The future scenarios and strategies for the dredging sector in the Netherlands and Belgium

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The future scenarios and strategies for the dredging sector

Preface.

It is with great pride that I present this report, an initiative led by NMT-IRO, which highlights the strategic importance of the Dutch and Belgian dredging sector. This research, conducted by Erasmus University Rotterdam in close collaboration with leading companies within the dredging cluster, provides valuable insights into the unique and globally dominant position of the Netherlands as a leader in maritime civil engineering.

The Dutch and Belgian dredging sector sets the benchmark for innovation, expertise, and sustainable solutions. The sector is not only a vital economic cornerstone but also a strategic asset that strengthens the Netherlands' position on the world stage. By safeguarding our coasts, maintaining critical infrastructure, and enabling the development of renewable energy projects, Dutch and Belgian dredging companies continue to demonstrate their unparalleled capabilities and commitment to addressing global challenges.

Through workshops and interviews with over 60 industry experts, this report identifies key trends, challenges, and opportunities for the future. It underscores the importance of collaboration, innovation, and sustainability in maintaining and enhancing the Netherlands' competitive edge in a rapidly changing world.

I invite policymakers, industry leaders, and all stakeholders to embrace the findings and recommendations in this report, ensuring that the Dutch and Belgian dredging sector remains a global leader and a source of pride for the maritime industry.

Jeroen de Graaf
Director, NMT-IRO

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Executive summary.

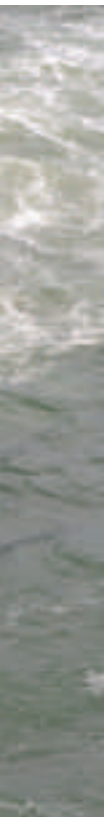
Dredging technology and operations capability of the Netherlands and Belgium is recognized as the most advanced in the world. The dredging industry is also vital to the economic, environmental, and security interests of the Netherlands and Belgium. Ports such as Rotterdam and Antwerp depend on continuous dredging for their standing as global trade centers, supporting hundreds of thousands of jobs. At the same time, these low-lying nations rely on dredging to maintain and protect essential flood defenses. Beyond such core functions, the industry facilitates major construction and sustainable development initiatives, including land reclamation, offshore wind farms, and innovative coastal defense projects. Beyond jeopardizing economic competitiveness, the loss of local dredging capabilities would also undermine resilience against environmental threats, thus emphasizing the need for strong, future-proof dredging ecosystems.

This report is based on five co-creation workshops and interviews involving 66 industry leaders from the Netherlands and Belgium. Participants proposed multiple trends and uncertainties across six key domains—Environment, Politics, Policy, Regulation, Technology and Competition—to identify those most likely to shape the dredging sector over the next 15 years. From these insights emerged three plausible scenarios labeled Green, Teal, Brown scenarios collectively highlighting critical junctures where the industry must adapt or risk decline.

Despite the diverging scenarios, these workshops revealed three recurring strategic priorities for the industry: (1) developing technology and innovation capabilities, (2) cultivating partnerships and an ecosystem, and (3) attracting and developing talent.

Developing technology and innovation capabilities

Whether adopting autonomous vessels in a sustainability-driven Green scenario, seeking incremental efficiencies regionally in the Teal scenario, or targeting operational excellence



amid protectionist markets in the Brown scenario, robust innovation capacities are essential to stay competitive. Firms can respond to uncertain technological paths—alternative fuels, AI and automation—through "real options" strategies by making small, flexible investments before committing large resources. Hence, maintaining a balanced R&D portfolio from incremental upgrades to disruptive innovations, with agility to pivot as market or regulatory changes arise, becomes critical for the industry.

Cultivating an ecosystem

Industry-wide collaboration, including research institutions, government agencies and other maritime players, allows for shared risks, pooled expertise and cost efficiencies. Moving from one-off partnerships to a structured ecosystem model can foster deeper alignment, support breakthrough innovations, and help maintain critical know-how in the region. This strategy emphasizes moving beyond competitive mindsets by institutionalizing cooperation—forming alliances, for example, to develop zero-emission technologies, to co-finance large infrastructure projects, and to collectively respond to environmental regulations.

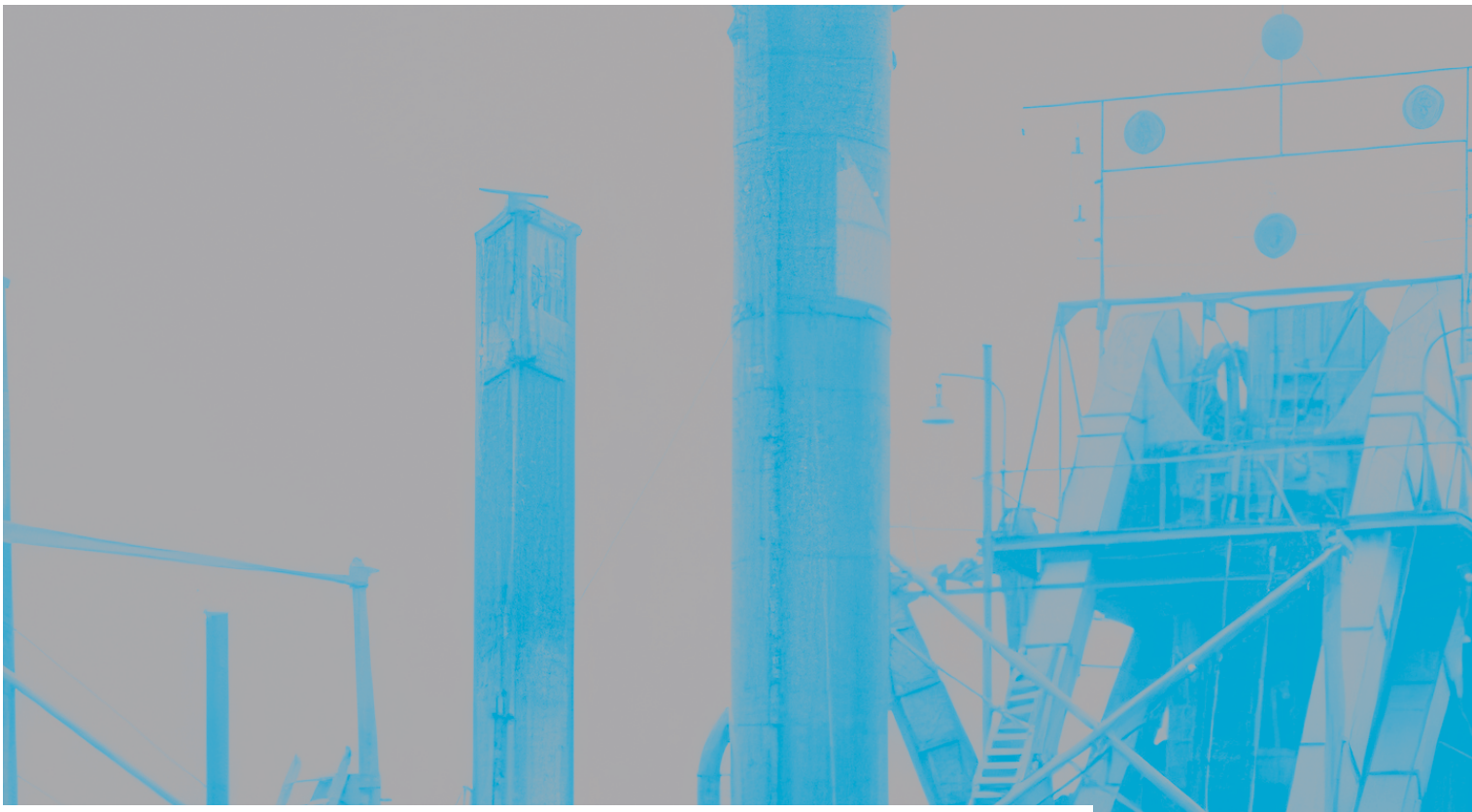
Attracting and developing talent

Addressing both high-tech and traditional skill shortages will be essential in all future scenarios. Companies can invest in scalable training programs, partner with educational institutions, and improve the industry's public image. Here, dredging stakeholders can create scalable local and international training programs, as well as launch public campaigns to highlight the dredging sector's essential contributions to coastal safety, sustainability and global trade.

This range of scenarios and related strategic directional review seeks to aid dredging firms and their stakeholders secure a resilient future, whether engaging global cooperation, regional protectionism, or heightened resource scarcity. This proactive, collaborative strategy not only ultimately sustains the economic leadership of the Netherlands and Belgium in this crucial sector; it also preserves national capacities to defend coastlines, harness sustainable energy, and remain at the forefront of maritime innovation.

DISCLAIMER

This report and the workshops informing it were funded by NMT-IRO and hosted at Rotterdam School of Management facilities. We are grateful to all participants and sponsors for their generous contributions. While every effort has been made to compile and accurately reflect the discussions and viewpoints expressed at the workshops, the ideas and proposals contained in this report do not necessarily represent the official positions of NMT-IRO, Rotterdam School of Management, or any organization to which our participants belong.



Strategic importance of the dredging industry.

The dredging industry in the Netherlands and Belgium is globaly known for its innovativeness and deep expertise. This global recognition has turned the industry into a crucial economic sector for the Netherlands and Belgium, providing a substantial number of jobs and supporting many other sectors. The industry is also a lifeline that sustains their national roles as maritime leaders and shields their territories from environmental and security threats. The importance of maintaining clear waterways, protecting coastlines, and supporting sustainable development requires retaining the competitive position each country has developed. Here, the dredging industry means more than merely moving sand and sediment; it is integral to economic vitality, environmental sustainability, and national security.

First, at the heart of the Netherlands' and Belgium's economic prowess are their ports, like Rotterdam and Antwerp, serving as major hubs to global trade. The Port of Rotterdam alone handles approximately 439 million tons of cargo annually and creates 193,000 jobs[1], while the Port of Antwerp processes nearly 290 million tons and creates 164,000 jobs[2]. Regular dredging keeps these vital shipping lanes navigable, allowing continuous flows of goods that underpin both national economies. Without consistent dredging efforts, silt and sediment would accumulate with reduced access for larger vessels and higher shipping costs, potentially jeopardizing portal status as key international logistics hubs. The dredging sector also ensures navigable inland waterways crucial for hinterland transport to Europe.

Second and beyond its significance for waterways, the dredging industry is critical for national security and disaster preparedness. Both countries are highly vulnerable to flooding. Approximately 26% of the Netherlands lies below sea level with about 60% of the nation prone to flooding from the sea, rivers and lakes[3]. A significant portion, too, of Belgium's population concentrates along its coast and rivers. Dredging is a key tool in managing water levels, maintaining flood defenses, and enhancing the resilience of critical infrastructure.

Annual Dutch expenditure on water management and flood protection is substantial. For instance, its Delta Programme allocates €1.3 billion yearly to flood risk management and water quality improvements[4] sourced from the Delta Fund, local water authorities, and its Ministry of Infrastructure and Water Management. In Belgium, the expenditure on flood protection and water management is also significant, though generally lower than that in the Netherlands with its smaller Flemish footprint and distinct landscape. For example, Flanders has invested over €418 million since 2020 in flood protection and water management initiatives focused on infrastructure improvements and maintenance[5].

Annual expenditure on dredging the Westerschelde to ensure accessibility at the Port of Antwerp is sizeable. The Flemish government, alongside its Antwerp Port Authority and other seaports, allocates around €140 million annually for this purpose. The annual

[1] Port of Rotterdam, 'Feiten en cijfers'.
[2] Port of Antwerp-Bruges, 'Wereldhaven'.
[3] Pieterse et al., *Overstromingsrisicozonering in Nederland. Hoe in de Ruimtelijke Ordening Met Overstromingsrisico's Kan Worden Omgegaan.*
[4] Waterstaat, 'Delta Programme'.
[5] Belga, 'Blue Deal'.

expenditure for dredging for the Port of Rotterdam is also large, involving multiple projects to maintain and improve its accessibility. Each year, the Port of Rotterdam Authority invests between €150 million and €300 million in port infrastructure, which includes dredging activities[6]. For instance, the dredging of the Nieuwe Waterweg, a key waterway connecting Rotterdam to the North Sea, involves extensive work to ensure accessibility for modern vessels.

Third, the dredging industry is key in advancing sustainability and climate adaptation goals for both nations. It supports the construction and maintenance of coastal defenses, such as dunes and seawalls to protect against rising sea levels—a growing concern as icecaps melt. Moreover, dredging facilitates the development of offshore wind farms—a key component of the energy transition in the Netherlands and Belgium. The European Union aims to install nearly 60 GW of offshore wind capacity by 2030 and 300 GW by 2050[7], and both countries are heavily involved in this initiative. Dredging companies provide the specialized services needed to prepare and maintain the seabed for these projects, ensuring the stability of turbines and other infrastructure crucial for meeting national and EU-wide renewable energy targets.

Finally and importantly, dredging is a leading economic sector in the global economy. Mimicking the high-tech industry around ASML, this sector leads its field as a "global star." It is important for countries in a globalized economy to have such stars that lure governments and businesses to purchase products and services, as well as for the international visibility. Dredging is a key part of the water engineering sector in the Netherlands, globally known for its innovation and deep expertise. This industry contributes to the Dutch identity as a nation specialized in water management. Being a global star, dredging is a significant economic driver for the Netherlands and Belgium, providing a substantial number of jobs and supporting many other sectors.

