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The Dutch and Belgian Dredging Industry

An Exploration of the Future

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Executive summary

This report analyses the evolution, dynamics and plausible future scenarios of the Dutch-Belgian dredging sector, with an emphasis on the process of innovation. Based on interviews with a number of key players in the sector and on archival research, we investigated the main trends the sector has been experiencing and its innovation capabilities to stay relevant in the future. The main conclusions of the report are that the dredging sector in the Netherlands and Belgium still has a strong international position, but should redefine how it sees competition and innovation.

Two innovation arenas have created this position: the triangle of dredging firms, shipbuilders and equipment manufacturers producing high quality dredging vessels and equipment, and the triangle of dredging firms, research institutes and government agencies developing new methodologies for dredging. The report indicates that several trends exist that can strengthen the sector further: new demands for dredging, such as those resulting from global warming and coastal urbanization, and the quest for sustainability, which can enhance the leading innovative position of the Dutch-Belgian dredging sector. Despite this positive outlook, Chinese competition is coming up and must be expected to increase severely in the near future.

The trends of increasing protectionism and idiosyncratic differences in terms of sustainability requirements challenge the competitive position of the Dutch and Belgian dredging sector. This report advices the sector to re-strengthen collaboration vertically as well as horizontally between parties. In addition, new business models such as servitization, disruptive innovation, influx of knowledge from other sectors, such as data analytics, and collaborating with start-up companies can rejuvenate the sector's innovative potential. The national governments and European institutions can facilitate such actions by supporting innovative and sustainable projects, and by putting much more pressure on the creation of a level playing field internationally in this sector.

About this report and disclaimer

This report was prepared by a team of researchers at Rotterdam of School of Management. The team was led by Jan van den Ende and Murat Tarakci as principal investigators. The graduate students, Matthew de Jong, Thijmen Julien, Lorenzo Antimiani, Panagiotis Mourikis and Peter de Looze, also actively contributed to the data collection as well as writing of the report as part of their Master theses.

As part of this research, we conducted 35 interviews lasting between 30 minutes and one and half hours, carried out desk research, collected secondary data, and organized several workshops with industry participants.

The project was commissioned by a group of companies (see final page). An independent and diverse board of advisors oversaw the project progress and ensured researchers' independence:
Richard Brakenhoff, *Rabobank*
Arnold de Bruijn, *Netherlands Maritime Technology*
Wim Hulsink, *RSM*
André Kik, *Royal IHC*
René Kolman, *IADC (International Association of Dredging Companies)*
Edwin Lokkerbol, *Vereniging van Waterbouwers*

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All the statements in the report reflect the research team's own opinions, and are not associated with the opinions of the companies or organisations involved, or of RSM.

Design and realisation Kris Kras content, context and design

Contents

Introduction

"Lots of companies don't succeed over time. What do they fundamentally do wrong? They usually miss the future. I try to focus on that: What is the future really going to be? And how do we create it? And how do we power our organization to really focus on that and really drive it at a high rate?"

(Larry Page, CEO of Google's parent company, Alphabet Inc.)

The Nature and Importance of the Dredging Industry

Dredging refers to the excavation of material from river, sea or ocean beds to deepen and clean waterways and/or for land restoration and reclamation. Globalization of trade requires bigger vessels transporting their goods between new deep-sea harbors. Urbanization of coastal areas requires new spaces to create new habitats. The coastal areas have experienced rising sea-levels due to climate change. The dredging industry offers solutions for several of these problems. With their dredging vessels, the dredging companies are able to transform sea into land. This land can be used as a seawall against rising sea levels and, thereby, provide new living spaces. It is also possible to maintain harbors, using the same vessels, to keep or increase the water depth, as well as to create access for bigger transport vessels. Dredging companies also explore and extract minerals from underwater deposits. Last but not least, dredging companies contribute to the environment by removing polluted sediments, protecting shores and beaches, and they support offshore activities preparing the seabed to install structures and pipelines for oil, gas and renewable energy projects.

Dominated only by Dutch and Belgian companies until recently, the dredging industry is a jewel for these economies. Total sales of dredging companies in the Netherlands and Belgium were €4,3 billion in 2017, which was 40% of the global dredging market [1]. The main Dutch and Belgian players are Van Oord, Jan De Nul, Boskalis, and DEME. Importantly, China's increasing dredging activities has recently reshaped the competition. China Communication Construction Company (CCCC) has 2-3 times more ships than the average of the other four companies [1]. The Chinese government, Chinese exploration companies and Chinese dredging companies are working together in areas where they have bought harbors in Southern

Europe and Africa. Local companies tend to become stronger competitors in the future. At the same time, a higher level of protectionism makes it more difficult for Dutch and Belgian players to globalize their dredging businesses. The US and Chinese markets shielded off foreign competition. This has discernible effects on the activities of Dutch and Belgian dredging firms in these countries, and in European countries such as Belgium and France, where dredging jobs have been carried out by national firms for decades.

In addition to the changes in competition and protectionism, the dredging industry is exposed to many growth factors because of the broad applicability and the global commitment of their dredging vessels. At the same time, the industry experiences business cycles. The industry has been undergoing significant changes in terms of increased competition and tightening regulations.

Environmental concerns become increasingly important in the dredging industry. Energy consumption, particularly, the use of fossil fuels, contributes strongly to climate change and global warming. Energy plays a role in the entire lifecycle of dredging projects and decisions made early in the project initiation phase can have huge impacts on later energy consumption. Legislation for emissions and sustainability is becoming increasingly strict. The International Maritime Organisation (IMO) has adopted regulations to reduce Sulphur and Nitrogen emissions from ships. With the Energy Efficiency Design Index (EEDI), IMO has also adopted mandatory energy efficient measures to reduce emissions of greenhouse gases from international shipping. Also, the requirements increase with respect to environmental impact of dredging on the water bottom and waste water disposal from dredging.

Given these tectonic shifts, and as the opening quote illustrates, staying relevant in the dredging industry requires developing an understanding of how the future might become and how the industry players can shape the future accordingly. Hence, this report reviews major shifts that the dredging industry experienced in the last 25 years to draw plausible future scenarios and craft winning strategies for the dredging companies to stay relevant in those scenarios.

Previous work

There have been several similar attempts for writing a comprehensive analysis and report for the shipping industry in general [2–5] and for submarkets such as ro-ro and chemical tanker [6-7]. The most recent comprehensive attempt for the dredging industry dates back to 1993: the report 'De economische kracht van de baggerindustrie' ('The economic power of the dredging industry') by D. Jacobs and colleagues [8]. That report applied the canonical frameworks of Michael Porter, particularly the 5-forces model and the diamond model for nations. The report concluded, amongst others:

- The Dutch and Belgian dredging sector was a strong competitive sector with an international orientation, with high entry barriers. In spite of the small number of players and potential protection of knowledge, the sector remained innovative.
- The sector consisted of a strong cluster of parties: contractors, shipbuilders and equipment developers. The Belgian contractors aligned with the Dutch cluster.
- The sector was threatened by protectionism and financial constructions by Asian countries.
- The reliance on a single dredging shipbuilder in the top-segment was felt as a threat by the contractors because of market power and appropriation of specialized knowledge, but the price-performance ratio of ships was nevertheless good.
- Equipment developers could expect more competition from Japanese and Korean suppliers.
- The government was advised to try to open markets, particularly in the creation of the WTO agreements. International protectionism was a threat for the industry.
- The sector was advised to create better access to the World Bank and EU, and improve the renewal and quality of the labor force.

In contrast to the report by Jacobs and colleagues, the current report takes a more dynamic perspective and focuses on the innovation capabilities, in line with theories of disruptive innovations, co-opetition and open innovation [9,10]. We show that not only the industry has experienced a metamorphosis since 1993, although some of the conclusions above still hold. But we also see that the industry is at the brink of new tectonic shifts. Hence, this report becomes important to make sense of the changes that the industry has already gone through since 1993 and to prepare for the future.

Dredging for Palm Islands

Macro trends in the dredging industry

Several macroeconomic trends affect the dredging industry [1]. On the one hand, macro-economic and climate trends create new markets for dredging or enhance the size of existing markets; on the other hand some trends to put limits on the operation of dredging companies: sustainability policies of governments, increasing protectionism and increasing safety requirements. We will first discuss macro trends creating new demands, and then turn to the limiting trends.

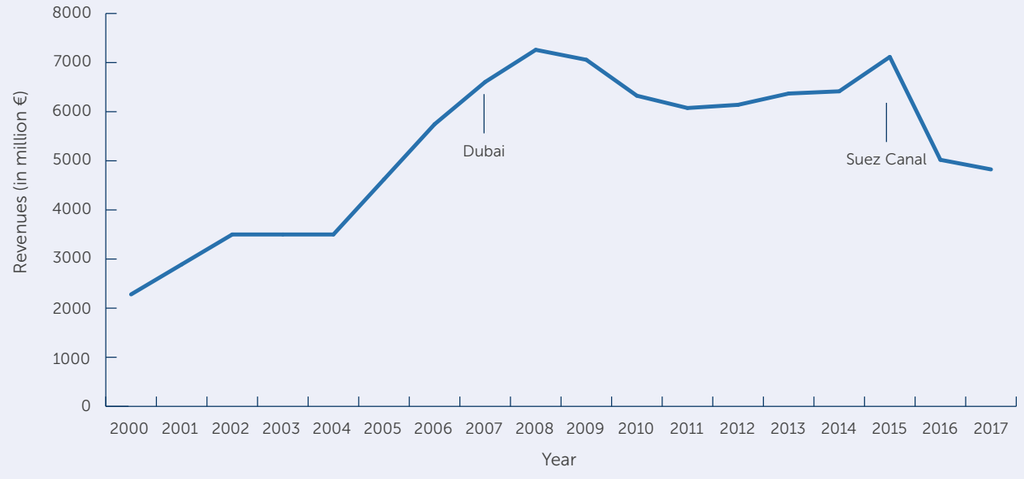
Demand for dredging

Several trends generate an increasing demand for dredging, on the shorter or longer term:

- Global warming, leading to a rising sea level;
- Population growth, particularly in coastal areas (people moving from rural areas to cities);
- Growth of seaborne trade: this is an issue for the growing size of containers vessels;
- Rise of the global consumption of energy and metals: this entails the construction of ports
- Growth of global tourism: construction of new airports and infrastructures (Dubai, Hong Kong Airport)
- Scarcity of natural material and the quest for national or regional autonomy in materials supply.

