)	River	India	3	8	9	20
3	Mumbai (Bombay)	Coastal	India	2	13	5	20
4	Tianjin	Coastal	China	7	1	13	21
5	Ho Chi Minh City	River	Vietnam	9	10	16	35
6	Lagos	Coastal	Nigeria	31	11	1	43
7	New York-Newark	Coastal	USA	8	9	33	50
8	Chennai (Madras)	Coastal	India	13	35	10	58
9	Jakarta	Coastal	Indonesia	11	35	12	58
10	Shenzhen	Coastal	China	5	30	26	61
11	Abidjan	Coastal	Ivory Coast	12	35	15	62
12	Surat	Coastal	India	14	35	14	63
13	Karachi	Coastal	Pakistan	49	15	3	67
14	Manila	Coastal	Philippines	30	31	11	72
15	Xiamen	Coastal	China	19	35	20	74
16	Krung Thep (Bangkok)	River	Thailand	18	35	23	76
17	Al-Iskandariyah (Alexandria)	Coastal	Egypt	23	27	30	80
18	Qingdao	Coastal	China	43	7	32	82
19	Dhaka	River	Bangladesh	21	32	33	86
20	Houston	Coastal	USA	42	6	40	88
21	Shanghai	River/Coastal	China	54	35	4	93
22	Dar es Salaam	Coastal	Tanzania	61	35	6	102
23	Kochi (Cochin)	Coastal	India	24	35	44	103
24	Yangon	Coastal	Myanmar	40	35	29	104
25	Los Angeles	Coastal	USA	39	18	47	104

CASE STUDY: BLUE REVOLUTION NORTH SEA

While no Dutch city was in the top 25 city ranking, the Dutch have a long history of adapting to the water. Many of the problems that are found in delta areas all over the world, are present in the Dutch delta as well. The Netherlands is located in one of the most densely populated delta areas in the world. Almost half of the county is located below sea-level. Floating urban development has gained much interest in the past two decades as alternative option for climate adaptation. Floating neighbourhoods such as Steigereiland, IJburg (2011) Amsterdam and iconic projects such as the Floating Pavilion Rotterdam (2010) were realized.

More recently, floating urban development became part of the ‘Blue Route’ in the National Science Agenda in 2017. A large research project Space@Sea was started as part of the Horizon 2020 innovation and research agenda of the European Commission. The Dutch Topsector Water embraced the concept of floating urban development (Topsector Water, 2016). The water sector has been designated Topsector by the government because of the strong position of the Dutch in water management and the opportunities that water presents for economic growth. The Topsector aims to facilitate collaboration between the government, companies and researchers to stimulate innovation.

Figure 3: The Floating Pavilion in Rotterdam, the first step for the city to create floating neighbourhoods in the Port of Rotterdam (DeltaSync, 2014).

The objective of the Iconproject was to develop a concept for floating urban development with a positive impact and a circular metabolism of nutrients and CO_2. The spatial concept was based on the BlueRevolution concept (Blue21, 2016). Moreover the project should function as "Iconproject" overarching and uniting the different Topsectors of the Dutch economy. The project was developed in cooperation with Topsector Water. Existing initiatives and projects were mapped and an exploratory design was made how floating developments could be added to this. For this purpose, 4 integrative themes were formulated:

1. Netherlands 100% CO_2 Neutral
2. Netherlands 100% BioBased & Circulair
3. Resilient Urban Delta
4. Smart Floating City & Logistics Mainport

For each theme innovative existing and new projects and initiatives were collected and designed as part of an integrative plan. The plan included both floating functions and areas developed by more traditional land reclamation. Table 2 shows an inventory of innovative projects and initiatives per theme. These projects were included in the plan. The main concept is that the waterbased development on the North Sea uses the waste products of land based cities such as wastewater, industrial CO_2 and waste heat in a productive way by applying floating aquatic biomass such as algae and seaweed. As a result a circular metabolism and symbiosis between cities on land and water is created. Figure 4 shows how the different initiatives and projects were integrated in a spatial plan for the Dutch coast. The plan answers to many urgent global challenges such as sea level rise, land scarcity, food security and CO_2 emissions. Moreover the project BlueRevolution North Sea could serve as a platform to integrate many different fields of technology such as civil engineering, water management, biotechnology, information technology, energy and food technology. The concept could be realized first as a showcase in the Netherlands first. Since many delta areas

all over the world are facing similar problems, the concept could be adapted and applied in many areas, including the port cities that were analysed in this article.

Table 2: Inventory of initiatives, projects and plans sorted per integrative theme. These initiatives were included in the spatial concept for BlueRevolution North Sea.

100% CO_2 neutral	**100% biobased and circular**	**Resilient urban delta**	**Smart Floating City and Logistics Mainport**
Energy island	Strengthening food and agriculture sector	Protecting existing coast	Floating city of 1 million inhabitants
Smart grids, decentral energy production	Using coastal cities and ports as source for CO_2, heat and nutrients	Building with nature, Zandmotor (Sand Engine)	Living Lab for sensors, internet of things, monitoring, drones, Autonomous vehicles and ships
Wave and tidal Energy	Aquatic biomass	Showcase for light corrosion proof (nano) materials	New Economy: testing ground for high tech start-up companies
Blue Energy and saltwater batteries	Aquaculture	Artificial reefs	Expand mainports: Floating Airport and Floating Sea Hub
Offshore wind	Create Blue-Green Jobs; cluster of biotechnology, biobased resources for circular economy	Floating breakwaters	Hi speed vacuum tube transport connection to Amsterdam and Rotterdam
Gas at sea	Self-supporting protein supply	Closed watercycle	Smart solutions for internal logistics
Floating solar	Use industrial CO_2 in horticulture greenhouses (Kas energiebron/ OCAP)	Biggest wetland of Western Europe, fish shelter	

Figure 4: Spatial concept for BlueRevolution North Sea, a sustainable expansion near the Dutch coast (Source: Blue21 and Topsector Water, 2016; design: Bart Roeffen).

CONCLUSION

With a combined analysis of three criteria expected population growth, flood risk and land required for urban growth, an overview was made of port cities that could benefit most from floating developments. A first screening was done as indication where the most promising areas are located. With the combined ranking, an outline was made for the port cities with most potential. Most of the cities in the ranking are located in Asia, in particular in India and China. An innovative case study was presented for the Dutch North Sea coast. This spatial concept of BlueRevolution North Sea addresses many global societal challenges such as population growth, CO_2 mitigation, the energy transition and ecological enhancement. The project could serve as a model how to deal with this challenges in delta areas all over the world. The floating developments use the waste products of land based cities such as wastewater, CO_2 and waste heat in a productive way by applying floating aquatic biomass. Moreover the project BlueRevolution North Sea could serve as a platform to integrate many different fields of technology such as civil engineering, water management, biotechnology, information technology, energy and food.

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