[6] Port of Rotterdam, 'Annual Reports'.
[7] Widuto, 'Wind Energy in the EU'.

Approximately 26% of the Netherlands lies below sea level

About this report.

This report is the result of a collaborative co-creation effort aimed at answering a crucial question: "How can we sustain and further develop a competitive dredging ecosystem in the Netherlands and Belgium?" We organized five consecutive workshops that assembled 64 industry leaders from the Netherlands and Belgium, collectively representing the breadth of expertise and experience within the dredging sector. Our approach was structured around six key steps[8]. Figure 1 below portrays the steps we followed.

Step 1

To envision the future, we first needed to understand the past. Maritime historian Joke Korteweg expertly led us through the rich history of the dredging industry, offering insights as to challenges and uncertainties that have shaped its evolution. This historical perspective was essential in identifying both critical factors that once drove the industry's success and pitfalls that could have been avoided.

By reflecting on these past lessons, we aimed to illuminate the path forward navigating the future of dredging in the Netherlands and Belgium.

Steps 2 and 3

We undertook scenario planning to envision the future of the industry. Scenario planning is a strategic approach that explores and prepares for multiple plausible futures. It involves first identifying key trends and uncertainties that could significantly influence the industry, then developing a set of plausible scenarios based on different combinations of these trends and uncertainties. Specifically, we analyzed political, economic, societal, technological, environmental, and legal trends that could impact the dredging industry. Unlike trends that reflect steady, predictable developments, uncertainties are defined as potential changes yielding future outcomes we cannot reliably project. We brainstormed events with uncertain outcomes that might affect the industry, such as geopolitical shifts, technological breakthroughs, or unexpected regulatory changes.

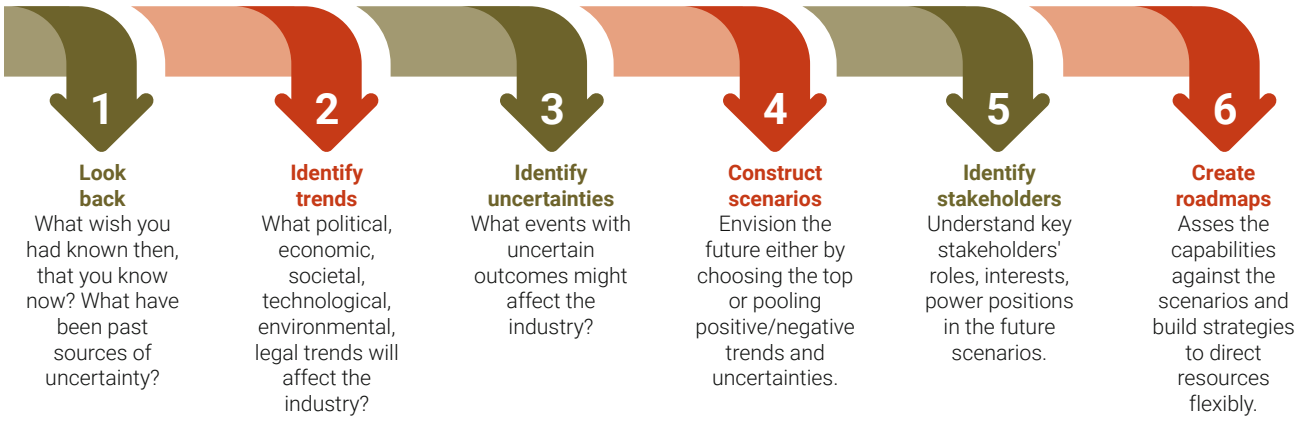


Figure 1. Six steps we followed across the workshops

[8] see Schoemaker, *Advanced Introduction to Scenario Planning*; Schoemaker, 'Scenario Planning'.

During these sessions, hot debates ignited regarding the very definition of "dredging." One major point of contention was whether projects like offshore wind-farm installations should be deemed part of the dredging industry. The ultimate consensus was to define dredging in its traditional sense: as the process of moving sand and sediment from one place to another. This definition helped us to focus our scenario planning more clearly on the core activities of the industry.

Another crucial aspect of our scenario planning was determining how far into the future we should look. One participant suggested an ambitious view, proposing that we look a *century* ahead to consider how the industry might evolve toward returning materials or salvage equipment from *space*—whether low Earth orbit or the asteroid belt—to Earth. While this sparked intriguing discussions, we agreed to focus on a more practical, middle-term horizon of 15 years. This timeframe allowed us to more feasibly track the impact of our strategies and make adjustments as needed, ensuring that the dredging industry stays adaptable and forward-looking without venturing too far into speculative territory.

Step 4

We crafted plausible future scenarios using two complementary approaches: ranking and clustering. Scenario planning is a strategic tool that explores and prepares for multiple plausiblefutures by analyzing how a set of trends and uncertainties could interact to shape the industry.

For our first approach, we *ranked* trends and uncertainties by assessing plausibility and potential impact on the dredging industry. Such ranking was critical in helping us identify the most salient factors steering the industry's future. We evaluated each trend and uncertainty in terms of how likely it was to occur and the magnitude of its impact, should it materialize. This allowed us to prioritize top factors most dramatically shaping the industry, yielding a clear basis for constructing our scenarios.

Our second approach employed *clustering*, which involved grouping similar trends and uncertainties together based on their traits and potential interactions. By clustering related factors, we were able to develop more integrated and cohesive scenarios capturing the nuances of potential future developments. For example, a positive scenario might pool trends such as technological advances in dredging hardware with favorable environmental regulations, while a negative scenario might merge geopolitical tensions with restrictive trade policies and environmental degradation. By exploring distinct and ranked scenarios, we were able to create a set of narratives showcasing varied ways the future could unfold, depending on how these trends and uncertainties might interact.

Step 5

Next, we identified the likely relevant stakeholders. Envisioning future plausible scenarios would be of little value unless insights are translated into actionable strategies. Successful strategies often hinge on the concerted efforts of various industry actors, each playing a crucial role in shaping the

future. Therefore, it was essential to identify these stakeholders and gain a deep understanding of their roles, interests, and power positions within the context of our scenarios.

Stakeholders in the dredging industry include not only companies directly involved in dredging operations but also port authorities, government regulators, environmental organizations, suppliers, shipbuilders and other manufacturers, plus communities affected by dredging activities. Each group has its own set of interests and degrees of influence over the industry's direction. By mapping out stakeholders and analyzing their potential responses to different future scenarios, we could develop more robust strategic visions. Alignment across stakeholders is necessary to forge the collaboration and coordination required to implement strategic actions effectively. By engaging stakeholders early and considering their perspectives, we aimed at creating a shared vision of the future able to guide the industry toward sustainable, competitive growth.

Step 6

We created strategic guidelines to ensure that the dredging industry stays relevant and competitive across all identified scenarios. We then visualized whether current capabilities and technologies are sufficient to meet future demands and achieve business objectives[9]. This allows organizations to identify gaps in resources and capabilities for planning how and when to acquire the necessary assets. This forward- and outward-looking approach is crucial for navigating the uncertainties that lie ahead.

We began by assessing current capabilities against each scenario. We first addressed the fundamental question of *why* each scenario is critical to maintaining the industry's competitive edge and *which* business objectives and prescribed jobs will be essential in each scenario. By understanding the why or the raison d'être (i.e., the reason for being) within each plausible scenario, we could focus on what products, systems, opportunities, and services the industry might need to offer. This step is essential in securing that the industry's offerings remain aligned with market demands and technological advances. Following this, we explored how to deliver these products and services. This part involved detailed discussions on the needed technologies, business processes, skills, partnerships, and programs required to build and sustain the required capabilities. Doing so ensured that the industry could adapt and thrive for any scenario that unfolds.

We also scrutinized the current state of the industry, particularly in terms of market conditions and customer needs. This involved evaluating our existing technological capabilities, business processes, and production methods. By contrasting the current situation with the envisioned future, we could clearly identify discrepancies between today's industry and where it needs to be. This gap analysis served as a catalyst for developing guidelines to mobilize the capabilities needed to meet future demands.

[9] Phaal et al., 'On Self-Facilitating Templates for Technology and Innovation Strategy Workshops'..

The final step was to turn these insights into an actionable innovation strategy, formulating a focused set of strategic priorities easily understood by all stakeholders. This aimed to equip an industry workforce able to contribute meaningfully toward the development of the products and services able to realize the industry's future. By making the strategy actionable, we ensured a practical strategic guideline for sustained relevance and success in a rapidly changing world beyond any mere theoretical exercise.

Having established a clear, structured approach during our workshops, we now turn to the key outcomes that emerged from these five co-creation workshops. In the following sections, we will provide a historical reflection of the industry, and present the trends and uncertainties identified, the scenarios we developed, and the strategic guidelines crafted by industry experts. These elements represent the collective vision and strategic direction necessary for the dredging industry in the Netherlands and Belgium to best navigate future challenges and opportunities.

Navigate future challenges and opportunities together.

A historical reflection of the dredging industry.

By blending its rich history with a forward-looking perspective, Dutch dredging can better plan for the unknown. Dutch dredging has chronicled a multi-century, eventful past having weathered many ups and downs. Firms in this sector have often adapted quickly to external challenges like shifts in global economics or new political mandates. Their resilience stems not only from technical skill but also from strong local ties, family ownership, and the wider maritime network.

Let's start with the past. In the late 19th century, dredging in the Netherlands evolved from manual labor with wheelbarrows into a sophisticated industrial process. The increasing scale of hydraulic engineering projects, such as the Noordzeekanaal and the Nieuwe Waterweg, required specialized equipment. Dutch contractors from the region near Rotterdam collaborated with shipbuilders in Kinderdijk and Sliedrecht to create innovative dredgers and solutions for complex challenges. This collaboration laid the foundation for Dutch dredging contractors to gain international recognition, working on projects across the globe in partnerships that emphasized expertise and efficiency. The interconnectedness of contractors, shipbuilders, and suppliers remains a hallmark of the industry.

The successes of the past significantly influence today's dredging landscape. From the beginning, flexibility was essential as each project presented unique challenges. Companies learned to adapt their focus as market demands fluctuated between dredging, offshore activities, and other maritime engineering efforts. The ability to pivot and diversify remains a core strength, positioning the Dutch and Belgian dredging sectors as global leaders.

The People Behind the Progress

The enduring success of the dredging industry is as much about the people involved as it is about technology. Dutch and Belgian dredgers are known for their hard work, pride, persistence, and community-focused mentality. They possess qualities as valuable as the most advanced equipment—qualities that have fostered a reputation for world-class excellence.

A dredger from Zuiderzeeweken illustrating innovativeness, people and flexibility

Image source: Joke E. Korteweg

Manpower and cooperation have been a central part of the dredging practice.

Image source: Joke E. Korteweg

One telling case is the Kiev Suspension Bridge (1846–1853), designed and built by British engineer Charles Blacker Vignoles (1793–1875). He hired two Dutch engineers in 1849 to reinforce the riverbed, the sediment had riddled the cofferdams and endangered the bridge's foundations[10]. Exploiting willow mattresses, a technique well known in the Netherlands, engineers stabilized the riverbed and secured the project using equipment from Sliedrecht. It was a long trek for coaches and pedestrians, and local food lacked appeal. The engineers brought their own potatoes from home. Their journey exemplifies two enduring traits of the sector:

International Visibility and Focus

Dutch engineers have long traveled the world to apply their water-management expertise.

Pragmatism and Innovation

They brought local knowledge and innovative techniques to consistently deliver solutions for urgent challenges.

Community Ties and Family Networks

The industry's core strength lies in close ties among contractors, builders, suppliers, and families. This has allowed businesses to shift focus rapidly when one market dries up. One prominent example is the Smit family network in Kinderdijk. Over six generations, the Smits intermarried with other families who owned or led related firms, keeping expertise and capital within a tight circle. This community focus ensured that:

Local Knowledge Retention

Innovations remained in the region, allowing quicker prototyping, refinement and deployment.

Ease of Collaboration

Shared ownership facilitated by marriage eased mergers and partnerships.

[10] Vignoles, 'The Construction of the Kiev Suspension Bridge 1846–1853'.