The demand for the dredging industry can be characterized to be cyclical with rapid booms and busts — as illustrated in Figure 1 below. Despite this cyclicality, the overall trend indicates an increase in demand for dredging over a longer period.

Figure 1 **Estimated size of the open dredging market**



Source: IADC (2002-2004 estimate is based on Boskalis)

The rise in temperature, with 16 out of 17 of the warmest summers of the last 130 years occurring between 2001 and 2017 [11], is an opportunity for the dredging industry on the one hand; but it also opens a debate on sustainability on the other hand. Opportunities coming from global warming and rising sea levels are likely to increase the demand for dredging related activities in coastal areas. The effect of this trend is amplified by the growth of populations in coastal areas, which are higher than in the hinterland [12]. For instance in China, the growth of the population in coastal areas is three times higher than the national rate. At the same time, the majority of world 'megacities' are located near the sea [13]. This creates a demand for new land extensions and building dikes along the shore. Another element of global climate change is the increasing frequency and impact of hurricanes [1].

The growth of seaborne trade, the increasing international trade of energy and metals, and the rise of the global tourism are other factors increasing demand for dredging. More harbors have to be constructed, and existing harbors should become deeper. Some doubts exist on the growth of seaborne trade for products, energy and metals. The current trend towards 're-sourcing', bringing back production from emerging economies to the home regions of companies, can reduce trade, and the growth of trade in energy and metals might be reversed by alternative energy production and recycling of metals. But on the short term these trades will increase demand for dredging.

Finally, scarcity of metals and other natural resources create markets for deep-see mining, in which dredging companies can become active (see below, under 'Technologies'), although currently many objections arise from environmental perspectives. All in all, these trends suggest that in the near and distant future demand for dredging will be rising.

Sustainability

A major trend affecting the industry is the quest for sustainability, as exemplified by the Sustainable Development Goals of the United Nations. Although the importance of this trend for the dredging industry is most evident in Europe, this trend also becomes increasingly relevant in other parts of the world, for instance in Asia, where international institutes such as the World Bank finance projects and require certain levels of sustainability in the execution. Companies in the maritime sector in general have to comply with the rules set by IMO, a UN body in charge of naval and maritime regulations.

Over time a change in perception of the attitude towards sustainability in the dredging industry can be observed, based on industry associations' annual industry reports. The observed main shift in attitudes concerns dredging companies shifting from a policy taking, to a policy making position. This is best illustrated by the introduction of the concept Building with Nature and the EU-NATURA 2000 law. Before the introduction of the EU-NATURA 2000 regulations, the environment was regarded as a separate market to the dredging industry. Environmental projects mainly concerned the clearance of contaminated soils, in compliance with existing pollution laws [14,15]. With the introduction of the EU-NATURA 2000 regulations for sensitive environmental habitats, these new laws were integrated into project design by promoting decision making based on the early assessment of possible environmental effects created by dredging activities. Companies are deemed to limit, lower and base the decisions on the environmental effects of their activities. This integration was mentioned in reports by the International Association of Dredging Companies up to 2007, after which "Building with Nature" causes the second major shift in the industry regarding the environment. Building with Nature, can be seen as the tipping point at which the industry shifts from a policy taking, to a policy making position regarding environmental initiatives and industry standards. The aim of this approach is to balance both economic development and environmental care in marine engineering projects, such as dredging activities (see Section Technology Trends, page 19).

In the period after 2012, we see a second trend around the environmental effects of dredging. This time the industry not only considers the direct effects of projects on the environment, but focuses on the reduction of the emission of ships. Changes in EU-regulation generate a new incentive to reconsider the current way ships are built and the fuels they run on [16]. We observe that dredging companies desire to limit emissions through the adaptation of their vessels, first by optimizing both the space and weight of new vessels. The second consideration, being switching to different fuels,

is directly tied to the first since some motor types directly influence the way ships are constructed [16] (see Section Technology Trends, page 19). Both dredging companies and vessel builders are highly influenced by policy makers, their investments being both dependent on changing emission laws and policies influencing port infrastructures. As we will see in Section Advice, sustainability requirements limit the operations of dredging companies, but at the same time are an important stimulus for the development of new dredging techniques.

IMO has adopted the International Convention for the Prevention of Pollution from Ships, now known universally as MARPOL. In 1997, a new annex was added. The regulations (Annex VI) seek to minimize airborne emissions from ships (SOx, NOx, ODS, VOC shipboard incineration) and their contribution to local and global air pollution and environmental problems. Annex VI entered into force on 19 May 2005 and a revised Annex VI with significantly tightened emissions limits was adopted in October 2008 which entered into force in 2010. After 2010 limits have been further tightened, particularly for Emission Control Area (ECA): the Baltic Sea area; the North Sea area; the North American area (covering designated coastal areas off the United States and Canada); and the United States Caribbean Sea area (around Puerto Rico).

The IMO also adopted measures to reduce CO_2 emissions. These mandatory measures (EEDI: Energy Efficiency Design Index) came into force on 1/1/2013. EEDI requires a minimum energy efficiency level per capacity mile. For dredging companies an adapted EEDI was made. CO_2 has to be reduced 10% every 5 years until 2025. (30% in total). Limitations apply also to wash water emissions and turbidity [17].

Protectionism

An important political trend is market protectionism. The U.S. and Chinese markets are almost completely closed off for external companies. For example, since 1920 the Jones Act stipulates that dredging companies must be owned by U.S. citizens, employ only Americans and use equipment built there. Consequently, US domestic dredging is more expensive than elsewhere. Although Asian markets in general gradually seem to become more open, high protectionism in the dredging market persists [18]. Even though foreign dredging companies can get the necessary licenses eventually, they still can only undertake small, foreign financed projects. As a consequence of protection, only about half of the global dredging market is open for competition.[19] The Trump administration in the U.S. currently strengthens this trend towards market protection. Change could come from stronger collaboration between the EU and China, which may lead to a more open Chinese market (see Chapter Advice). However, very little concrete efforts are seen from the EU authorities.

Sea mining robot

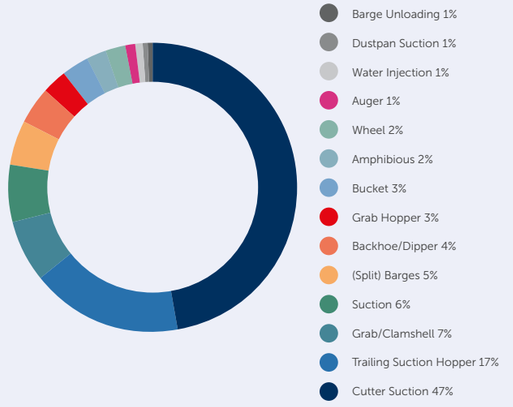
Technology trends

Growing ship sizes

A dominant trend in the dredging industry has been, and still is, the trend towards larger ships equipped with new dredging techniques. Cutter Suction Dredgers (CSDs) and Trailing Suction Hopper Dredgers (TSHDs) dominate the market, making up 64 percent of the dredgers in the market. (see Figure 2). Trailing Suction Hopper Dredgers dominate the market in terms of tunover.

In the period 1990-2000, large dredging companies built the so-called 'Jumbo hoppers', with capacities ranging from 15,000 to 20,000 m^3. At the end of the 1990s, Boskalis even built a larger so-called 'Mega hopper', with a capacity larger than 20,000 m^3. Hoppers are operated with a capacity of even more than 45,000 m^3. The trend towards larger ships is currently particularly evident in cutter dredgers (see Figure 3: heavy duty cutters, with a capacity of 13,000 – 23,000 kW,

Figure 2 **Share of Dredger Types in terms of Number of Ships in 2018**

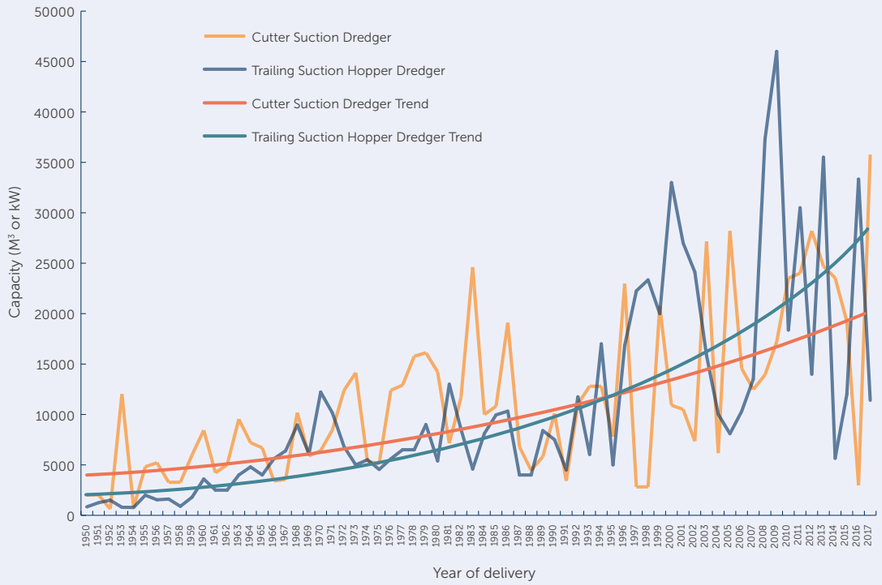


Source: J. van den Berg, Royal IHC

and mega cutters have been built in the 2000s, with even larger capacities. Currently, the largest cutter dredgers have a capacity of more than 40,000 kW installed power, referring to the 'Willem van Rubroeck' and 'Spartacus', owned by resp. Jan De Nul and DEME.

The development of the large hopper dredgers has been stimulated and justified by several extremely large projects that have come to the market, particularly the Hong kong airport, Chek Lap Kok island and the Dubai Palm Island. Large cutter dredgers have been used for the excavation of the Suez Canal. The larger hopper capacity ships are also more efficient in other projects. Larger cutters are not always more cost-effective than smaller ones, but they can be applied for new purposes such as harder rock and longer discharge distances, which were unaddressed before.

Figure 3 **Capacity of largest built dredgers per year between 1950 and 2017 (in m³ for TSHDs and in kW for CSDs)**



Source: J. van den Berg, Royal IHC.

Responses to sustainability requirements

On top of efficiency considerations, sustainability requirements currently lead to two types of new technologies:

1. Reducing emissions from dredgers;
2. Building with Nature

1. Reducing emissions

Since emissions regulations for nitrogen (NO_x) and sulphur oxides (SO_x) are getting stricter and there is a drive to reduce greenhouse gas (GHG) emissions, such as carbon dioxide (CO_2), there are two solutions to reduce emissions:

» Use after-treatment to clean exhaust gas ('scrubbing', not for CO_2);
» Switch to cleaner and/or more renewable fuels.

In recent years several fuel alternatives were considered as viable options to meet the emission reduction targets, particularly liquefied natural gas (LNG) and biofuels. Vessels currently run most of the time on either heavy fuel oil (HFO) or marine diesel oil (MDO) depending on the location the vessel is operating and the emission legislation in place there. Marine gas oil (MGO) is a solution to comply to the global 0.5% sulphur limit of 2020 without any modifications of the vessel. An alternative, which requires a modification of the vessel (design), is the application of scrubbers to wash the SO_x emissions from the exhaust gas. Complying with the IMO Tier III NO_x emission limits in emission control areas (ECA's) would require diesel engine powered vessels to use a selective catalytic reduction (SCR) system.

LNG is a fossil fuel, but results in much lower NO_x (-80%) and SO_x (-99%) emissions and in up to a 25% reduction of CO_2 emissions. The equipment required to use LNG on vessels is more expensive than that for the more traditional fuels, amongst others since the vessels need adjustments due to fuels lower energy density, the low storage temperature (-163 °C) and the required additional safety measures. Royal IHC started in 2015 with the development of two LNG powered vessels for DEME which have dual fuel engines capable of operating on natural gas, but also on the traditional MDO and MGO fuels [20] The operational capability on traditional fuel is necessary as LNG is not readily available in every port. LNG is considered as a fuel for the future as it is at the moment considered the fuel with the highest emission reducing capability [21].

Boskalis in cooperation with Goodfuels started a program to develop biofuels for the maritime sector. Since the current biofuels are based on oil and fats, they decided to use sustainable ingredients, particularly waste and residue streams. In 2015- 2016, Boskalis supplied two of their vessels with this alternative sustainable biofuel [22]. Other initiatives in the sector focus on energy storage and waste heat recovery, as well as on intelligent power distribution systems. Claims are that heat recovery from the engine enables vessels to consume up to 11% less fuel [23]. Hydrogen or hydrogen carriers such as methanol, dimethyl ether and ammonia are expected to become the energy carriers for vessels in the distant future solving the emission issues while also being 100% renewable.

2. Building with Nature

Endeavors to meet sustainability and stakeholder requirements have resulted in smart solutions in the last decade often named as 'Building with Nature' or eco-engineering (see also Section Macro Trends, page 13). The concept essentially entails using nature as a base for building infrastructures whereby nature and end-infrastructure co-exist. Examples are:

» Using natural forces for sand transport. Natural currents can move sediment to the target location. This was one of the purposes of the Dutch Sand Motor project, which served to replenish sand on the coast for a longer period;
» Creating an end situation that aligns more with the natural ecosystem on the specific location (which may be more self-supporting, and thus need less continued dredging or replenishment of sand);
» Using the momentum of a dredging project to realize other natural environment projects in the vicinity.

The Netherlands is at the forefront in this trend. Building with Nature is promoted by a public-private innovation program carried by the Ecoshape Foundation, in which contractors, engineering companies, research institutions, governments and NGOs collaborate. The aim of the foundation is to further develop and spread knowledge about the Building with Nature approach, in which forces of nature are integrated into the design of hydraulic engineering solutions [24,25]. It involves the use of the private-public collaborations, not only incorporating engineers but also ecologists and economists in project designs. The common goal of this collaboration reads: "effective solutions for engineering problems and a boost for nature, recreation and economy" [26].

Ecoshape

On the 16th of July 2003 the building project of the Westerschelde Container Terminal (WCT) was canceled. The WCT was to be constructed within the premises of a site marked as an EU-NATURA 2000 area, safeguarded against potentially damaging developments by European directives on nature conservation. As such, when the Council of State ascertained that research on the possible environmental impact of building the WCT had not been thoroughly conducted, it ruled against its construction. The court-ruling became a turning point for the Dutch dredging industry. As negative attention increased, it became a threat to the dredging contractors' operations, causing delays in both project development and execution. Accordingly, the firms realized that to retain their license to operate, a new approach towards the environment was needed within the dredging industry. This new approach became Building with Nature (see page 22), which emphasizes the use of forces of nature in realizing marine infrastructure. The aim of this approach would be to balance both economic development, societal development and environmental care in marine infrastructural projects. As one engineer explained: "If you want to change such an attitude, you have to provide means in order to state something about these positive impacts. You must make design rules, for improving that. It was clear that there was a need and a knowledge gap." As it became clear that the knowledge gap was not going to be filled by a single company, in 2008, Van Oord and Boskalis founded the Ecoshape consortium. Currently the consortium holds 12 main partners, the initiating dredging contractors, six engineering consultancies, one shipyard, one university, one industry association and the Dutch ministry of Infrastructure and Water Management. The primary aim of the consortium is the collective development of knowledge on the Building with Nature approach. As such the consortium publicly promotes and shares knowledge on how to use the forces of nature in realizing marine infrastructure that promotes both economic, societal and environmental benefits.

An Asian case study that has become scholastic regarding 'Building with Nature' is the one of the city of Demak. This is a coastal city in South Indonesia built on a muddy mangrove soil. The area is subjected to serious erosion with 3 km of land being swallowed by the sea, with dramatic consequences for over 70.000 people [27]. To solve this problem, a joint collaboration between WUR and UNESCO came up with temporary permeable structures made from local material [28]. In this way, the structures ensured both the mangrove recolonization and protection against waves and tides. This example demonstrates that Building with Nature could be an important opportunity to explore in vast scale for companies in the sector.

Deep dredging

There are several new markets for deep dredging: pipeline projects and dredging in regions with sand shortages. The concept used is a long suction pipe with submerged dredge pump. This techniques ranges over 100 m. dredging depth. It is also used for sea bed preparation, which entails levelling the sea bed for laying offshore pipelines [29]. Damen shipyard developed the RoRo Deep Dredge, a modular unit. It is a submersible drag-arm, similar to the drag-arm of a trailing suction hopper dredger, which can be lowered to higher depth [29,30]. In the future, dredging on even higher depth may be used for mining purposes. Boskalis is currently preparing a project to mine phosphate near New Zealand. In the future, deep sea mining may be used to extract scarce minerals. Dedicated modules to scrape materials from deep sea surfaces still need to be developed. At the same time, the effects on the deep sea mining on the environment has to be researched and managed.

Data analytics

Expectations are high for the use of data analytics in dredging. On the one hand, engineers can use data analytics to improve the efficiency of dredging operations. Currently already a multitude of data is collected from the equipment on ships during operation, which can be analysed to improve that same operation. Data analytics can also improve the efficiency of the dredging plans, dredging operations and their impact on the environment. However, so far, the actual implementation is limited. Companies have problems to find the needed expertise to apply these new techniques.

Reducing environmental effects

An important requirement from an environmental perspective is to reduce the impact of dredging on the under-water environment. Environmentalists have particularly criticized the Dubai Palm Island project for its negative effects on the environment. Dredging companies have developed several techniques to diminish the effects of dredging on the environment. Van Oord has developed the FaunaGuard, to keep animal life at a distance with sound. Boskalis developed artificial coral, and research institutes experiment with growing coral. Royal IHC developed the "Plumigator" and the company Dragflow invented the anti-turbidity bell for dredge pumps to reduce environment effects of dredging [31].