Pride, Rivalry, and Quality

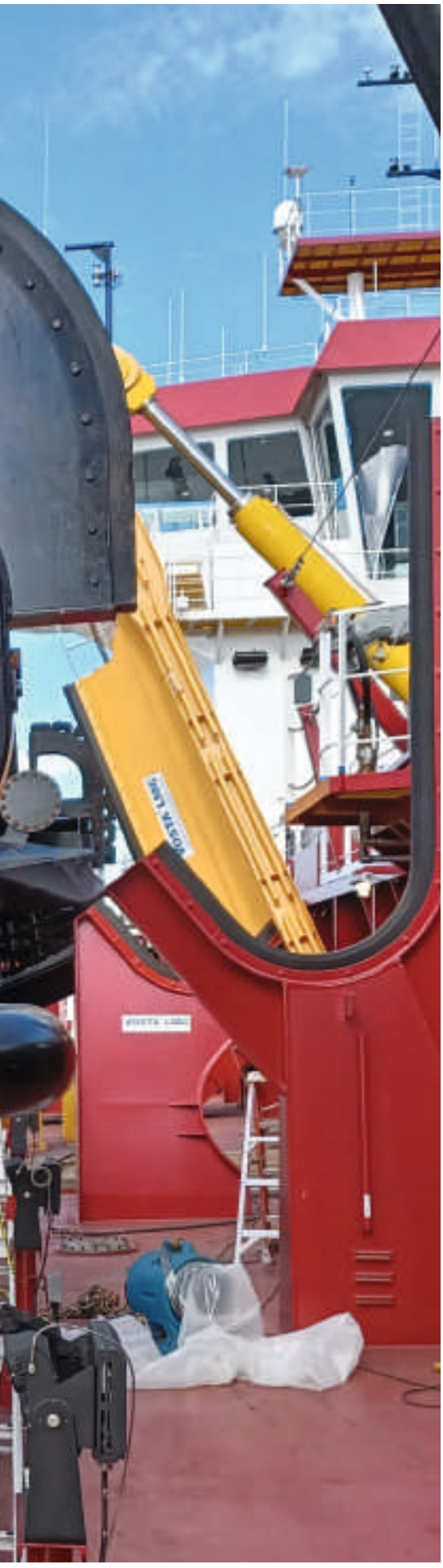
Pride in accomplishments drives quality and innovation. Dredgers celebrate tangible achievements—deeper ports, new land, and engineered waterways. However, pride can lead to tensions between builders and contractors, who may view each other as either theoretical planners or practical doers. Despite these divisions, pride and competition fuel the pursuit of excellence.

Lessons for the Future

The future, of course, does not always follow from the past successes. Large shipyards in the Netherlands once fell away because they lacked a plan for the long term. By contrast, many yacht builders have thrived by telling a clear story to buyers seeking both luxury and heritage. Dredging can learn from them: do not hide your successes. Let people see what you do—both inside the firm and out in the world. This can lead to more trust, visibility, and a better market position. Sharing its rich story with the world will strengthen its position as a global leader.

Meanwhile, innovation remains vital. The same drive that pushed Dutch engineers to Kiev can still spur breakthroughs in land reclamation and offshore wind. By blending the old and the new drawn from family stories, past blunders or modern engineering leaps, as well as by strong ties and a shared story, the dredging sector can respond to trends and uncertainity that we will discuss next.

Outcomes of the workshops.



Trends and Uncertainties Facing the Industry

Our participants identified several trends and uncertainties that will shape the future of the dredging industry in the Netherlands and Belgium (Figure 4). Their insights categorize into six key areas: Environment, Politics, Policy, Regulation, Technology, and Competition.

Figure 4. Trend-Uncertainty List Suggested via Workshops Clustered across Six Areas

Environment

- Climate change
- Rising sea levels
- Loss of biodiversity
- Increasing population
- Scarce natural resources

Politics

- Immigration
- Multi-polarisation
- Political instability
- Wars
- Macroeconomic volatility
- Social and political activism

Policy

- The Belt and Road Initiative
- Protectionism
- Chinese, ME and Indian competition
- Lack of industry policy in the NL/EU and openness
- External funding & subsidies
- Level playing field

Regulation

- Stricter regulations
- CSRD (Europe)
- Increasing bureaucracy

Technology

- Uncertainty about energy sources
- AI & Digitalization
- Starlink
- Software & Cybersecurity
- Autonomous vessels
- Incremental innovations in Dredging
- Increasing complexity
- Alternative fuels

Competition

- Talent scarcity & mobility
- Costs increase
- Partnership an institutionalization of collaboration
- Lack trust & dialogue
- Close of the shipyards/ Offshoring
- Big projects in Middle East
- Large fluctuations in demand
- Deep sea mining
- Coastal defense needs
- Diversification
- Flexibility

Workshop Discussing Trends and Uncertainties

Environment

Participants highlighted the trends of climate change, rising sea levels, loss of biodiversity, increasing population, and scarce natural resources.

Climate change is intensifying weather patterns, leading to more frequent and severe storms that can directly impact coastal regions. The United Nations Office for Disaster Risk Reduction has estimated that climate-related disasters have incurred economic losses of at least US$171.3 billion in 2020 alone[11]. This means a dredging industry facing increased demand for coastal defense projects, such as reinforcing dikes and maintaining flood protection systems. The Netherlands, with its large areas below sea level, is particularly vulnerable. As a result, the dredging sector will play a critical role in mitigating these effects by maintaining and upgrading *coastal* infrastructure. But *inland* water management, too, under rising intensity of rainfall will require more dredging and infrastructure projects.

Rising sea levels, driven by climate change, present another major long-term trend. The Intergovernmental Panel on Climate Change (IPCC) has predicted that global sea levels could rise 1.1 meters by 2100[12]. For low-lying countries like the Netherlands and Belgium, and countries such as Bangladesh and parts of Indonesia, this will require extensive dredging to protect coastlines, ports, and other critical infrastructure from flooding. The dredging industry will be essential in constructing and maintaining barriers, such as sea walls and levees, as well as managing sediment to ensure that rivers and canals remain navigable as water levels rise.

Loss of biodiversity, particularly in marine and coastal ecosystems, will influence the regulatory landscape for the dredging industry. As ecosystems degrade, there will be increased pressure to implement more sustainable dredging practices that minimize environmental impact. For example, the European Union's Biodiversity Strategy aims to protect 30% of EU land and sea areas, plus 25,000 kilometers of rivers, by 2030. This focus on conservation will likely lead to stricter environmental regulations and mandate the dredging industry adoption of new technologies and methods that protect habitats while meeting operational needs.

Increasing world population growth will elevate demand for land reclamation and infrastructure development. The UN foresees global population reaching nearly 10 billion by 2050, with burgeoning urban areas. In response, the dredging industry will be enlisted to create new land and expand existing cities to accommodate this growth. This includes projects like port expansions, coastal development and the construction of artificial islands—all requiring extensive dredging activities.

Scarce natural resources, particularly sand and gravel essential for construction and land reclamation, pose a challenge for the dredging industry. With global demand for sand totaling

[11] UNDRR, '2020: The Non-COVID Year in Disasters'.
[12] IPCC, Global Warming of 1.5°C.

50 billion tons per year and resource availability shrinking, dredgers see rising costs and potential supply constraints for endeavors that include construction, infrastructure development, and coastal protection projects. The dredging industry must innovate in sourcing and utilizing these materials more efficiently, perhaps by seeking alternative materials or enhancing recycling efforts. Further, this scarcity will likely drive a shift toward more sustainable practices, such as using dredged materials in a circular economy framework.

Politics

Our participants cited the following political factors that underscore the complexity and interconnectedness of the challenges facing the dredging industry.

Migration patterns are likely to influence the dredging industry by population growth and urban expansion in coastal areas. As people move into these regions, demand for housing, infrastructure, and services will increase. This trend could lead to a surge in land reclamation projects and the expansion of ports and coastal cities that require extensive dredging to accommodate growing populations. Meanwhile, rising anti-migrant sentiment and restrictions on legal immigration across Europe could limit access to both white- and blue-collar talent. This could exacerbate labor shortages, increase project costs, and slow the pace of infrastructure development. The dredging industry may end up competing more fiercely for a shrinking pool of skilled workers, thus hindering its ability to meet the rising demand for dredging services.

Multi-polarization, as power distributes among various global and regional players, could increase both competition and collaboration in the dredging industry. China and India are becoming more influential, investing heavily in infrastructure projects both domestically and abroad, often through initiatives like the Belt and Road Initiative. This global competition may drive innovation and efficiency in the dredging industry as companies strive to maintain their competitive edge. However, it could also lead to geopolitical tensions that affect trade routes and the availability of resources, thereby impacting dredging activities in key global regions.

Political instability, both within the European Union and elsewhere, can exert major repercussions on the dredging sector. For instance, global unrest that disrupts supply chains can raise costs and delay dredging projects. Political uncertainty within the EU, i.e., rise of populism or changes in government policies, could result in fluctuating regulations and funding for infrastructure projects.

Armed conflicts and wars can have direct and indirect impacts on dredging as well. Unresolved warfare in Ukraine plus piracy and attacks in the Red Sea have all greatly impeded global trade flows and shipping routes, spawning logistical hardships and delays for numerous industries. Finally, war damage often necessitates massive reconstruction efforts, including rebuilds of ports, harbors and other maritime assets, that would demand substantial dredging work. The award of recovery work here may depend on political, instead of economic forces.

Macroeconomic volatility rife with fluctuations in economic growth, inflation, oil prices and currency exchange may create unpredictable business terrain for the dredging industry. Economic downturns could lead to reduced government spending on infrastructure projects, while periods of rapid growth could elevate demand for dredging services as nations invest to expand ports and coastal defenses. For instance, the COVID-19 pandemic disrupted much of the global economy, affecting both public and private sector investments toward infrastructure.

Social and political activism, particularly concerning environmental issues, will likely impose a growing influence on the dredging industry. Increasingly, activist groups and localities have become vocal as to environmental impacts of large-scale dredging projects, leading to stricter regulations and more rigorous environmental assessments. For example, activism around the preservation of marine ecosystems, such as that over port expansion near the Great Barrier Reef or dredging in the Manila Bay area, has led to legal challenges against projects perceived as harmful. CEDA and IADC has developed guidelines for sustainable dredging[13]. Political movements advocating climate action may push for policies that directly impact the industry such as restrictions on certain types of dredging or incentives for eco-friendly technologies. Such carrots and sticks may pose new opportunities for an innovative dredging sector[14].

Policy

Participants also identified policy-related trends and uncertainties that will shape the future of the dredging industry. The emergence of protective policies at both the national and international level creates an increasingly complex, uneven playing field.

Protectionism is on the rise, posing a challenge for the dredging sector that relies on international trade and open markets. More nations favor protectionist measures, such as tariffs, trade barriers and local content mandates, tending to restrict market access for Dutch and Belgian dredging companies. This could lead to reduced opportunities abroad and force companies to focus more on domestic markets offering quite less growth potential. Protectionism could also drive up costs by limiting access to key materials or equipment sourced from international suppliers, which makes it harder to compete on price.

China's Belt and Road Initiative (BRI) is a massive infrastructure investment project spanning Asia, Europe, and Africa. This program has greatly boosted demand for dredging and maritime infrastructure development by Chinese rivals as their nation builds and expands ports, canals, and shipping routes. The scale of the initiative could lead to Chinese dredging firms gaining a larger share of the global market, leveraging state-backed finance and extensive resources. As of 2021, China had invested over $1 trillion in BRI-related projects that challenge European companies by offering lower-cost services backed by hefty government support. The BRI's influence could lead to a realignment of global trade routes, potentially reducing the strategic importance of

[13] Laboyrie et al., *Dredging for Sustainable Infrastruture.*
[14] Acar, Tarakci, and van Knippenberg, 'Creativity and Innovation under Constraints: A Cross-Disciplinary Integrative Review'.

European ports and diminishing demand for dredging services in our region.

Heightened competition in China, the Middle East and India, with substantial government backing, competitive prices and state-of-the-art technology, is increasingly winning contracts in regions where European dredgers once prevailed. For example, the China Communications Construction Company (CCCC) is now one of the world's largest dredgers, especially given its prominence in many large-scale projects globally and its operating technology advances. The influx of players into Europe and other key markets could erode both Dutch and Belgian market share. Notably, these competitors often benefit from state subsidies and financial incentives that allow them to underbid European firms in global tenders.

Lack of industry policy in the Netherlands and the European Union, coupled with an open stance toward foreign competition, may leave Dutch and Belgian dredging firms vulnerable to foreign entrants. Without strong industrial policies or strategic support, European operators may struggle to contest foreign firms that receive substantial backing from their governments. The lack of coordinated EU-wide policies to protect and promote the maritime and dredging industries could erode competitiveness as firms face unfair price wars from state-supported rivals. This policy vacuum could also result in a "race to the bottom" where price competition vaporizes profitability and investment toward innovation, only to weaken the industry's global position.

Access to external funding and subsidies is crucial for large-scale dredging projects, especially those with delayed payback periods or high upfront outlays. Unlike their foreign counterparts, European dredgers often struggle to secure financing. NGOs add to the challenge by resisting projects unable to guarantee no harm to the environment or local communities. Chinese firms frequently benefit from low-interest loans and subsidies provided by state-owned banks, giving them a major competitive advantage[15]. The absence of similar funding structures in Europe could prevent Dutch and Belgian companies from investing in cutting-edge technologies, scaling their operations, and securing large international contracts.
The confluence of these trends and uncertainties creates an uneven playing field. Vying with state-backed rivals who benefit from subsidies, favorable financing, and strategic government support puts European firms at a disadvantage.

Regulation

Participants also cited their expectations for onerous regulation and bureaucracy.

Environmental and operational regulations may tighten with growing concerns about climate change and environmental degradation. The European Green Deal imposes stricter environmental standards across many fields[16] that could lead to more rigorous requirements for dredging projects: limitations on emissions, waste disposal, and harm to marine ecosystems. Compliance with these mandates could increase operating costs and require significant investments in cleaner technologies and more sustainable practices.