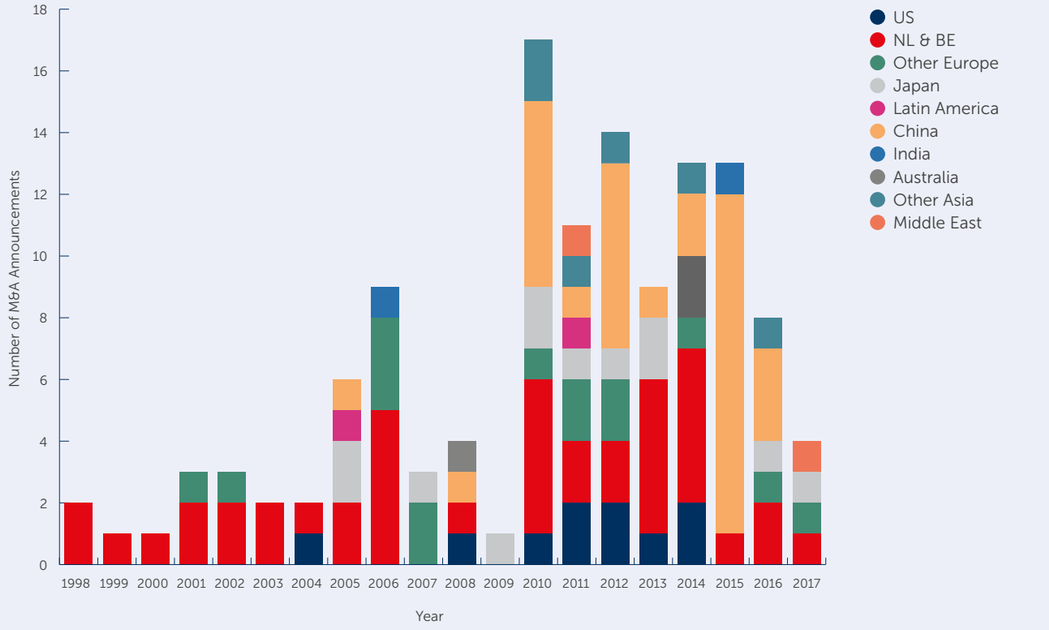
Evolution of the industry

The dredging industry consolidated in the past 25 years. The European industry is now dominated by four large players: Jan De Nul, DEME, Boskalis and Van Oord. Boskalis and DEME are listed on the stock market, the other two companies are family-owned or owned by investors, while specific families have stakes also in Boskalis and DEME. Revenues of each of the companies are around 1-2 billion with strong fluctuations due to volatility in market demand. To different degrees these companies are active in related fields: Boskalis in sea transport for offshoring and infrastructure and towing and salvage, and Van Oord and DEME in offshore wind energy. In addition, there are some smaller players in the market, such as Van der Kamp, Van den Herik and Dutch Dredging (Baggerbedrijf de Boer).

A sequence of mergers and acquisitions between 1988-1991 and 1999-2004 concentrated the industry and created larger entities. Only Jan De Nul grew organically to its current size.

Figure 4 below depicts the merger and acquisition activity across the globe. This figure shows that Dutch and Belgian firms have traditionally been very active in mergers and acquisitions. The figure also shows a sudden and exponential increase in Chinese firms' acquisition activity. For example, 11 out of 13 M&A deals in 2015 (85 percent) were carried out by Chinese firms. As we will discuss later in this section, this observation in Chinese firms' increasing acquisition activity reflects their aim for a more dominant role in the dredging industry. The figure also documents that the industry has been experiencing another exponential growth in number of M&A deals in recent years. These results demonstrate the fact that the dredging industry continues to be a hot spot for competitive actions.

Figure 4 **M&A Activity Across the Globe from 1998 to 2017**



Source: Zephyr Database

Unique characteristics of the dredging industry

Similarities such as large-scale projects, the cyclical nature of the demand following business cycles, and increasing competition from emerging markets make the dredging industry similar to other industries such as construction and telecommunications. Yet, the dredging industry's oligopolistic nature, strong government involvement in commissioning and financing large dredging projects, the bidding process as well as the financing model separate dredging from other similar industries.

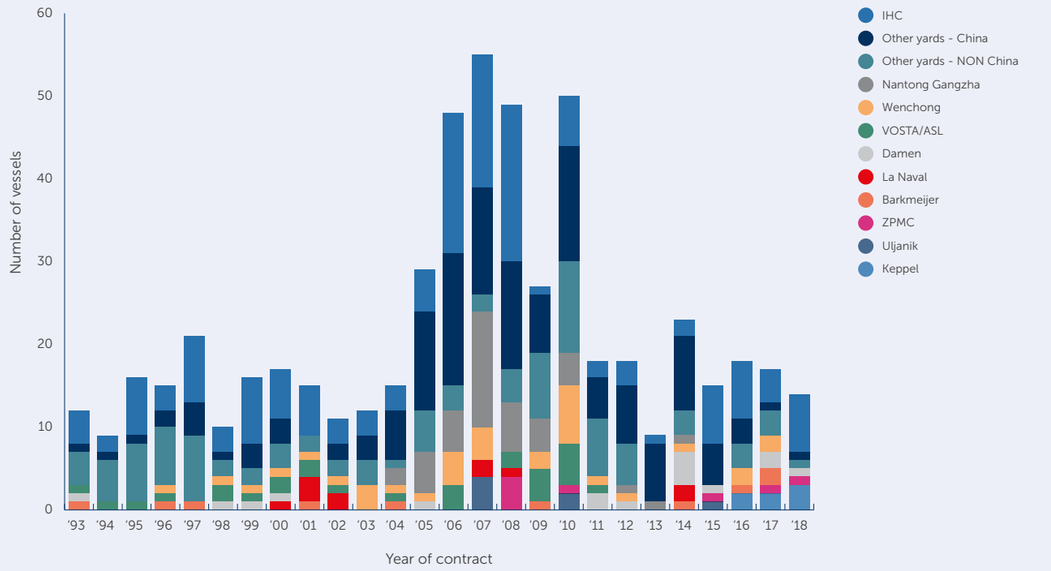
First, the four biggest industry players are concentrated in the Netherlands and Belgium. For the construction industry, competition is spread among several players around the globe. While the telecommunications industry is also concentrated and experiences competition from Chinese companies such as Huawei and ZTE, the wave of technological changes is more frequent than in the dredging industry.

The dredging industry is a tender based market. Thus, a client, often a public authority, comes up with a project and engineering companies prepare the project design. Subsequently a tender procedure is held. Prior to the increase in size of the dredging contractors, not the dredging companies themselves but large infrastructural contractors (such as Royal BAM Group in the Netherlands) would compete for a contract. The dredging companies would then accordingly be hired as a subcontractor to fulfil the required dredging operations. With their increase in size, dredging companies have increasingly grown into the position of being main contractors, and accordingly of hiring subcontractors themselves.

Competition in the dredging industry is based on capacity and ship features. The possession of the right ships for a certain dredging tender provides a strong competitive advantage. As a director of one of the big four dredging firms explained during an interview: "We were just managing a fleet of assets, vessels. And as long as you had a good occupancy of those vessels, then at the end of the year, in very simple terms, there would be a nice profit margin." The time needed to design and build a ship is too long to react to new demands. So, firms have to forecast and estimate the size and characteristics of future demands, and build ships based on those uncertain estimates. Since investments in ships, particularly in the more advanced ones, are high, the investment decisions of the leadership of dredging firms have a strong impact on their future profitability and even survival. While strategic considerations are evident in planning of the fleet, intuition is also an important element in the decision-making process. Decision-making under such high uncertainty is likely to be affected by top decision makers' biases, who have experience in risky decision-making, have high efficacy, and thus are confident to be able to do so, partly based on past performance.

The introduction of Design, Build, Finance & Maintain (DBFM) contracts in tendering has broadened the basis of competition. Now dredging firms need to cover all phases of a project, including the coverage of financial risks. The introduction of DBFM contracts is a move away from price-based tendering, which has been prevalent over the past 25 years. This shift is related to the decreasing levels of knowledge embedded in clients, especially within the Dutch governmental organization, Rijkswaterstaat. This additionally has increasingly put pressure on the dredging contractors to internalize new types of knowledge and skills and to come up with revolutionary

Figure 5 **Market shares of largest shipbuilding firms in terms of orders from 1993-2018**
Based on number of dredging ships (All TSHDs and CSDs with tubes larger than 660 mm)



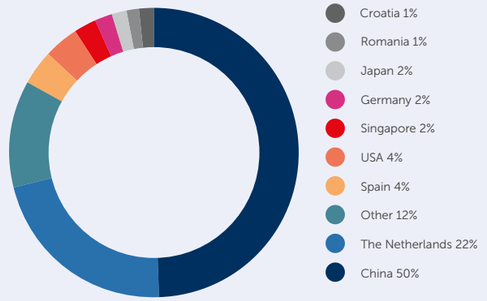
Source: J. van den Berg, Royal IHC

innovative solutions. As such, with the shift towards DBFM-tendering, contractors have increasingly changed from asset-driven organizations, to knowledge- and risk-driven organizations. To manage risks of delivering large projects under DBFM, dredging companies have increasingly united in joint-ventures for tender applications. The increased equipment flexibility, drawing from a larger pool of assets, allows them to compete in a larger number of tenders. If a contract is won, both contractors can carry out their own share of the project, sharing in its profits. As such within the industry coopetition is mainly used as a form of risk sharing, not for innovation.

Competition

A major trend in the dredging industry is the emergence of competition from China. When the market analysis on the state of the art was performed 25 years ago by Jacobs and colleagues [8], the nation was still secluded to a close and centralized economy. While China is becoming a dominant player around the world, its dredging market is still closed (see above). Companies in Europe are in an open context, where they compete on winning project contracts through competitive bidding. In the closed context of China, contracts can be awarded only to local players. At the same time, the largest Chinese dredging company, China Communication Construction Company (CCCC) has developed itself into a competitive player in the international open market, be it with direct or indirect subsidies from the Chinese government, which owns this state company. Amongst others, the government acquires projects in Africa by investing in harbours and by requiring the choice of Chinese dredging contractors in return. CCCC has 2 times more ships compared to the

Figure 6 **Market shares of major shipbuilding countries in terms of number of ships built from 1993-2018**

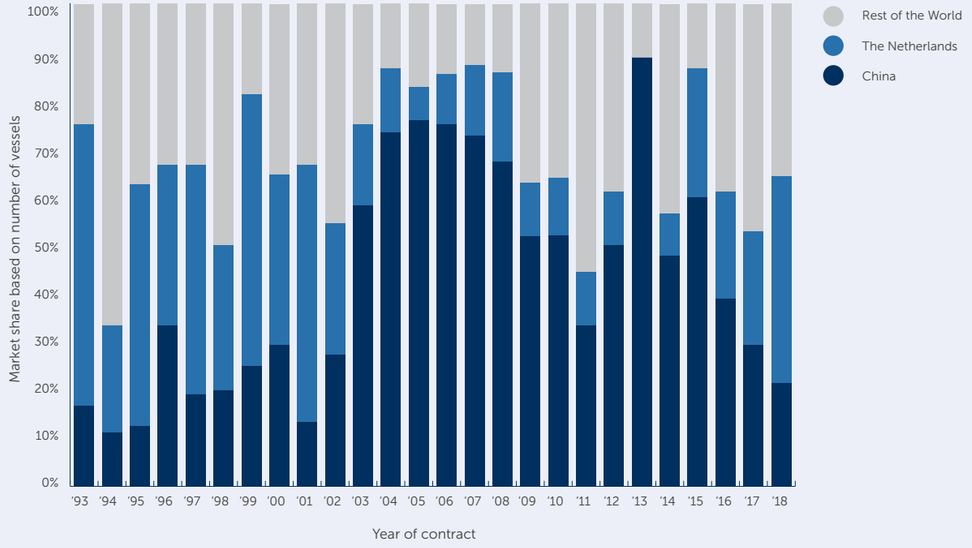


Source: J. van den Berg, Royal IHC

average Benelux competitors if you count all ships, and 3 times more if you count hopper and cutter suction dredgers only.

The figures 6-9 show the sudden emergence and scale of Chinese competition. Figure 6 documents that China has captured half of the shipbuilding market since 1993. As it can be seen in Figure 7, shipbuilding in China spiked especially after the mid-2000s. Finally, Figure 8 and 9 depict the dredging projects taken up by the European and Chinese companies after 2013. We see that China has become very active in obtaining international dredging projects. In particular, China has been very active in the developing and underdeveloped markets such as Africa and Southeast Asia.

Figure 7 **Market shares of shipbuilding in terms of number of ships built in China, The Netherlands & Rest of the World 1993-2018**



Source: J. van den Berg, Royal IHC

Figure 8 **Global Distribution of Dredging Projects between 2010-2013**

The edges connect the countries of the contractor and the client.
The data were retrieved from news announcements.

Figure 9 **Global Distribution of Dredging Projects between 2013-2017**

The edges connect the countries of the contractor and the client.
The data were retrieved from news announcements.

In addition to the increasing competition from China, local players have a strong presence in the market. Local players are national firms such as Hegemann in Germany, Adani Ports in India, Allonda Ambiental in Brasil, and Hall Contracting in Australia. In addition, harbor authorities in more remote places operate their own dredging equipment. Some of the local players, such as Hall Contracting, compete in international markets. While the market share of these local players currently seems to be stable, they may become a threat in the lower end of the market in the future.

Innovation in dredging

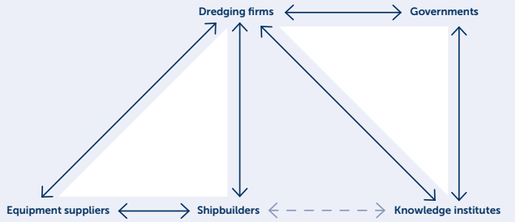
The core of the innovative power of the dredging and shipbuilding industry in the Netherlands and Belgium has traditionally been located in what we call the double innovation triangle. The left-hand triangle is on ship design, which happens between dredging firms, shipbuilders and equipment suppliers (Figure 10). Traditionally, much of the innovation originates from this triangle. Dredging firms have a strong input in the design of new high-end ships. Experience in dredging is highly relevant in ship design, and effectively translating that experience in innovative solutions affects future efficiency and effectiveness of operations, and thus competitive advantage. Smaller dredging companies, such as Dutch Dredging, strongly rely on what we call 'tacit' knowledge of their operational personnel in the process of ship design.

Larger shipbuilding companies traditionally bring in their system integration capabilities in the process of ship design. System integration means that different components are aligned to each other to create an overall design, in a way to meet the requirements in an optimal way. An example is the car industry, where car manufacturers develop the overall design of the car, integrating different parts. Suppliers in the dredging industry are firms such as Bakker Sliedrecht for electrical installations, MAN for Marine engines and systems and Damen Dredging or IHC Dredge Equipment for dredging installations, which are specialized towards these and similar technologically advanced industries, and which propose innovative equipment designs. Dredging firms partly deal directly with such equipment suppliers to explore new equipment technologies.

The right-hand triangle is on dredging technologies, and is between dredging firms, knowledge institutes (e.g., Deltares, TU Delft) and governments. This triangle executes research projects on future dredging methodologies, planning methodologies, impact analyses, stakeholder management, and, to a limited extent, technologies for ship design. The first joint-research project between the dredging companies was set up for fundamental research already in 1937. This was followed by joint-research projects on sand pumps in 1963 and 1969 [32].

Shipbuilders participate to a very modest extent in these activities. A strength of the Dutch dredging industry is the location of the whole cluster in a small region, with distances of only some tens of kilometers. Communication is relatively easy, as long as it is not hindered by intellectual property protection concerns. Also, personnel sometimes moves between the different actors. Belgian dredging companies do participate in the left-hand triangle, but they participate in the right-hand triangle only irregularly.

Figure 10 **The Double Innovation Triangle**



Changes in the Double Innovation Triangle

Recently, some changes happen in the left-hand triangle. Some dredging firms appropriate the role of designer of the ship, including system integration, relegating the shipbuilder to a dependent position. Jan De Nul was the first dredging company to create this capability, but other dredging companies such as Van Oord are following. In some cases, dredging companies hire engineering design agencies such as Vuyk Engineering for that purpose. Although this process is currently hindered by financial and operational problems at the supplying shipbuilders, the trend seems to be persistent. In such cases, shipbuilders have to take more the role of executor of the design developed by the dredging firm. Increasingly, dredging companies use shipbuilders in Eastern Europe or emerging economies for the shipbuilding task. Also Western shipbuilders use such shipyards or they own shipyards themselves in those countries. Such Eastern European and Asian shipbuilders are mainly dependent parties, since they get the specifications of the design from the dredging company or from the Western shipbuilders, with minor influence from themselves. They usually do not have a system integration capability, further stimulating this process. The dredging firm may also develop the equipment himself (Jan De Nul) or work closely with equipment developers directly, because equipment is key in the performance of the ship. In fact, the system integration role of the shipbuilders is excluded, and the left-hand triangle becomes a fork, with the dredging firm in the center, working with non-specialized shipbuilders on the one hand and with equipment developers on the other.

The relationship between shipbuilder and equipment developers is sometimes further deteriorated by opportunistic behavior of equipment suppliers toward shipbuilders. For equipment suppliers, orders of shipbuilders only come in irregularly, and thus they have to take advantage of them. Hold up problems and opportunistic behavior can result, for instance by charging higher amounts for every design change during the process.

Some dredging firms seem to follow another path, potentially with a similar result. They tend to order more and more ready-made ships, or copies of earlier designs. In other words, the integration capability is transferred to the shipbuilder, who, however, only applies it for a series of ships at the same time. While these copies of ship designs can still target at higher ends of the market, some high-end shipbuilders also start entering to low-end market with ready-made ships. A nice example of such 'disruptive innovation' (see Section Advice) is the Easydredge project of Royal IHC as explained in the box below.
The right-hand triangle is more stable, although the role of the government (e.g., Rijkswaterstaat) is decreasing in the execution of research, due to a reduction of human capacity in that area, but it still participates, partly as an orchestrator. Recently, the Ecoshape consortium has demonstrated both the ability of the dredging firms to cooperate and to benefits of such cooperation.

The Easydredge® as an Exemplary Disruptive Innovation

Royal IHC experienced a deteriorating presence in in the very low-end of the trailing suction hopper dredgers (TSHDs) market (i.e. regionally bound dredging vessel operators, mainly dredging local rivers and harbours), which demands capacity ranging between 500 up to 4,000 cubic metres. This low-end market was in need for standardized TSHDs. Large contractors charged high prices for their inland and maintenance dredging operations. In addition, large projects such as the Suez Canal, Panama Canal, and land reclamation projects in Dubai, Hong-Kong, and Singapore reduced the available capacity (i.e. availability of TSHDs in the world) [33]. This market segment is served with complex, medium and large-sized, custom-made vessels with the focus on optimizing the operational expenditures, due to the size of the dredging operations. Royal IHC successfully identified the disruptive potential of this market. As one manager explained "We said, well we have to do something about it, because if our competitors are able to build these smaller vessels they will grow and become bigger competitors for us, so that's why we decided to develop a standardized smaller low-cost vessel, the Easydredge in order to compete with these kinds of companies." This is when Royal IHC decided to build a low-cost TSHD in 2011, which would be built on stock with a maximum production time of one year and a maximum capacity of 4,000 cubic metres.