[15] Abi-Habib, 'How China Got Sri Lanka to Cough Up a Port'.
[16] The European Green Deal, 'Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions'.

One participant noted, "The pace of regulatory change often outstrips the business sector's ability to adapt, especially regarding emissions. Companies are required to submit compliance plans for new regulations even before governments have established clear criteria for evaluation. For example, engine manufacturers face difficulties in keeping up with emissions standards, resulting in less reliable engines due to rushed compliance efforts." On the other hand, recent research has posited that restrictive statutes can spur breakthrough innovations[17], thus prompting the industry to become more innovative.

The Corporate Sustainability Reporting Directive (CSRD), similarly, mandates that dredging firms disclose sustainability practices and their impact of business activities on the environment and society. For the dredging industry, this means investing in data collection, reporting systems, and verification processes to ensure transparency and accountability in adopting more sustainable practices and in meeting stakeholder expectations and regulatory requirements. On the international dredging market, this may lead to an operational disadvantage for Dutch and Belgian dredging firms where international companies are less regulated. Here, dredging firms might opt to offshore operations.
Increasing Bureaucracy is likely to be a minus in the emerging regulatory landscape, both nationally and Europe-wide. Burgeoning red tape may slow project approvals, extend timelines, and add to the administrative burden for companies.

For example, obtaining environmental permits for large-scale dredging projects means navigating multiple regulatory bodies, each with its own requirements and processes. This may incur delays and increased costs, making it more challenging for companies to remain competitive in the future, especially for bids on international contracts. Another case is the EU Emissions Trading System regulation that forces shipping companies to monitor and report greenhouse gas emissions, as well as surrender precribed emissions allowances accordingly for ships sailing to and from European Ports.

Technology

As the dredging industry grapples with stricter regulations, it must also keep an eye on rapid technological advancements and innovations that are redefining the landscape. Our participants noted the following technological trends and uncertainties:

Uncertainty as to energy sources and alternative fuels will heavily impact the dredging industry, especially with global efforts to decarbonize. As traditional fossil fuels face growing regulatory pressure, dredging must transition to alternative, cleaner energy sources such as hydrogen fuels, electrification and biofuels. But availability, cost, and technological readiness as to these alternatives remain uncertain, making it tough to allocate long-term capital. This uncertainty was vividly captured during the workshops when one participant exclaimed, "Just tell me which energy source, and we'll invest," highlighting deep concern among executives as to making right choices. Adopting alternative fuels is vital toward meeting future environmental regulations and sustainability goals.

[17] Acar, Tarakci, and van Knippenberg, 'Creativity and Innovation under Constraints: A Cross-Disciplinary Integrative Review'; Park, Wu, and Funk, 'Regulation and Innovation Revisited'.

Hence, the industry's ability to navigate this energy transition will be crucial for its future competitiveness and environmental compliance.

Artificial Intelligence (AI) and digitalization are transforming industries worldwide, and the dredging industry is no exception. The adoption of AI can enhance efficient dredging operations by optimizing the dredging process, reducing fuel consumption, and improving predictive maintenance of equipment. Additionally, digital twins—virtual replicas of physical assets—can simulate dredging projects to allow for better planning and risk management. Continued digitalization of the industry will likely lead to increased automation and the need for a workforce skilled in data analysis and digital tools, driving both efficiency gains and the need for new competencies.

Satellite internet service has the potential to revolutionize connectivity in remote and offshore dredging operations. Reliable high-speed internet access, even in the most isolated locations, can improve communication, enable real-time data transfer, and support the use of high-tech tools for remote monitoring and autonomous systems. For dredging, satellite internet services could facilitate coordination between on- and off-site teams, enhance operational efficiency, and reduce downtime. Improved connectivity can also support the integration of AI, IoT (Internet of Things), and other digital tools to further advance the industry's technological evolution.

Software and cybersecurity will likely emerge vital as the dredging sector relies more on digital technologies. The risk of cyberattacks poses a significant threat to critical infrastructure and operations. These risks may require large investments that harden capabilities to protect sensitive data, ensure the integrity of automated systems, and comply with international cybersecurity standards.

Autonomous vessels are another trend that our participants deem transformative to the dredging industry. Autonomous dredgers can run with scant

human intervention, reducing labor costs and increasing operational efficiency. These vessels can work continuously without need for breaks, therefore abbreviating project completion time. Still, widespread adoption of autonomous vessels in dredging also raises challenges, such as building software capabilities to ensure reliability and safety of autonomous operations in complex marine environments.

Incremental innovation has long prevailed as the main trend in the dredging industry. Incremental innovation refers to small, gradual improvement in current technologies and processes that enhance efficiency, curb environmental impact, and offer savings. Participants in the workshops cited this trend as expecting to continue, with ongoing advancements in areas such as dredging equipment, precision technologies, and operational practices. However, they also noted diminishing returns on investment for incremental innovations; the cost of implementing change is worsening while the benefit yield shrinks. Consequently, attainable innovations in dredging appear less impactful over time and lead to flattening overall efficiency and financial capacity. In addition, while past incremental innovations have served the industry well, these may soon be at odds with more disruptive trends on the horizon, such as the transition to alternative energy and the push for digitalization. Such emerging trends will likely require the industry to move beyond the incremental and embrace more breakthrough innovations to stay competitive in future regulatory and environmental scenarios.

Escalated technological complexity seems to be the main trend, with the integration of AI, autonomous systems, digital twins, and advanced materials. Managing complexity requires not only technological expertise in hardware but new software capabilities along with effective project management and coordination. As the industry adopts more sophisticated technologies, the complexity of dredging projects will increase, necessitating higher skill levels and coordination among teams. Moreover, regulatory complexity and need for interoperability among different systems and technologies will add layers of challenges that operators must navigate.

Competition

Trends and uncertainities related to technology and innovation are likely to transpire in a shifting competitive landscape. Evolution in the global market presents new challenges and opportunities, requiring firms to maintain a competitive edge. The following competitive trends and uncertainties have been keeping our participants awake at night.

Talent scarcity and mobility will likely be accentuated with the growing demand for specialized roles in engineering, environmental science, and digital technologies. According to the European Commission, the EU needs over 20 million ICT specialists and must double its portion of the population having basic digital skills by 2030[18], which could elevate the dredging industry's reliance on digitalization. Our participants were concerned whether the current educational system sufficiently engages young people and piques their interest in pursuing careers in this industry. Moreover, there is a growing shortage of skilled blue-collar

[18] European Commission, 'Europe's Digital Decade'.

workers, such as machine operators, welders and technicians—all critical for the day-to-day operations of dredging projects. Scarcity, combined with talent mobility worldwide, means that firms must vie more aggressively to lure and retain both types of workers.

Rising costs are projected to undermine profitability in both the manufacture of dredging equipment and delivery of dredging projects. Stricter environmental rules and the shift toward sustainable practices are likely to increase operational expenses. This scene is further aggravated by high inflation in the Eurozone. As costs escalate, dredgers must prioritize improved efficiency and adoption of cost-saving technology. One significant risk is that nations with less strict regulations could gain a competitive edge here and capture larger market share. Additionally, protectionism and regulatory barriers will make outsourcing a challenge.

Partnerships and institutionalized collaboration are more likely to prevail under increased complexity of modern dredging projects, particularly in global markets. Here, collaboration among multiple stakeholders is needed to meet all the technical, financial, and regulatory challenges. By forming strategic partnerships, companies can pool resources, share risks, and access new markets more effectively. However, our participants noted that the industry still faces significant challenges related to trust and communication among stakeholders. The industry must work to build stronger rapport and forge a culture of trust to ensure collaborative success. Beyond ad-hoc alliances, institutionalizing such collaborations may also arise that will need robust governance, clear communication, and mutual trust among partners.

Closure of shipyards/Offshoring refers to the shuttering of shipyards in Europe and the offshoring of manufacturing to regions with lower labor costs. From 2014 to 2022, the number of active shipyards in Europe has nearly halved[19], and with few shipyards remaining worldwide that can and are willing to construct complex, customized dredging vessels. The financial stability of the remaining yards has sharply declined. This downturn makes constructing large, complex dredging vessels within Europe increasingly challenging[20]. While manufacturing in regions with a lower labor cost offers cost savings, it complicates the maintenance, upgrade, and local construction of dredging vessels. Consequently, the industry may rely more on foreign suppliers, leading to longer lead times, higher transportation costs, and quality control issues. Also, there is a risk that tacit knowledge and innovation will migrate abroad along with the manufacturing. The loss of both technical expertise and jobs in Europe could weaken the region's competitive position in the global market.

Big projects in the Middle East offer significant opportunities for dredging outfits, but they also attract global competition, particularly from Chinese and regional players that increasingly win contracts in the area. Nations such as the UAE and Saudi Arabia are investing heavily in projects such as NEOM, port expansion (Jebel Ali), and the Red Sea Project. Our participants believe that the Middle East will continue to be one of the most lucrative markets for dredging.

[19] Statista, 'Active Shipyards Worldwide 2014-2022'.
[20] Johannsmann, 'Breaking out of the Crisis'.

To maintain competitive advantage and ensure sustained success, dredging companies may need to collaborate closely to retain critical knowledge within this cluster. This collective effort aims to prevent fragmentation of the industry and maintain a competitive advantage over other regions.

Demand fluctuations due to economic cycles, shifts in government spending, and the timing of large infrastructure projects will continue to define the sector. Figure 6 demonstrates that the demand not only fluctuates over time, but also across regions. For example, demand for dredging services spike with investment in large projects, but drop during recessions or periods of fiscal austerity. The COVID-19 pandemic highlighted the volatility of global markets, with many construction projects delayed or canceled, thus affecting demand for dredging. To hedge against demand volatility, dredging companies and equipment builders may develop strategies by diversifying project portfolios, investing in flexible resources, maintaining strong cash reserves, and by anti-cyclical investing.

Deep-sea mining represents a potential new frontier for the dredging industry by extracting valuable minerals from the ocean floor. However, this emerging sector is fraught with uncertainties, including environmental concerns, regulatory challenges, and technological hurdles. While deep-sea mining may offer a new revenue stream for dredging companies, it also requires large investments in research, technology, and compliance with evolving international law. Obtaining concessions here can be tough.

Coastal defense requirements are likely to accumulate as climate change accelerates. The Netherlands, Belgium, and other low-lying countries are particularly vulnerable to sea-level rise and storm surge, necessitating continuous investment in infrastructure such as dikes, seawalls and

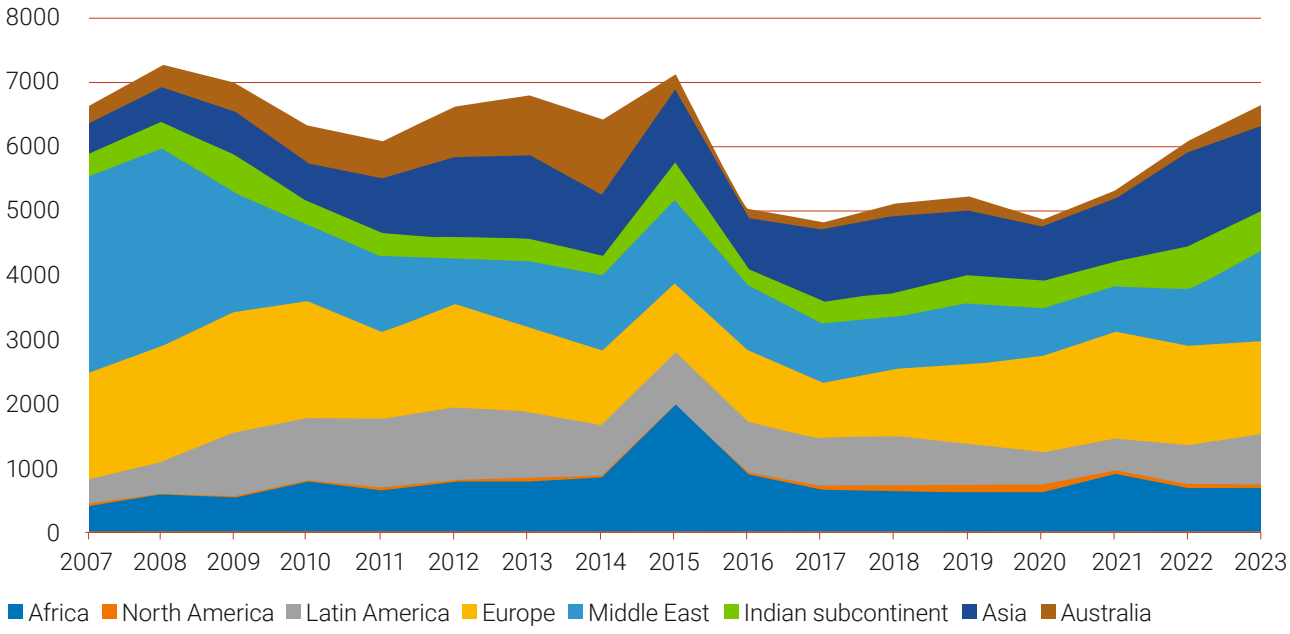


Figure 6. Dredging Turnover in Open Markets (values are in million euros)

Source: IADC

flood barriers. Rising complexity and size of such projects will need the dredging sector to innovate new techniques and collaborate more closely with governments and other stakeholders to effectively address these challenges.