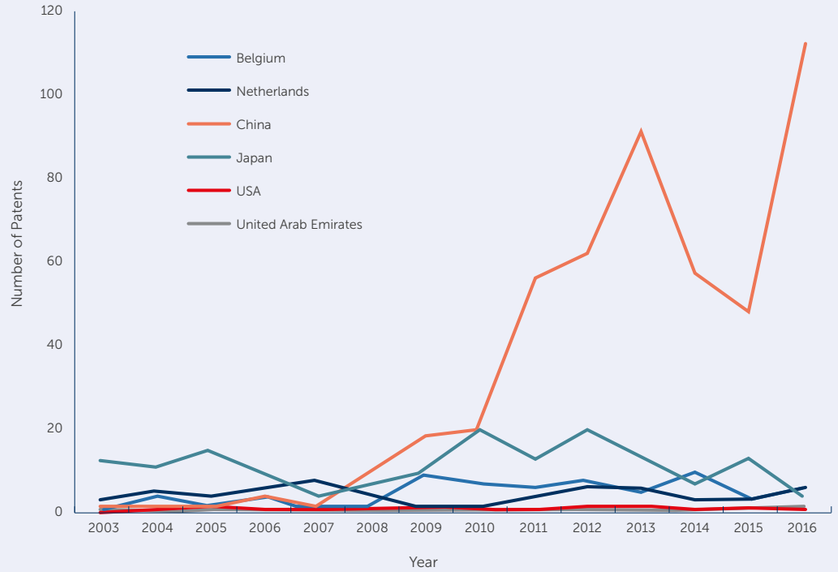
However, disruptive innovations come with their inherent challenges. The nature of this standardized vessel required a different way of thinking compared to the core business, which was about building high-tech equipment and complex custom made vessels. Selling this new vessel required a different culture of the salesforce, since the standardized TSHDs had to be produced and sold at significant lower cost of large custom vessels.

The development of the Easydredge® started outside of Royal IHC in a joint venture. However, the company realized the potential synergies and later continued the development of Easydredge® in-house. The development team benefited from high operational autonomy and received strong support from top management, which allocated sufficient resources to the unit.

Inventive activity in the industry

To better understand inventive activity within the dredging industry, we searched each country's respective patent office database (e.g., USPTO for the American dredging firms, and EPO for the Europeans, etc.) and financial reports presented in the Orbis database. Unfortunately, information on research and development spending was not always publicly shared by the dredging companies. This is why we relied on the number of patents as a proxy for inventive activity. Figure 11 below depicts a striking picture: the inventive activity in China has skyrocketed after 2007 whereas the rest of the world has been following a stable flat pattern. Although a difference in IP strategy (patenting versus secrecy) may explain part of the prominent relative position of China, this figure indicates that the inventive activities of that country have increased strongly, which may create a leading position in the future.

Figure 11 **Number of Patents Filed in Dredging**



World's first LNG dredger Minerva

Scenario Analysis

Dredging industry can stay relevant in the future only by preparing for it. Therefore, envisioning possible scenarios of how the dredging industry might look like in the future can help decision makers to makes sense of the changes they are experiencing, and be prepared for the future.

Figure 12 below depicts these trends and reveals four plausible future scenarios for the dredging industry. Requirements for sustainability and protectionism constitute the axes. Regarding sustainability, the European Union, European governments and International Maritime Organization (IMO) have all played a pivotal role in shaping the dredging industry by imposing several sustainability-oriented regulations. For example, mandatory emission limits of Sulphur Oxides (SOx) and Nitrogen Oxides (NOx) are imposed by IMO both globally and within designated areas called Emission Control Areas. Although most countries as members of IMO have already

Scenario planning

Scenario planning exercises provide decision makers a better understanding of possible futures created by current trends. The 1973 oil crisis brought scenario planning to the fore in the business world when the oil giants such as Shell tried to make sense and prepare for different future scenarios [34]. Recent research has shown that scenario planning indeed helps decision makers to craft flexible strategies [35]. This is why we conducted a scenario planning workshop on July 6, 2018, with the participation of 14 leading experts in the dredging industry. The workshop participants were first asked to list trends the industry is experiencing. After prioritizing the most important trends, the participants created future scenarios for the industry. During the workshop, the participants agreed on sustainability by both the regulators and customers as well as protectionism being the most important and plausible trends.

complied with these limits [36], country regulations also apply when ships operate entirely in domestic waters. Another trend as reviewed in Section Macro Trends (page 16) is increasing protectionism closing markets to international competition. For example, the Trump administration currently emphasizes this trend towards market protection. While benefiting from a home market closed to competition, Chinese dredging companies are becoming increasingly active in the rest of the world.
These two trends create four plausible future scenarios as they delineate the size of the market available to the Dutch and Belgian dredging companies and define the degree and basis of competition. The size of market refers to what extent the operations of the Dutch and Belgian firms are limited across the globe. The degree of competition indicates competitive intensity regarding the number of firms being in active competition. Finally, the basis of competition is related to whether the firms compete over price or try to differentiate themselves through innovation. Based on these trends, we next discuss four plausible scenarios, which will be followed by strategic advice that can help the industry to stay relevant in each scenario.

Figure 12 **Scenarios for the Industry**

Source: Scenario Workshop, July 6, 2018, RSM

Scenario 1: Fragmented dredging market

This scenario depicts a future in which the dredging industry experiences shrinking globalization and stricter regulations and demands on sustainability. Protectionism keeps the U.S. and Chinese markets closed, and perhaps this trend will be followed up by other governments including the European countries to close their dredging markets to international competition favoring only the local firms. The immediate consequence of this scenario will be a fragmented global dredging market, where the market size available to Dutch and Belgian firms is significantly diminished. At the same time, increasing requirements within each closed market determine the competitive base and its degree. Because international players are not allowed to enter particular markets in this scenario, the competition is likely to take place among the local players on a global dredging market that becomes increasingly fragmented. However, these players need to comply with increasing demands from regulators and customers for more sustainable solutions.
This pressure prompts dredging companies to innovate to be able to compete in the market. That is, this scenario induces the dredging companies to be more innovative to address the sustainability requirements, but the decreased working area results in a lower workflow. Consequently, this scenario envisions overcapacity of the dredging fleet, which directly impacts the prices of dredging works. The sales margins drop and the dredging companies supplying the most innovative solutions get the job. This trend is already present in some Western European countries, which commission the dredging jobs to the dredging companies with the best economic and sustainable bidder (EMVI in Dutch). To fuel their innovative capabilities, the dredging companies are likely to benefit from collaborating with external parties (e.g. universities, research institutes, start-ups, non-direct competitors, etc.) to develop sustainable innovative solutions. This strategy is known as open innovation, which we elaborate more in the Section Advice. At the same time, the dredging companies can explore new business models, such as servitization by shipbuilders and Industry 4.0, to smoothen and reduce their operating expenses (see Section Advice).

Scenario 2: The innovators win

This scenario envisions a future with more sustainability related demands and freer markets. The basis of competition remains to be differentiation through innovation. However, market size as well as competitive intensity at a global scale are higher. Increased regulations and sustainability requirements require a more specific approach for every project to deal with the required specification based on regulations and local legislations. In this scenario, with increased globalization, the business area is also enlarged. This means that the focus needs to be on regulation while also seizing new market opportunities due to globalization. This scenario already takes place in the road transport industry where every country has its own regulations for emissions of trucks. In that industry, globalization increases, but the increased working area offers more regulations, and companies need to deal with them. Consequently, technological competition and innovation become key. Because the competition becomes global, the Dutch and Belgian competitors can explore collaborative arrangements — a strategy is known as co-opetition where firms compete and cooperate at the same time. Here, collaboration does not entail only capacity sharing, but also require active cooperation among competitors to develop innovative solutions together. This collaboration can involve external parties as well, which invites a shift from closed research and development practices toward embracing the open innovation paradigm.

Scenario 3: Protected negligence

This scenario entails decreasing global trade due to protectionism creating a significant challenge for the dredging companies to operate globally. This means that market size significantly deteriorates. At the same time, lowered sustainability requirements shift the dredging companies' focus away from developing innovative solutions that care about the environment. Instead, the competition becomes severe among local companies, who compete based on price to win local tenders. With a trade war which is currently happening between USA, China and Europe as well as the withdrawal of U.S. from the Paris Agreement on climate change, this scenario is quite plausible albeit not desirable. Companies can explore operational excellence through servitization and by adopting Industry 4.0 practices.

Scenario 4: Commodity market

This scenario pictures a plausible future where the dredging industry is active in every corner of the world with open boundaries and there is lower regulatory pressure and customer demand for sustainable solutions. Therefore, the dredging companies that are active in a protected area such as U.S. and China have to deal with increased competition. Internationally active dredging companies can easily compete with the local dredging companies by extending their capacity. This creates a higher spread of the projects over the globe and creates a stable foundation of their order book, as well as stable revenues. At the same time, this scenario entails Chinese competitors penetrating into the European market. As sustainable solutions can no longer keep these competitors at bay, they become a serious threat as the basis of competition shifts from innovation to price. The cut-throat global competition will add more pressure on dredging companies to improve their operating margins. That may entail a new wave of merger and acquisitions where firms try to create synergies and benefit from economies of scale. At the same time, this trend may prompt the dredging firms to explore new business segments with less price wars. The strategy to develop new businesses require new innovative capabilities, which is likely to demand collaborating with external parties through open innovation frameworks. Because those new businesses may conflict with the existing value chain, this scenario may also prompt companies to organize differently through forming ambidextrous organizations.