Diversification will remain a viable strategy for dredging company responses as to fluctuating demand and increasing competition. This could include moves into related areas such as environmental remediation, renewable energy, deep-sea mining, and offshore construction. Diversification can help firms reduce reliance on traditional dredging projects and create new revenue streams. For example, growth in offshore wind energy presents opportunities for dredging companies to install and maintain wind farms. Projects aimed at defending the nation against foreign navies can also provide opportunities long-term. Yet, diversification also requires investment in new capabilities and can incur additional risks as firms migrate into unfamiliar markets.

After identifying key trends and uncertainties, clustered across six critical areas, our participants also developed three scenarios representing a range of plausible futures for the dredging industry. This process involved merging similar trends to streamline the analysis, as well as ranking each trend and uncertainty based on its plausibility and potential impact. A scenario matrix was then arrayed selecting the two most critical and uncertain drivers as the axes (e.g., strong vs. weak regulation, rapid vs. slow technological adoption), each axis spanning a continuum of possibilities for its respective driver. The four quadrants of the matrix thus represent different combinations of uncertainties, each leading to a distinct scenario. For each quadrant, a detailed narrative was crafted to describe a plausible future where the specific combinations of uncertainties might arise. We aimed to make these narratives vivid and comprehensive, enabling our participants to visualize and grasp the implications of each scenario effectively. In the following section, we present three scenario narratives.

Three plausible future scenarios for the dredging industry.

Collaborative efforts of our participants converged to identify three scenarios, each reflecting distinct plausible futures for the dredging industry. These scenarios—labeled Green, Teal and Brown—capture a spectrum of possibilities shaped by the key uncertainties and trends cited during the workshops. Each scenario presents a unique set of challenges and opportunities, offering a holistic view of how the industry may evolve in varying conditions.

Summary of the Three Scenarios Generated during the Workshops

Sustainable & innovative future

The industry differentiates by focusing on eco-friendly practices, large-scale projects, and renewable energy diversification, driven by technological innovation and environmental stewardship. Advanced AI, digitalization, and autonomous vessels are widely used.

Innovative but locally protected

Companies navigate protectionist barriers through local partnerships. The dredging industry thrives on regional projects, and diversification into renewable energy, driven bytechnological advancements and regional regulatory support.

Protectionist & resource-tight Future

Modest innovations, with a focus on basic automation and digital tools. The industry struggles with protectionism, resource constraints, and regulatory complexities, requiring a focus on operational efficiency and strategic partnerships.

The Green Scenario: Sustainable and Innovative Future

This scenario is based on the following trends and uncertainties:

Environment & Population Growth

- Accelerating climate change and rising sea levels heighten coastal defense needs.
- Sustainable dredging practices are demanded by elevated environmental awareness.
- Growing populations and scarce resources push for efficient resource management.

Politics & Regulation

- Major regions remain politically stable, with greater focus on environmental policies.
- Global cooperation tempered by multi-polar interests shape environmental initiatives.
- Stricter environmental regulations worldwide require advanced-level compliance.
- Anti-competitive measures in China and India spur local innovation and adaptation.

Resources & Financing

- Talent scarcity, especially tech-savvy, drives investment in training, AI, automation.
- Limited subsidies and funding prompt new financing models and partnerships.
- Rising project costs drive efficiency gains and the adoption of new technologies.

Competition & Collaboration

- Strong Chinese competition fuels innovation and cost-consciousness in other markets.
- Co-opetition in the Benelux region promotes shared technologies and joint projects.

Technology

- Green energy adoption, AI, and digitalization are becoming the industry standard.
- Autonomous vessels lower operating costs.
- Reliable satellite assets (e.g., Starlink) ensure robust communication at remote sites.

New Business Opportunities

- Large-scale Middle Eastern projects remain highly lucrative.
- Technological advances make deep-sea mining more feasible.
- Global coastal defense efforts expand the market, while diversification into renewable energy infrastructure opens additional revenue streams.

Here's how we envision the Green scenario: By 2040, the dredging industry has evolved into a beacon of sustainability and innovation, driven by the urgent challenges posed by climate change and the rising tides of the world's oceans. Coastal cities worldwide face more threats from flooding and erosion, leading to an unprecedented demand for coastal defense projects. Governments and private firms alike are focused on not just protecting these vulnerable areas, but doing so in ways that minimize environmental impact. As a result, sustainable dredging practices are no longer optional—they are the industry standard. Companies that once thrived on traditional methods have had to adapt quickly, integrating eco-friendly technologies that reduce emissions and protect marine ecosystems.

The world's growing population, coupled with scarcer natural resources, has forced the dredging industry to prioritize efficiency in resource management. Innovations in material recycling and resource optimization spearhead the sector, driven by necessity and regulation.

Examples of Strategic Guidelines Developed during the Workshops

Politically, the global landscape is one of relative stability, but with a strong focus on environmental stewardship. Governments have enacted ambitious environmental policies, spurred by the visible impacts of climate change and the collective realization that swift action is required. This political environment encourages global cooperation, particularly in environmental initiatives, despite continued multipolarity of international relations. The EU leads by example, implementing stringent environmental imperatives: innovate or perish.

In China and India, however, protectionist policies have impeded foreign entrants, prompting local industries to innovate and adapt rapidly. The pressure to comply with these shifting regulatory landscapes drives European dredging companies to push the boundaries of technology and efficiency, ensuring they remain competitive in a challenging global market.

The scarcity of tech-savvy talent has become a critical issue, particularly as the sector increasingly relies on AI-driven processes and digitalization. Companies have responded by heavily investing in training programs, creating a new wave of workers not only expert in dredging but also adept in cutting-edge technologies. The industry has tapped AI to optimize operations, reduce costs, and improve decision-making. Meanwhile autonomous vessels, now a common sight, further reduce operational costs and enhance efficiency.

However, the road to this green future has not lacked its challenges. Limited funding and subsidies have pushed companies to explore innovative financing solutions and to form strategic partnerships. *Co-opetition*—collaborative competition[21]—has become a defining feature in the Benelux where firms share technologies and resources to tackle large-scale projects together, ensuring ability to meet rising costs and complex market demands.

Despite intense rivalry from Chinese firms, European dredgers have maintained their edge through relentless innovation and a commitment to sustainability. Widespread adoption of green energy sources, advanced digitalization and AI has allowed firms to stay ahead, while reliable global communication by providers such as Starlink ensures that even the most remote projects are seamlessly managed.

New business opportunities have also emerged. The Middle East, with its ambitious infrastructure projects, has become a lucrative market for large-scale dredging operations. Meanwhile, advancements in technology have made deep-sea mining a viable and sustainable enterprise on the ocean floor. The global need for coastal defense has skyrocketed, expanding the market and creating endless possibilities for those willing to innovate and adapt.

In this Green Scenario, the dredging industry is not merely surviving—it is thriving! Embracing sustainability and innovation, companies have positioned themselves as leaders in a rapidly changing world, proving that it is possible to protect the planet while still driving growth and profitability.

[21] Brandenburger and Nalebuff, Co-Opetition: A Revolution Mindset That Combines Competition and Cooperation.

A market with favorable tailwinds.

Martin Smouter

Director Dredging and Infra at Van Oord

As an international marine contractor with over 155 years of experience, Van Oord has a clear goal: to contribute to a better world for future generations. In this interview **Martin Smouter** (Director Dredging and Infra at Van Oord) explains the company's view on the future scenarios and strategies for the dredging sector.

Tarakci starts the conversation by asking about the current state of the industry: "*Van Oord is a global marine contractor with 155 years of experience and a history of turning complex challenges into marine solutions. What new developments and challenges do you see in the industry today?*"

"Currently, we are experiencing a market with favorable tailwinds", **Martin Smouter** replies. "The demand for dredging services was up driven by a steady baseload of

small to medium sized projects topped up with several large-scale projects in recent years. This resulted in higher equipment utilization levels and improved margins.

Four main drivers support these market dynamics: Climate adaptation, maritime transport, urbanisation, and energy. While all four drivers point to solid future growth, I would like to highlight energy and climate adaptation. We are currently in an energy transition period, which is progressing unevenly across different parts of in the world. Some regions are more aggressive in their approach than others. We all know climate change poses a huge global challenge. As a dredging cluster, we have the knowledge and capabilities to make a solid contribution to this global challenge.

While these favorable tailwinds have been persistent in recent years, the balance is also fragile. If the market slows down, the threat of overcapacity looms. Strangely enough, although dredging is a capital-intensive market where you have to have a lot of money to buy the assets, we do see commoditization in the market.

Adding to the challenge is increased protectionism. China and the United States are already well-known industry examples of closed dredging markets. Other major markets like India and Abu Dhabi are also becoming increasingly difficult to access as a (main) contractor."

This shows an insight in the present situation. **Tarakci** looks further at the future and asks: "*Looking at the next fifteen years, what kind of industry do you envision?*"

Smouter explains: “This is a very broad question to answer in a few sentences, but I would like to highlight a few important themes. Our world is changing. Geopolitical dynamics are reshaping the global landscape resulting in more local protectionism and shifting trade patterns. I remember this was a topic in one of the co-creation workshops, mentioned in this report, which I joined.

We think emissions regulations outside of Europe will mature. We expect that emission regulations for our vessels, as well as our approach to executing projects and achieving net-zero goals, will first increase in Europe and then expand to other regions.

I personally expect a quantum leap. Quantum computing will likely happen within five to ten years, maybe even sooner. The increasing computing power will lead to innovations that we have not yet thought of. It might accelerate our steps into automation and even inspire new ideas about how and where we dredge. However, we still have vessels built for the next thirty years that we will have to manage.

I expect a scarcity of sand as building material. We need to innovate in working with soft materials, and with more computing power, we can come up with better solutions. I expect that more computing power will take us into a new, unknown world.
Considering these themes and the positive outlook for our market drivers, I think we have an interesting period ahead."

Tarakci: "*That's fascinating! From what I hear, you see a future echoing the green scenario. Is that right?*"
Smouter adds a little nuance to that statement. "My personal view is a mix of Green and Teal. I must highlight that part of it is due to the massive investments in dredging and offshore wind equipment we have made. We are in a world with much geopolitical uncertainty amidst major global challenges like the energy transition and climate change. So, the future market is not easily captured in a scenario. However, I do see key elements from both scenarios shaping our future markets. Diversification into renewables, environmental stewardship and advancements in AI and automation have and will drive our future markets. But I also see persistent challenges like continued protectionism highlighting the need for the right local partners."

Tarakci circles back to the present and asks: "*What is Van Oord's current strategy?*"
Smouter explains: "Van Oord delivers long-term client and stakeholder value through our synergistic portfolio of marine businesses covering dredging, infra, offshore wind and offshore.

Our portfolio is split over two Business Units. Dredging &Infra delivers climate adaptation and sustainable marine infrastructure solutions. Offshore Energy focuses on enhancing the energy transition. Both Business Units strive to become the partner of choice for our clients.

Becoming the partner of choice requires the right balance between operational excellence, product leadership and client intimacy across all our activities. Notable examples of these value disciplines include the three LNG-driven hoppers (Vox Ariane, Vox Apolonia and Vox Alexia) and methanol driven offshore installation vessel Boreas in our fleet, our market leading position in subsea rock installation, and our focus on the large-scale restoration of marine biodiversity and ecosystems through Van Oord Ocean Health."

Following up on this statement, Tarakci wants to know: "*What capabilities does the sector need to build to remain relevant in this vision?*"
Smouter elaborates: "We continue to evolve and develop as an industry leader. Think of building with less suitable material and better reuse of materials due to the scarcity of sand. Another area of focus is machine learning and autonomous vehicles. This doesn't mean substituting people, as the maintenance of our vessels will always require human involvement. We need to be open to ideas and resources from a larger part of the world. We need to develop different skill sets in our personnel than we currently have. While we have many technical people, we need to bring in new skills to tackle future challenges.

Building with Nature.

Sustainability is crucial. Not only in Europe, but increasingly in other developing countries as well. Countries like India will leapfrog in this area. We must keep pace and remain frontrunners by, for example, adopting more building with nature solutions and lowering our emissions."

Tarakci: "*What should the industry do to attract the type of talent you highlighted?*"
"We really need to explain our purpose better", **Smouter** starts his answer. "We are determined to create a better world for future generations by delivering Marine ingenuity. In our industry, talented employees really have the opportunity to contribute to building a more resilient world by creating innovative and sustainable solutions that enhance the energy transition and accelerate climate adaptation. We are not good enough at communicating this. There are many are bright young people in universities outside of Europe whom we haven't really taken on board yet. They can take us much further than currently think possible."

"*What role does collaboration play in the industry?*" **Tarakci** asks.

Smouter: "Collaboration can advance our industry and enhance our contribution to society. We can do much better in research and development by working together to generate new ideas and test different approaches. As a dredging, infra and offshore energy contractor, Van Oord can do research that benefits the entire industry. For example, we are collaborating with other industry parties to develop an engine that can run on methanol with significant power changes. This engine will be made available for the entire industry. Another example is EcoShape. Within EcoShape, Van Oord has joined forces with contractors, engineering companies, research institutions, public authorities, and NGOs to develop and disseminate knowledge about Building with Nature. We also work with TU Delft, where we present our technical challenges. I believe we can leverage these collaborations even more in the future."