The next natural question following these scenarios is that how Dutch and Belgian players in the dredging industry can prepare for each scenario. Two common threads emerge in each scenario: competition and innovation. In the following section, we argue that these players need to redefine how they see competition and change their approach to innovation from closed in-house research and development to a more open approach to foster disruptive innovations.

Advice

These scenarios unanimously highlight that protectionism and sustainability related trends are likely to shape the competition and size of the market where the competition takes place. In this section, we discuss a number of strategies for Dutch and Belgian dredging companies to keep their competitive advantage in the future. In particular, we propose four lines of action:

- Co-opetition between dredging companies;
- Involving external parties for research and development: Open Innovation;
- Organize for Disruptive Innovations;
- Servitization and Industry 4.0 initiatives.

Co-opetition between dredging companies

Co-opetition mandates balancing conflicting demands of competition and cooperation. Co-opetition can rejuvenate the right-hand side of the triangle (see Figure 10), but it may even be applied to the left-hand side. On the one hand, competition favors opportunistic behavior and private gains. Hence, firms are asked to carry out frequent, aggressive, complex, and diverse strategic maneuvers to gain competitive advantage [37]. On the other hand, cooperation emphasizes mutual interests and achieving collective goals [38]. At the outset, competition and cooperation seem to be competing logics. For example, recent research documents that seeking private benefits can be at the expense of extracting common benefits as firms underinvest in shared resources, become overprotective on their intellectual property and fear from retaliation or misappropriation [39]. The same line of research also shows that co-opetition yields higher organizational performance [37,40,41]. Given the contradictory logics of competition and cooperation as well as the positive performance benefits of balancing the two, firms in the dredging industry should develop capabilities that enable

them to balance cooperation and competition in order to reap the performance benefits. These capabilities and hence the advice for coopetition are particularly important in the second and fourth scenarios where Dutch and Belgian dredging firm experience competition at a global scale and need to innovate to differentiate themselves and/or to address increasing demands for sustainable solutions.

Dutch and Belgian firms have been dominating the dredging market. The increase in scale led to a cut-throat competition. Yet, the dredging industry is a tender-based market. With their increase in size, dredging companies have increasingly grown into the position of main contractors in these tenders. To hedge the risks, the dredging companies have combined forces in joint ventures to enter tenders together. As we indicated in Section 'Evolution of the Industry' (page 25), coopetition in the sector is mainly used as a form of risk sharing, not for innovation. However, to stay competitive in the global dredging market that is increasingly experiencing competition from China — a closed emerging market, the coopetitive arrangements should also include collaborating in innovation activities.

In the Section Technology Trends, we described knowledge development in the Ecoshape project (see page 16). Ecoshape illustrates how competitors come together to generate knowledge that help them to stay relevant. A member of the consortium indicated this aim during an interview: "if we work together and develop great things and concepts, we will all gain a competitive advantage." This objective is achieved by providing clients with a proof of concept and offering advisory services on how to embed Building with Nature components in designs.

Source: Deltares

Ecoshape also reveals the important capabilities needed for a successful collaboration between competitors. The first element is delineating clear collective boundaries for collaboration, set by the competing firms. Here the common purpose and goal should be placed at the forefront. An interviewee in one of the consortium partners illustrates this point: "because we all have that common goal, it is really easy to just be enthusiastic about what we are doing there. And not really be bothered with the competitive elements which are in that." Prior research emphasizes that the purpose and common goal should be mutually recognized by the competitors, and the competitors should equally invest in the consortium. In fact, once the purpose for collaboration (the 'why') is linked to the desired outcomes (the 'what'), the competitors can also justify the equal investments made into the collaboration.

The need for coopetitive relationships for innovation, such as Ecoshape, is increasingly been recognized in different industries due to today's increasingly complex and dynamic business context [37,40,41]. Although the benefits of coopetitive arrangements have long been shown in academic research, carrying out these arrangements proves to be a managerial challenge because of the inherent tension between competition and cooperation. Therefore, to unleash the true potential of competition and to retain the Dutch and Belgian firms' competitive advantage in the dredging industry, these managerial tensions should be managed. Our field research at Ecoshape provides a solid base for building and implementing coopetitive innovation, managing coopetitive tensions from the outset and throughout the existence of the relationship, truly addressing the dynamic and multi-level nature of coopetitive relationships. By collectively setting boundaries for coopetitive innovation, competing firms can increase the likelihood of turning coopetitive innovation into a win-win scenario from the outset of the coopetitive relationship. Within the dredging industry these findings are especially valuable, contractors being forced by clients to broaden their knowledge and skills; shifting from purely asset-based to knowledge-based organizations. As such in the future, comparable consortia based on the same premises might be of great value for the contractors in the dredging industry. As decreasing levels of knowledge within Rijkswaterstaat are not limited to marine-infrastructural projects, this strategic advice might additionally be interesting to other Dutch tender based infrastructural markets.

Co-opetition emphasizes joint innovation activities between competitors. Toward the goal of boosting innovation capabilities and the competitive advantage of the dredging industry in the Netherlands and Belgium, collaborating with universities, start-ups and other institutions is yet another viable strategy. This strategy is known as open innovation, which we elaborate next.

Involving external parties for research and development: Open Innovation

Redefining competition which should include cooperation also entails changing how firms in the dredging industry approach their in-house research and development. Unique sources of knowledge and technology that can help Dutch and Belgian dredging firms reside also in suppliers, universities, startups or in firms in completely unrelated industries. The paradigm of including actors outside of a company's boundaries is known as Open Innovation [10]. Open Innovation stresses the 'abundancy'

of external knowledge outside firms that waits to be captured and converted in products and services [10,42,43]. External knowledge providers can be suppliers, competitors, universities, startups (the empirical observation of this study) and firms from unrelated industries.

Prior research has demonstrated that an open innovation approach increases the inflow of new ideas and exposes firms to early innovations [44,45]. This approach has been shown to lower research and development costs, reduce time to market, and yield more sales [46–49]. This advice is viable in all four scenarios identified above. Through open innovation, firms can collaborate with outside parties to develop solutions improving their operating margins (Scenarios 3 and 4) and/or addressing sustainability requirements (Scenarios 1 and 2).

Dredging firms have traditionally invested in large R&D functions with the aim of maximizing innovation solely on their own. Firms in the sector are proud of in-house innovations because it is a synonym of strong brand recognition. Productions of fleets are costly, and they are built based on trust and expertise of the producer. Vessels are tailored by clients' requests and the span of innovation activities of dredging incumbents is limited to deliver a project as requested by the contractor. Adding to that, the average time of construction of a vessel is between 2 and 5 years. Nonetheless, sustainability pressures imposed by the regulators and the stakeholders and increasing competitive pressures for lower prices, as discussed in the scenarios above, demand more innovative solutions built in shorter amounts of time. It is therefore admirable that Royal IHC, Boskalis, Van Oord and DEME have recently joined PortXL accelerator as partners. However, our field observations and interviews reveal that open innovation has not yet been embraced by the firms in the industry to the fullest. In line with redefining competition, firms can benefit from a change of mindset from closed in-house research and development to a more open and collaborative approach to innovation.

Organize for Disruptive Innovations

Disruptive innovations have allowed firms of any size and maturity to enter into a new market and to conquer it, causing the previous market leaders to either fail or to settle for a marginal presence. To remain competitive, Dutch and Belgian firms in the dredging industry not only need to develop one-time disruptive innovations, but also establish the necessary structures that allow them to do so in a continuous manner. This advice is relevant for all scenarios. For example, Scenario 4 (commodity market) envisions that the dredging firms explore new business as the dredging industry itself experiences a cut-throat competition. Similarly, Scenario 3 (protected negligence) considers a future in which the dredging firms move away from their current value proposition on developing sustainable solutions to developing new cost effective solutions. Both Scenario 1 (fragmented market) and 2 (the innovators win) also emphasize developing disruptive innovations due to their very emphasis on differentiation through innovation.

Business history is full of once successful companies who had to kneel down to disruptive innovations. Examples include Polaroid's instant print cameras becoming obsolete by digital cameras, Kodak's bankruptcy when mobile phones mounted cameras on them, Nokia's demise due to Apple's iPhones, and Netflix's streaming disruption of Blockbuster in video on demand market, etc. Slower paced industries are not immune to disruptive innovations either. Consider how large integrated steel mills, the proud producers of high quality steel, became disrupted by mini mills, a lower quality but also lower cost contender. The experience of integrated steel mills resembles the current situation of dredging industry. The core business market segment consists of the largest contractors, such as the big four (i.e. Boskalis, Van Oord, Jan De Nul and DEME). As the industry has limited its focus mainly on large dredging ships (see Section Technology Trends, page 19), not only the lower segment remains untapped, but also this segment invites potential disruptors, who might later encroach to the higher end of the market, just as the mini mills did in the steel industry. That is, the underlying assumption in the sector is that dredging works are driven by external factors and global trade [1,50]. However, our research reveals that the industry is being disrupted from within by the very firms constituting it (see the example of Easydredge on page 33).

Disruptive innovations are aimed initially at customers in niche markets, such as low-end or new markets [51,52]. Hence, incumbent firms struggle with becoming aware of potential disruptive innovations in such niche markets due to a tendency to limit the strategic focus to mainstream customers, who are served by the incumbent's core business [52–54]. Senior and top management tend to focus on the more profitable sustained innovations as well as the needs of mainstream customers [52,54–56]. In contrast, incumbent firms often have sufficient resources to adapt to the niche market, but their deeply ingrained processes and values hinder the successful exploration of disruptive innovations [57]. On the other hand, there might be a fear of cannibalization, which relates to the organizational dualism between the core business and new

innovations with a potential to disrupt the core business [9,52,58–60]. While being a tremendous opportunity to beat the competition, disruptive innovations also represent an important threat to incumbents that do not understand and prepare against disruptive threats. Recently these threats not only originate from innovative Western firms, but increasingly also from companies in emerging economies. How can the dredging industry foster disruptive innovations and respond to disruptive threats?

Our research and analysis of the industry offer four lessons on how to cultivate disruptive innovations. First, prior academic research advocated that disruptive innovation initiatives should be developed outside of the company [53,57]. We see examples in the airline industry, where traditional airlines acquired or created budget airlines to compete in the low end of the

market. Firms can better organize such activities in a separate organization because internal processes, culture, values, and attitudes conflict with the processes and values required for both innovation types [9,61–63]. However, our research reveals the benefits of developing disruptive innovations within the same organizational unit. This is because the dredging firms can create significant synergies by leveraging their in-house capabilities. Second, the unit should be granted significant autonomy if set within the organizational boundaries. This is because disruptive innovations are highly uncertain, and existing procedures and decision-making structures might not accommodate such uncertainty. Third, disruptive innovation can potentially cannibalize existing business or diverge from the current value proposition. Such a divergence invites several critiques that want to sabotage or slow down the disruptive initiative. This is why strong support and sponsorship from top managers is essential. Fourth, top managers should put the money where their mouths are. The disruptors' time is better spent on developing the disruptive innovation than fighting other units for resources.

Shipbuilders may strengthen their market position by following the advice of the disruptive innovation scholars by more clearly separating the high-end ship design and construction activities, with large overhead, and a nimbler unit or company for cost-competitive smaller ships to be operated in less challenging or more cost-focused environment (such as Royal IHC did in the EasyDredge project). Separating the units facilitates the differences in goals and orientation and helps the lower-end activities to become successful.

Servitization and Industry 4.0 initiatives

In addition, shipbuilding companies may implement so-called servitization strategies, which involve providing a more complete service package in addition to ships and spare parts, such as predictive maintenance. Such strategies can be supported by - so called - Industry 4.0 initiatives. Industry 4.0 means that different actors in a supply chain create denser information sharing about their processes and intensified communication between them by means of IT. Products or equipment can be equipped with sensors, Internet of Things (IoT), and can be followed and monitored through their lifetime. This means for the dredging industry that equipment manufacturers and shipbuilders can monitor the equipment on a permanent basis and can do predictive maintenance and provide other services. They can develop expertise on how customers, operators of dredging ships, can be more effective in their activities. They may even rent equipment to customers in a subscription model, including the complete service package.

For the high-end market such service packages may increase efficiency in the sector, since shipbuilders would take advantage of scale effects by serving different customers in maintenance and support compared to isolated execution of these tasks by the dredging companies. So, these strategies particularly fit in the scenarios with strong price pressure (Scenarios 3 and 4). For local or regional dredging firms and harbors operating their own dredging equipment, such service packages may meet the need for skills in dredging activities, which these companies themselves are missing. Also, such service business models may better flourish in a separate unit in shipbuilding companies, due to the reasons mentioned above.

The dredging companies themselves can also make better use of their existing data by applying data analytics. They can develop strategies to collect more data on their activities, and on the effects of the projects on the natural environment afterwards. More effective use of data can both increase efficiency, and contribute to extending their expertise in managing the environmental effects of dredging projects.

What should governments do?

The European Union as well the Dutch and Belgian governments can provide support to the dredging sector by creating a global level playing field. The closure of the US, Chinese markets, and parts of the African market, while the European market being largely open, is a serious hindrance for European dredging companies' international competitiveness. For example, Chinese competition is taking advantage of this uneven playing field, aggravated by government support as a state-owned company. The Dutch government should plea in the European context and directly in communication with Chinese and US counterparts for ending this situation. While such actions may bring some improvements, we cannot be too optimistic in the current international political climate. Nevertheless, action should be undertaken even to bring small changes in this area.

The EU, European governments and International Maritime Organization have all played a pivotal role in shaping the dredging industry by using several regulations. Most of the current literature on regulatory tools and their impact on innovation explores specifically the effect of environmental regulations caused by the increasing importance of environmental issues [64]. Economists view regulations as a

necessary response to account for the absence of a market for environmental impact [65]. Early on Porter and Linde (1995), claimed that 'stringent but properly designed environmental regulations can trigger innovation.' More recent research has qualified this finding and highlighted that too many strict regulations can be detrimental for innovations [66]. To answer the question of whether extensive regulations have been helping or hurting the dredging industry, we conducted a study investigating the effects of IMO regulations on the patents by the dredging firms. Our findings show that emission regulations had a negative effect on the number of patents produced by the dredging firms. This is in line with prior research [67] which highlights that command-control regulations, such as emission regulations, do not always stimulate innovation as much as incentives-based tools do. These results indicate that the compliance of regulations raised the financial burdens for European firms, diminished the competitiveness whereas the Chinese government heavily sponsored CCCC, which innovated astonishingly.

Hence, the regulators should be more cautious when designing regulations. Considering that emission limits are the typical command-and-control policy, there are other sounder alternatives. Emissions can be controlled directly by taxes or marketable permits. Economic incentives, for instance, might prove more effective. Firms in this way will make their own decisions to choose optimal equipment, processes, procedures, or whatever they would come up with in order to maintain their status. Taking the classic United Stated Clean Air Act in 1990, the regulators instead of setting standards, they implemented a trading system that reduced both the sulfur emissions and the cost more than any prescriptive policies would do. Finally, it is vital for the designated sulfur and nitrogen control areas to extend to China and the Asian coastlines too. Environmental regulations are inefficient if firms dodge them by operating in countries that do not apply [68]. Governments might consider intervening with funding to firms, economic incentives to further embrace innovation and emission-free strategies.

Effects of environmental regulation on innovation
We collected data from the top 10 dredging firms, with a time window comprising from 2003 to 2016. We utilized the Orbis database for firm level data, IMO and EU sources for the regulation announcements, country level data on population and Gross Domestic Product per capita from the World Bank and Gross Domestic Expenditures in R&D as a percentage of GDP from UNESCO's Statistical Yearbooks. The final sample included 116 firm-year observations after deleting missing data. For example, Rohde Nielsen did not have sufficient public data and we could not obtain United Arab Emirates' Domestic Expenditure on R&D. For our statistical analyses, we utilized the fact that emission regulations were imposed across the globe in different periods and were enforced in different phases.


Sand Motor

Marker Wadden

Conclusion

This report has documented that the dredging sector in the Netherlands and Belgium still has a strong international position. The four large Dutch-Belgium dredging companies jointly have a dominant position in the global dredging market, and the sector is leading in innovation and performance in shipbuilding and dredging technologies. Two innovation arenas have created this position: the triangle of dredging firms, shipbuilders and equipment manufacturers producing high quality dredging vessels and equipment, and the triangle of dredging firms, research institutes and government agencies developing new methodologies for dredging, such as Building with Nature.

Several opportunities can strengthen the sector further. First, global warming and rising sea levels, urbanization and investments in coastal areas, intensified international trading and tourism are likely to keep the demand for dredging high. In addition, sustainability requirements may pose new opportunities on which the Dutch-Belgian dredging sector can outcompete their global competitors. In particular, the sector can outperform the international competition in caring the environmental and social impact of dredging projects.

The current competitive position depends on the extent that international markets open up and that sustainability becomes the credo across the globe. Chinese competition is here, and most likely to increase in the near future. Competition concerns shipbuilding, where Chinese shipbuilders have already created a strong position especially in the developing and underdeveloped markets whereas the Chinese market remains closed to international dredging companies. Whether the sustainability related regulations, for example those imposed by the International Maritime Organization, get increasingly adopted in the rest of the world will determine the extent that the Dutch and Belgian dredging companies use their knowledge advantage in developing sustainable

solutions to have a competitive position across the globe. Yet, the scale of this competitive advantage is determined by the question whether protectionist tendencies become tamed and large markets such as U.S. and China open up.

To respond to the growing international competition, collaboration in the sector should be re-strengthened. Both vertical partners (equipment manufacturers, shipbuilders, and dredging firms) as well as the competing dredging firms need to redefine how they compete and to cooperate in developing innovative solutions. We plea for combining competition and collaboration, which is to some extent already happening in the dredging methodologies arena (e.g., the case of Ecoshape) but can be extended to innovation in equipment design and maintenance. Such collaboration can maintain the strength and leading position of the Dutch-Belgian cluster. Additional advice includes business model innovation, for instance by a servitization strategy of shipbuilders, disruptive innovation, and open innovation where the sector taps into the innovative potential of different parties including but not limited to universities, governmental organizations, and data analytics start-ups inside and outside of the sector. Such a paradigm shift toward competition and innovation can further rejuvenate the sector.

The government can support such a trend by putting more pressure to create an international level playing field in the dredging market. The Chinese and US market, and even several EU markets, are shielded from international competition, whereas open tendering is the rule in the other EU states. The Dutch and EU governments should put more pressure to resolve this situation. Concerted efforts from different parties are needed to keep the Dutch-Belgian dredging sector innovative and leading in the world.

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