Tarakci follows up on these examples and asks: "What changes would you like to see in this industry?"

Smouter replies: "What I would really love to see is a level playing field. I think if there is a level playing field, the industry will mature even further and faster. Innovation will also happen more quickly. For example, consider how we deal with soft sediments as a building material. In many countries, people are discharging a lot of soft sediment. If that can be turned into building material, countries like Bangladesh and Vietnam could overcome some of their climate adaptation challenges in the future."

Tarakci: "*Thank you, Mr. Smouter, for sharing your insights and vision for the future of the industry.*"

The Teal Scenario: Innovative but Locally Protected

This scenario is based on the following trends and uncertainties:

Environment & Resources

- Climate issue, population growth drive demand for innovative, eco-friendly practices.
- Scarce natural resources push for sustainable management with a regional approach.
- The focus is on maximizing efficiency and reducing environmental impact.

Politics & Regulation

- Multi-polarity spurs strong regional alliances creating competitive, localized markets.
- Political instability in some areas disrupts project timelines and investment.
- Anti-immigration policies fuel local talent development.
- Regulatory efforts align primarily within the Netherlands and EU.
- Protectionist measures limit global trade but spark local innovation and self-reliance.

Resources & Financing

- Talent dearth is countered by regional training programs and educational alliances.
- Regional subsidies and innovative financial models partly enable investments.
- Partnerships are essential to pool resources for major projects.

Competition & Technology

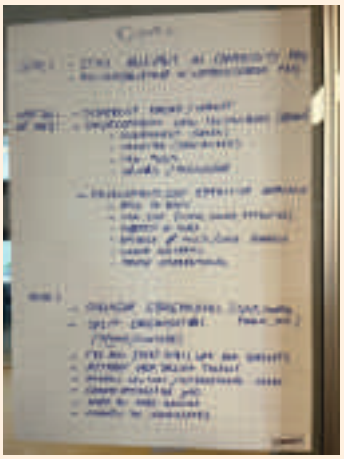
- Firms see fierce rivalry from Middle East, Chinese and Indian players, prompting local alliances.
- AI, digitalization, and autonomous vessels see rapid adoption, boosting efficiency.
- Incremental dredging innovations cut costs and improve environmental outcomes.
- Alternative energy gains traction where regional policies support its adoption.

New Business Opportunities

- Middle East and other infrastructure-heavy regions remain attractive markets.
- Deep-sea mining becomes viable in select regions under specific regulations.
- Diversification into renewable energy and infrastructure is driven by regional incentives and support.

Here is our vision for how this scenario could look: In 2040, dredging operates within a fragmented global landscape, where regional alliances and local markets define the future. Climate change and population growth drive the demand for innovative and eco-friendly dredging practices, with advances largely implemented inside regional boundaries. Scarcity of natural resources further emphasizes the need for sustainable management, with a focus on efficiency and resource optimization tailored to each region's specific needs.

As the world goes multi-polar, Europe—including the Netherlands and Belgium— solidifies into a strong economic bloc with harmonized regulations favoring sustainability and innovation. Still, this regional focus also fosters protectionist measures, creating barriers to international trade. While these measures limit the global expansion of European firms, they simultaneously spur local innovation and self-sufficiency, with dredgers working closely with governments to influence policies that promote regional interests.



Examples of Strategic Guidelines Developed during the Workshops

Political instability in other parts of the world casts uncertainty into global project timelines and investment decisions. Anti-immigration policies within Europe lead to a reliance on local talent development, prompting significant investments in regional training programs and educational partnerships. These initiatives help address talent scarcity, securing the skilled workforce needed to sustain dredging operations.

Regulatory efforts within Europe focus on harmonizing standards, driving innovation in sustainable technologies. However, a lack of global standardization limits the application of these innovations beyond European borders. Nonetheless, companies actively engage in shaping regional policies, ensuring they can capitalize on local market opportunities.

Resource management becomes increasingly critical, with innovative financial models and regional subsidies funding the projects. However, large-scale investments often require partnerships to pool resources, leading to a strong emphasis on collaboration within the region. This is particularly important as European firms face intense competition from Middle East, Chinese and Indian companies that dominate global markets. However, since the market remains partly regional, collaborative partnerships in the industry become harder to realize.

Technological advancements such as AI, digitalization, and autonomous vessels are rapidly adopted within the region, improving efficiency and reducing operational costs. Incremental innovations in dredging technology further enhance environmental performance, aligning with the region's commitment to sustainability. Green energy incentivized by regional governments becomes standard for operations within Europe, reinforcing the industry's focus on eco-friendly practices.

New business opportunities continue to emerge, particularly in regions like the Middle East with high infrastructure demand. However, European companies must navigate these markets cautiously, often forming partnerships with local firms to secure a foothold. Deep-sea mining becomes a viable regulated industry within certain regions, offering new avenues for growth. Diversification into renewable energy and infrastructure projects is driven by regional incentives, enabling companies to expand their portfolios and reduce reliance on traditional dredging activities.

In this Teal Scenario, the dredging industry is shaped by regional innovation and collaboration focused on efficiency or sustainability depending on the area, thriving in localized markets while adapting to a multi-polar menu of constraints and opportunities.

Be happy to take a role.

Derk te Bokkel

CEO, Royal IHC

Royal IHC is a Dutch company with 'dredging in their DNA'. They aim to make dredging operations futureproof, more efficient, and more sustainable. This interview, that **Murat Tarakci** (professor at Rotterdam School of Management) held with **Derk te Bokkel** (CEO of Royal IHC), illustrates the overlap between our participants' insights and the CEO's views reflecting this teal scenario.

Tarakci: "*You are a newcomer to the dredging sector. Can you tell me about the developments you see in the sector?*"

Te Bokkel: "If you look at the general development, the cost in Europe has risen disproportionately more than the costs have risen in the Far East. So it is logical that you become less competitive. And, in general, you react to such cost differentials by outsourcing more volume to a low-cost area. IHC has not done that. So the key decision, which also was quite a political decision, was to move to Vietnam. And then the next question is: what do you do with your yards in the Netherlands?

Tarakci raises the question: "*How do you see the industry in 15 years? What's Royal IHC's role in this vision?*"

"I think industry will be split in two parts", **Te Bokkel** starts. "You will have [a] very large Chinese presence on the external market, currently dominated by the Dutch and Belgian industrial contractors. And I see a cluster in Belgium and the Netherlands of dredging and offshore contractors that are cooperating a lot more to create cost advantages against Chinese operators.

My predecessor had taken the position that we are not competitive, so we will close the yards in the Netherlands. But then if you start calculating, you cannot keep upright your organization if you don't have a manufacturing base. You need the execution know-how for short lead time and technically complex vessels. So what I've said instead is that you need to move towards a dual building strategy and keep a part of the load, as well as the network upright also in The Netherlands.

What you see then, in general, is that China is, by far, dominating the market—it really is!

If you have a mixed building strategy where you focus on large, complex vessels, we can still build in the Netherlands for some business cases. Also, due to capacity constraints that exist in the market today, you still might have a chance, although the load will not be continuous. So, cost flexibility becomes a key issue."

Currently, they are all doing that by themselves. But it also means that, especially if you don't have IHC as a shared resource base, then you start to duplicate capacity and expertise, which is costly because it's high overhead cost on top of your operation cost. They are dedicated to gain market share at cut-throat rates.

In that scenario, it is very hard to stay upright unless you organize yourself very, very well in response to the threat of the Chinese industry. For example, we have four operators that all have or are building a technical department. All have different building strategies, and in doing that, they partly duplicate costs, also cost that is already present at IHC, and then operational cost disadvantages emerge. If we combine resources, we might have [a] more competitive position for the system as a whole. The idea is that cooperation creates scale advantages and by scales, and makes the entire industry more competitive.

We are a valuable part of the ecosystem.

Next, shipbuilding is becoming a strategic issue because of geopolitical tensions. You see in Europe the same realization that we are very vulnerable if we don't have our own shipbuilding capability. The military segment will be a heavy spender at least next 10 to 15 years. Do we want to continue building large naval assets on the coast of the Black Sea? So if you ask yourself the question, where will the large strategic asset be built? IHC thinks that naval construction capability in The Netherlands is a must, and [we] would be happy to take a role in that scenario."

Following up, **Tarakci** asks: "*Which technology trends will shape our future?*"

Te Bokkel explains his point of view: "There is continuous optimization on the dredging equipment side. I don't see that many other trends, except for greenification of drivelines and autonomous operations. For the drivelines we have everything available, and we're capable of

doing any kind of driveline. But it depends on the business case, and the business case depends on regulation. So a lot depends on regulation. So we sit and wait because we cannot decide that for the client. The second trend is autonomous operations. We have an autonomous system available and the question is who wants to use it and again when is the regulation ready to accommodate autonomous operations?"

Continuing on this, **Tarakci** wonders: "*Do you think IHC has the necessary talent and capabilities to deliver autonomous vessels?*"
"Certainly!" **Te Bokkel** is clear about that. "There needs to be a concerted effort. And what I now see is a very distributed landscape. There are many small initiatives, but there's no large drive toward autonomous operations. If we start changing, then we can build on the existing expertise with people that add value to the IHC company from the dredging ecosystem."

Tarakci returns to a previous point: "You have emphasized your desire to create a more collaborative dredging industry. What is curtailing such collaborations?"
Te Bokkel responds: "I think we should look much more into cooperative projects where important parts of the value chain are organized as efficiently as possible in the common interest and not in the interest of an individual part.

I don't have a background in dredging, and that has a big advantage. Many people have bruises from past projects where people were cheated or did not work well together; I don't have all that. The only reason why I'm here is because I think that IHC is a valuable part of the ecosystem, because it draws people into the industry, provides development and construction capacity, and it creates value by exporting its products, and that has value for the Dutch economy."

Tarakci: "I would like to thank you for your time and for sharing your insights, Mr. te Bokkel."

The Brown Scenario: Protectionist and Resource-Tight

This scenario is based on the following trends and uncertainties:

Environment

- Climate change intensifies resource scarcity and environmental degradation.
- Coastal defense needs rise, but projects are constrained by limited resources.

Politics

- Heightened protectionism, political instability disrupt global trade and supply chains.
- Anti-immigration policies restrict access to skilled labor.
- Macroeconomic volatility stifles funding availability and long-term project planning.

Regulation

- Bureaucracy increases, with no clear industry-wide vision for the future.
- Anti-competitive policies in key markets hamper international expansion.
- Stricter environmental rules in Europe escalate operating costs.

Resources

- Severe talent shortages push reliance on manual labor and basic automation.
- Limited external funding and subsidies restrict growth.
- Escalating costs force companies to cut expenses and boost efficiency.

Competition

- Chinese firms dominate international markets.
- Local shipyard closures imperil supply chain flexibility.
- Strategic alliances become necessary to pool resources and mitigate risks.

Technology

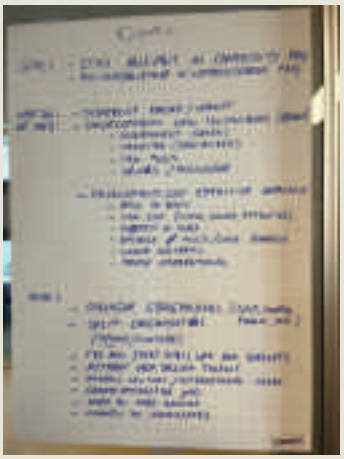
- Only basic automation, digital tools proliferate; AI and autonomous vessels are rare.
- Innovations in dredging focus on gradual cost reductions, not transformative changes.
- Adoption of greener energy is limited by high costs and technological barriers.

New Business Opportunities

- Coastal defense projects grow in urgency but face resource constraints.
- Deep-sea mining suffers due to stringent regulations, inadequate technology.
- Diversification into sustainable sectors is minimal as firms focus on core operations and incremental improvements.

Here is how we envision this scenario unfolding:
In 2040, the global environment is marked by heightened protectionism and severe resource constraints, creating an uphill landscape for the dredging industry. Climate change has intensified, exacerbating resource scarcity and accelerating environmental degradation. These factors have made both the extraction and management of natural resources increasingly difficult and costly, putting immense pressure on the industry to operate with ever-tightening margins.

The political climate is fraught with instability with protectionist policies dominating the global stage. Countries are focused on safeguarding their own industries, disrupting trade and supply chains. The global flow of goods, materials and skilled labor is heavily restricted, making it increasingly difficult for dredging companies in the Netherlands and Belgium



Examples of Strategic Guidelines Developed during the Workshops

to secure the resources they need. Anti-immigration policies further compound this challenge, severely limiting access to skilled labor and forcing companies to rely more on manual labor and basic automation to meet project demands.

Macroeconomic volatility imposes another layer of complexity as fluctuations in the global economy affect the availability of funding and the ability to plan long-term projects. Unpredictable economic conditions lead to cautious investment, with companies prioritizing short-term survival over long-term growth. This volatile environment paralyzes external funds and subsidies needed for expansion, limiting opportunities for growth and innovation.

The regulatory landscape is increasingly burdensome, with rising bureaucracy and a lack of coherent industry-wide policies that complicate the future of the dredging industry. While Europe enforces stricter environmental regulations, operational costs for companies increase significantly, creating a margin squeeze. Anti-competitive policies in major international markets further hinder the ability of European companies to expand beyond their borders, reinforcing the protectionist tendencies that dominate this scenario.

Resource scarcity is one of the most pressing challenges. With severe talent shortages, dredgers are forced to depend on basic automation and manual labor, stifling innovation and reducing operational efficiency. Local shipyard closures exacerbate supply chain inflexibility, making it difficult to maintain and deploy the specialized vessels needed for large-scale dredging operations. As project costs continue to escalate, firms are forced to implement stringent cost-cutting measures, focusing on operational efficiency to stay afloat.

Competition in the Brown scenario is fierce, with Chinese firms dominating world markets due to their scale, state support, and low-cost models. The few yards capable of building complex dredging vessels are all in China. European nations cramped by protectionist policies and resource limits struggle to compete on a global scale. To survive, strategic alliances within Europe become essential, allowing firms to pool their dwindling resources and to share the burden of increasingly expensive projects. Meanwhile, intensified competition in the European home market hinders such collaboration and may limit it to pre-competitive technology development.

Technological advancement in this scenario slows. While basic automation and digital tools are in use, more advanced technologies such as AI-driven systems and autonomous vessels remain rare due to lack of technological capabilities. Innovations in dredging are largely incremental, focused primarily on reducing costs rather than pushing the envelope of what is possible. The adoption of greener energy sources is also limited as the high costs and lack

of supporting infrastructure prevent widespread implementation, leaving the industry reliant on traditional, less sustainable energy forms.

New business opportunities are scant in this constrained environment. While the need for coastal defense projects grows as environmental conditions worsen, the sector's ability to harvest these opportunities is hampered by limited resources and technological capabilities. Deep-sea mining, formerly a potential growth area, faces steep regulatory and technological hurdles that make it largely infeasible. Diversification into sustainable business alternatives is restricted by resource constraints, leading companies to focus on their core competencies and incremental improvements rather than exploring new ventures.

In this Brown Scenario, the dredging industry is characterized by its struggle to adapt to a world of protectionism, resource scarcity, and economic volatility. Firms must operate within tight constraints, prioritizing survival and efficiency over innovation and expansion. The future is one of incremental progress, where maintaining stability in a tumultuous environment is the primary goal.

With our three plausible scenarios—Green, Teal, and Brown—now defined, the next critical step is to translate these potential futures into actionable strategies. To effectively navigate the uncertainties and opportunities each scenario presents, it is vital to develop a strategy both dynamic and flexible[22]. Our approach in the next section will focus on creating adaptable strategies able to evolve as conditions change[23].

[22] Phaal, Farrukh, and Probert, *Roadmapping for Strategy and Innovation.*
[23] Mankins and Gottfredson, 'Strategy-Making in Turbulent Times'.

What will be the newer energy source.

Kees van de Graaf

CEO, Baggerbedrijf de Boer – Dutch Dredging

Baggerbedrijf de Boer – Dutch Dredging—a medium size, family-owned dredging company operating worldwide from its base in Sliedrecht in the Netherlands. This interview illustrates the overlap between our participants' insights and the CEO's views reflecting this brown scenario.

Tarakci opens the conversation with a broad question: "*What threats and opportunities do you see in the industry?*"

Kees van de Gaaf: "*One of the biggest, of course, is the energy transition. Basically, what will be the newer energy source?*

We see that the big dredging companies are betting on different technologies. We just want to follow and see. So that's I think a big challenge. Second challenge is attracting

and keeping talent. The number of young people willing to sail is decreasing. Third, we see increasing competition from Chinese, Indian, Middle Eastern companies. I really see that the industry is struggling with competing against the state-owned enterprises, which is becoming more and more of a challenge. Although those international competitors are not too interested in our small, niche markets for now, they might do so in the future. Fourth, we do have more issues with protectionism, bureaucracy, and regulations that we have to deal with in each country."

Looking at the future, **Tarakci** asks the CEO: "*What world will your successors find?*"
"*I'm pretty convinced that young people will find new solutions even for the yet unknown challenges*", **Van de Graaf** emphasizes the positive first. Then he continues: "I'm not so convinced about the pace with which the sustainability issue is presented. It's going to be a much longer and costlier transition. Clients are struggling as well. For example, we recently won a subsidy with a 67-year-old vessel because it was green enough. I'm also afraid that that we'll still be focused on competition on price too much. For example, we had the greenest ploughing vessel, with zero exhaust. We spent half a million extra on a clean engine. When I go to the customer and ask if they are willing to pay €20 an hour more, the answer is often a no. The industry organizes congresses and conferences every year talking about sustainability, and everybody's cheering and applauding. But during the coffee breaks, I hear people telling that it's not going to work like this, main issues being the slow pace of development and lack of money. So, we should really start moving and doing things. We should team up together as an industry, and give it a go, see if it works. If we keep talking and not doing anything, nothing will be changing. The biggest challenge is that we expect the neighbor go green first. If we start partnering up, however, we can at least try to get things moving. In the end money talks, so as a society we should also be willing to pay for sustainability."

Continuing on this, **Tarakci** states: "*This is rather a dim image of the future. What is your current strategy and how do you think your strategy should change to stay relevant if the future will be as you envision?*"

Go work in dredging.

Van de Gaaf clarifies: “We try to find the niche markets where other companies are not that interested in. We focus on cost and watch out if other companies from down below come up and disrupt us. When it comes to sustainability, we cannot afford to be the frontrunner because we’re too small and it’s going to be too expensive for us. But we have to stay extremely agile to change as quickly as we can. Our small size, flexible crew and being family-owned allow us to adapt rapidly to whatever comes up. We try to stay focused and be flexible at the same time. And at the same time, we do really try to focus on partnerships and try to find other partners that are that are willing to share their knowledge and try to make the world a better place. If

you go together, you get father. It's the only way forward."

Tarakci is curious about this and what that entails. "*Do you have a specific example for this partnership strategy?*" He asks Van de Graaf.

Van de Gaaf: "It starts with identifying the problem and then trying to find the solutions in a partnership. What I often find is that a customer's question or a tender is not really answering their problem. We regularly go back to the customers and try to understand what their issue is and maybe we find a better solution than they found themselves. However, there is too much distrust across customers and contractors. We're often afraid to partner up and find the best solution together. When both parties try to be smarter than the other one and take the shortcut, things go wrong.

I fully support that there should be way more partnerships. If a customer has a new challenge, they should talk to the market and say, you know, we want a full green solution and how can we get it done? Is it feasible? For example, if you want to go dredging on hydrogen or methanol. Make it into a small pilot and learn from it together. Customers, companies, knowledge institutions, universities, all the people, all the suppliers come together and try to get to somewhere. Because I'm afraid if we if we do not partner up we will start dancing alone and that's never fun."

Tarakci returns to a previous point: "*You stressed that talent is a challenge.*" He poses the question: "*What steps should the industry and your firm take to boost the talent pool?*"

Van de Gaaf acknowledges this challenge and says: "Well, one big issue is the image that we have. When you receive a Google alerts email about Bagger or dredging industry, eight out of the ten alerts are negative. The connotation of the words doesn't help our image. Yet, I believe we are the solution to a lot of sustainability problems. As an industry we offer so many solutions.

But somehow we are unable to promote those solutions enough and well to the outside world, including the students and young generations. I would advise any young technicians to go work in dredging. The new generation can and will shape the industry's future. That's why our ambition is to be the company where you have the most fun at work."

Tarakci: "*Thank you so much for sharing your strategy, vision of the industry's future and call for action.*"

A strategic direction for the dredging industry.

Across all three scenarios, certain themes consistently emerge as critical for success: technology and innovation, partnerships, and attracting talent. These elements form the foundation of the industry's ability to navigate the uncertainties and opportunities ahead.

Consider *technology and innovation*. Whether it's adopting AI and autonomous vessels in the Green scenario, focusing on incremental innovations in the Teal scenario, or relying on automation for cost reduction in the Brown scenario, the industry's capacity to innovate will determine its competitive edge. *Partnerships and ecosystem* building are equally crucial to pool resources and share risks, whether such be regional alliances or strategic collaborations. These partnerships, for example in research on more efficient dredging techniques, enable industry flexibility to adapt to varying degrees of market protectionism, resource availability, and regulatory environments. *Attracting and developing talent* is the third cornerstone, since the industry's ability to draw skilled workers and foster a versatile workforce will directly influence its operational success and ability to innovate.

By focusing on these common elements, the industry can build a robust strategy adaptable to different futures[24]. Whether facing global cooperation, regional protectionism, or resource constraints, the industry can leverage technology, partnerships, and talent to remain resilient and competitive for any scenario that unfolds.

Embracing New Technologies and Fostering Innovation

The dredging industry is currently seeing what is known as an "era of ferment," which describes a period of high uncertainty and variation as multiple competing technologies and solutions emerge, with no clear dominant design yet established[25]. For example, the industry is grappling with various energies such as hydrogen, electricity and green methanol, but there is no consensus which will prevail as standard. This lack of clarity extends to customer behavior too—there is ambiguity about whether customers are willing to pay a premium for new, more sustainable technologies. Also, impacts of emerging technologies like AI and digitalization remain unclear, with questions as to how effectively these integrate into existing operations and what their long-term effects will be.

[24] Mankins and Gottfredson.
[25] Kaplan and Tripsas, 'Thinking about Technology: Applying a Cognitive Lens to Technical Change'.

Dredging companies must therefore navigate a complex landscape where different technological paths are explored amid market preferences not yet well-defined. The uncertainty and variety in potential technologies mean that firms must be strategic in their approaches to R&D investment and innovation. Several principles can help the industry navigate.

Openness and Agility

Dredging firms may consider embracing a culture of openness and experimentation by actively exploring a range of technological options. This goes beyond just testing different technologies to also engaging the broader industry in shaping market preferences and grasping emergent user needs. Such a focus on anticipating customer needs that swiftly evolve during an era of ferment can help dredgers prioritize customer feedback and market research to guide their technological investments and innovation strategies. Relatedly, companies must monitor technology developments beyond their own operations, staying attuned to innovation arising in other fields that may influence the dredging sector. This principle emphasizes adopting the "real-options" strategy where initial small investments are made in diverse technological areas both within and outside the company. This strategy maintains flexibility by avoiding large commitments to a single technological path too soon. In an era of ferment, the eventual dominant design or technology is uncertain, so firms must remain agile and ready to shift focus as new opportunities or threats arise. Therefore, initial modest outlays should be continuously monitored and assessed in relation to the evolving external technological landscape. By joining forces in developing a strategy toward new fuels, costs can be reduced and chance of success improved. As new data arise, firms should be ready to pivot, reallocating resources from less promising technologies to those showing greater potential.

Building Strategic Portfolios

Companies in the dredging industry should build and manage a strategic portfolio that balances core, adjacent, and transformational innovations. This means wisely allocating time, resources, and funds to both small improvements and major advancements. A balanced approach prepares a company for different futures. Transformational projects need special attention in terms of separate funding, dedicated teams and unique managerial processes to succeed, giving high-risk, high-reward initiatives the best chances here to become new business opportunities.

As one participant stated: "When considering innovation programs, it's about allocating our time, resources and funding wisely. We must decide how much of our available resources—both in terms of people and money—to allocate to incremental improvements in our current business versus making significant leaps forward." Building a strategic portfolio involves allocating resources across a spectrum of innovation types—ranging from incremental improvements to breakthrough technologies—to ensure that a company is prepared for multiple future scenarios[26]. Transformational efforts should be carefully managed—whether needing separate funding, small investments aimed at learning and experimentation, dedicated teams,

or different management processes to thrive—to ensure that these high-risk, high-yield initiatives have improved odds of maturing into new business opportunities[27].

Collaborative Innovation and Partnerships

Dredging firsm can leverage collaborative innovation by forming strategic partnerships with other firms, research institutions, and startups. In the past, suppliers of dredging equipment played a pivotal role in the development of new technologies and pushing boundaries, for instance in the area of scaling up. The background knowledge gained from projects was effectively applied to new projects, elevating the industry's overall level of innovation. However, the more individualized approach of companies today has resulted in reduced cross-pollination, causing a slowdown in the development of new technologies. More collaborations not only accelerate access to emerging technologies and diverse know-how, but also help hedge project risks, share costs, and pool complementary resources. In an era where uncertainty is high and the path to a dominant design unclear, actively seeking and engaging joint ventures, research collaborations, and open innovation initiatives can offer the flexibility and shared strength needed to explore multiple avenues of innovation without bearing the full burden alone.

A prime example of such collaboration is ZEDhub.nl, that emerged as a result of the previous research in 2018 by two of the authors of the current report[28], where major industry players like Boskalis, Damen, Royal IHC, and Van Oord have allied to develop knowledge, technology, regulatory frameworks, and economic models to secure viability in zero-emission dredging. By partnering in this initiative, such firms are pooling their expertise and resources to tackle the significant challenge of reducing emissions in the dredging sector.

Building a Dredging Ecosystem

Advised to form partnerships focused on specific innovation projects, the dredging industry has the potential to elevate this strategy by fostering a vibrant dredging ecosystem in the Netherlands and Belgium. Here, an *ecosystem* refers to a *network* of organizations—companies, research institutions, government bodies and other stakeholders—that collaborate and co-create value within a shared environment. An ecosystem is a dynamic, multi-faceted system where participants continuously interact, share resources, and innovate together across multiple domains. In such an ecosystem, each participant plays a unique role contributing expertise, resources, and capabilities to achieve common goals while also advancing one's own strategic interests.

The dredging industry has traditionally followed a strategic playbook rooted in Michael Porter's Five Forces framework[29]. This classic framework analyzes the competitive forces within an industry, recommending strategies based on the following five factors: i) *competition* from rivals, *bargaining power* of both ii) suppliers and iii) buyers, and *threat* of both iv) new entrants and v) substitutes. This framework prods companies to engage in cut-throat competition

[26] Nagji and Tuff, 'Managing Your Innovation Portfolio'; Si, Kavadias, and Loch, 'Managing Innovation Portfolios'.
[27] Nagji and Tuff, 'Managing Your Innovation Portfolio'.
[28] Tarakci and Van Den Ende, 'The Dutch and Belgian Dredging Industry: An Exploration of the Future'.
[29] Porter, *Competitive Strategy.*

with peers, squeeze suppliers to cut costs, build barriers to entry to prevent new competitors and substitutes, and poke customers with premium pricing.

This approach has long guided businesses in achieving competitive advantage by focusing on sector dominance and control. As one participant observed: "this adversarial approach is unsustainable and threatens the future viability of shipbuilding. It's imperative to explore alternative collaborative frameworks to sustain shipbuilding's future." Another cited an example reaching the same conclusion: "The escalating risks associated with new construction projects, which no single shipyard can manage alone due to increasing costs and complexities, underscore the need for new collaborative models." In fact, dredging is facing a rapidly changing, globalized environment where this traditional playbook offers diminishing returns for the dredging industry. The challenges of maintaining competitive advantage have become more complex, requiring not just outmaneuvering rivals or controlling costs, but a concerted effort. One participant exclaimed: "Europe's future lies in renewed collaboration!"

An ecosystem approach offers a significant advantage over Porter's Five Forces framework by focusing on the interdependencies and collective success of multiple actors, rather than viewing the market as a battleground of individual firms. While Porter's model emphasizes competition and the struggle to capture value within a fixed industry structure, an ecosystem approach recognizes that value creation often depends on the collaboration within a diverse set of actors, including suppliers, complementors, and even competitors. This view shifts the focus from merely surviving in a competitive environment to thriving by strategic partnerships and collaborative innovation.

Ecosystem strategies allow firms to manage complex interdependencies and align the goals of different players—essential for delivering comprehensive solutions to end customers[30]. Moreover, the ecosystem framework better addresses the dynamic nature of the dredging sector where industry boundaries are increasingly blurred with the advent of AI, automation, and sustainable solutions. The ecosystem approach accounts for the co-evolution of technologies and markets, highlighting how firms can influence and shape their environments through strategic collaborations.

Accordingly, instead of relying on strategies that isolate and protect, the industry must adopt a more collaborative, integrated approach—one that recognizes the value of ecosystems over individual competition. By fostering a dredging ecosystem, firms and organizations can create synergies, share resources, and innovate together, ensuring competitiveness on a global scale while addressing the multifaceted challenges of the modern market. This shift from a competitive to collaborative strategy is essential for sustaining long-term growth and innovation in our increasingly interconnected world.

Consider the ecosystem of IMEC, a world-leading research and innovation hub in nanoelectronics and

digital technologies based in Belgium. Rather than compete solely within the boundaries of a traditional industry, IMEC has built a thriving ecosystem that includes academic institutions, industry leaders, startups, and governments[31]. This ecosystem enables IMEC to accelerate innovation by pooling assets, sharing risks, and forging collaboration across different sectors. For instance, IMEC's partnerships with semiconductor giants, medical device companies, and tech firms have led to groundbreaking advancements in chip technology, health tech, and smart cities. By leveraging its ecosystem, IMEC has not only maintained its own leadership in a rapidly evolving field; it has driven the global competitiveness of its partners, too.
Such examples demonstrate how an ecosystem approach can unlock new opportunities for innovation, growth, and market influence beyond the reach of strategies focused solely on competition within a defined industry.

Attracting Talent

One vital element in the dredging sector strategy is building and retaining a skilled, adaptable workforce. Developing scalable talent development programs is essential for ensuring that the industry can meet the demands of a rapidly changing environment for any future scenario. One of the participants noted: "We had a master's program in TU Delft focused on dredging, but the professor who led it has passed away. There is still no replacement." Moreover, enhancing the industry's public image is vital for attracting top talent and showcasing the sector as a leader in innovation and sustainability.
To address the growing need for both high-tech skills (such as AI, digitalization, and green technologies) and traditional skills (including manual operations and basic automation), the industry should develop scalable training and education platforms. Such programs must be flexible to expand or contract based on the availability and mobility of talent. For instance, firms can ally with educational institutions to create specialized courses and apprenticeships that equip workers with the skills needed to thrive both now and in future roles.

In addition to developing local talent, the industry should focus on accessing global talent for both white- and blue-collar roles. Given the global nature of the dredging industry, attracting talent from around the world can provide companies with a diverse range of skills and perspectives, enhancing innovation and operational efficiency. Companies can establish international recruitment strategies and partnerships with global educational institutions to tap this wider talent pool. This approach not only fills immediate skill gaps; it builds a more culturally diverse workforce—one crucial for operating in different regions and markets.

To attract and retain talent, the industry must focus on enhancing its public image. One participant highlighted: "Commercials from organizations like Greenpeace on deep-sea mining highlight the public's perception and the lack of understanding about dredging and deep-sea mining. Educating the public is crucial to counter misconceptions and build a more informed opinion." Accordingly, the dredging

[30] Adner, 'Ecosystem as Structure: An Actionable Construct for Strategy'; Adner, *Winning the Right Game*.
[31] Leten et al., 'IP Models to Orchestrate Innovation Ecosystems'.

sector should be marketed as a forward-thinking, sustainable, and tech-savvy field that offers exciting careers. By showcasing the industry's promise of environmental stewardship, innovative technologies and global impact, companies can appeal to a new generation of workers motivated by the opportunity to contribute to meaningful change.

An excellent model for this approach can be found in the 'HR Ecosystem' introduced by the Dutch Ministry of Defence (https://www.hr-ecosysteem.nl/). Through an ecosystem engaging government bodies, educational institutions and private sector firms, the Ministry of Defence has created a network where talent can be continuously developed, shared, and deployed across different sectors based on evolving needs. For the dredging industry, adopting a similar HR ecosystem could be transformative. By building an HR ecosystem, the industry can ensure a steady pipeline of skilled workers while fostering greater collaboration among companies, universities, and government agencies. This ecosystem would allow for the dynamic exchange of talent and knowledge, helping the sector adapt to changing demand and technological advancements. Such an ecosystem would further support the continuous professional development of employees, ensuring that the workforce remains competitive and capable of advancing the industry.

By investing in scalable talent-development programs and enhancing its public image, the dredging sector can build a resilient, dynamic workforce ready to meet future challenges.

How This Strategy Relates to the Three Scenarios

Whether the industry faces a more open, innovation-driven future (i.e., the Green scenario), a regionally focused system (i.e., Teal scenario), or a protectionist ethos under tight resources (i.e., the Brown), the three pillars highlighted (i.e., embracing technology and innovation, cultivating partnerships and ecosystems, attracting and developing talent) remain central in allowing the sector to adapt to shifting mandates, market demands and customer expectations.

Building a robust *innovation* capability gears the industry to handle multiple futures. In an era of rapid technological change, companies must be agile and open to exploring different fuels, automation levels, and digital tools. A "real options" approach—making smaller, diversified investments—helps manage uncertainty: if one technology fails, resources can quickly shift to more promising alternatives. Additionally, maintaining a balanced innovation portfolio (from incremental improvements to transformative R&D) prepares firms for both near-term efficiency gains and long-term breakthroughs. While some scenarios emphasize cost reduction over sustainability, others call for green solutions and AI-driven processes—but in all cases, firms with a strong innovation engine can deftly pivot.

Traditional competitive strategies often pit companies against each other, but a rapidly evolving, resource-constrained future calls for more collaborative frameworks. Fostering a dredging *ecosystem*—a linkage of companies, research institutions, government agencies, and other stakeholders—

allows organizations to share risks, costs, and knowledge. Such an ecosystem mindset better positions the dredging sector to shape emerging standards, respond to global trends, and pool resources in high-risk, high-reward initiatives.

Finally, a *skilled and adaptable workforce* will prove indispensable in every scenario. Evolving regulations, new technologies, and shifting business opportunities all require a base of talent that is agile and well-trained. Companies can establish partnerships with universities and vocational programs to address local skill shortages and create scalable training courses. At the same time, enhancing the field's *public image*—featuring sustainability, innovation, and global impact—can help attract top-tier candidates from diverse backgrounds. This very commitment to talent ensures that, no matter how the future unfolds, dredging firms will lure the talent needed to keep them competitive and agile, ready to seize new opportunities.

A a postscript scenario: The netherlands and Belgium without the dredging industry.

To appreciate the importance of dredging, imagine a hypothetical future scenario where this industry in the Netherlands and Belgium has collapsed, weakening the internationally renowned Dutch water engineering capability. Once-dominant Dutch and Belgian dredging companies, known for their innovation and expertise, have shriveled—replaced by global giants like the China Communications Construction Company (CCCC). While dredging activity continues, the care of their vital waterways is outsourced to foreign operators and equipment builders in Asia. This shift in control brings a host of new challenges and vulnerabilities.

Without local industry expertise, the strategic ports of Rotterdam and Antwerp remain operational, but the precision and efficiency that once characterized their maintenance suffer. Foreign outfits, driven by profit rather than national interest, dictate the terms and timelines of dredging operations. Shipping channels stay open, but not with the same urgency or care, leading to occasional delays and rising costs for transport companies. The economic impact is notable: goods still flow, but the competitive edge that once made these ports 'global leaders' is dulled, leading to a gradual decline in status as premier international logistics hubs.

Reliance on foreign dredging companies may jeopardize the ability to quickly respond to natural disasters, such as floods or storm surges, as decisions must pass through corporate headquarters located far from the immediate threat. In times of crisis, responsiveness that once protected low-lying regions in both countries is now hindered by the complexities of global contracts and logistics. This new reality heightens vulnerability in coastal defenses, exposing the Netherlands and Belgium more to climate concerns, as well as facing greater risk in times of political tensions where sabotage of infrastructure can be fatal for defense.

Furthermore, foreign players may not share the same commitment to environmental stewardship that Dutch and Belgian companies do. As a result, coastal protection projects and renewable energy initiatives like offshore wind farms face delays, or are executed with less regard for long-term environmental impacts. Any vision of a sustainable future driven by local innovation vanishes—replaced by a myopic, profit-driven approach that prioritizes short-term gains over long-term ecological resilience.

In this altered landscape, the Netherlands and Belgium have not lost dredging activity, but they have forfeited control over a critical industry that once underpinned their economic, environmental, and coastal security. The consequences of this shift are felt in the erosion of strategic infrastructure and the compromised ability to pursue ambitious sustainability goals. This scenario serves as a glaring reminder that control over key industries is not just about economic strength—it is also about maintaining the power to protect and shape the future.

This scenario is not unprecedented; history is rife with collapses of a once-thriving industries that spawn devastating consequences. Detroit, once the vibrant heart of America's automobile manufacturing industry, serves as a cautionary tale. Detroit c.1950 was a bustling city with a population of 1.8 million, driven by the success of the "Big Three" automakers—Ford, General Motors, and Chrysler. However, as manufacturing began moving offshore and Japanese competitors entered the market in the 1970s, the city's fortunes declined sharply. The population plummeted to 639,000 by 2020, and the construction of new homes virtually stopped after the 1970s. Detroit's economic decline culminated in 2013 when it became the largest U.S. city to file for bankruptcy, a stark reminder of how quickly a region's economic foundation can erode when its key industries subside.

The parallels with a potential future of the Netherlands and Belgium without their dredging industry are clear. In the Netherlands, the dredging sector forms an important part of the economy of the "Drechtsteden" region, the cities and villages surrounding Dordrecht— Sliedrecht and Papendrecht. Like Detroit, such regions could see a rapid decline in their economic and strategic importance if they lose control of this critical sector. The lessons of Detroit underscore the importance of maintaining strong, locally controlled industries to ensure long-term prosperity and stability.

Conclusion.

As this report demonstrates, the dredging industry in the Netherlands and Belgium stands at a crossroads where the right mix of *technology, partnerships*, and talent can turn external pressures into opportunities. Whether facing high-tech, globally driven growth or a regionally protected landscape, or even a resource-constrained environment, dredging's capacity for adaptation will hinge on collaborative innovation and strategic investments in human capital. By embracing a more ecosystem-oriented approach, cultivating future-ready capabilities, and consistently aligning with socio-environmental needs, the dredging sector can retain its global standing and continue to safeguard and enrich each nation's coasts, economies, and identities.

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Colophon.

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