An increasing amount of attention is being given to the concept of sustainability as an approach to informing social, environmental and economic development.

HOW CAN THE DREDGING SECTOR JOIN THE GLOBAL SHIFT TOWARDS SUSTAINABILITY?

A dredger is a tool. For hundreds of years, this tool has been used to shape and manipulate the interface between land and water in order to support a variety of human activities, including navigation, coastal protection, flood risk management, as well as residential, commercial, agricultural and hydro-power development. The use of dredging to achieve these purposes has always been guided by an understanding of the costs and benefits of applying the tool.

However, in the last several decades, the understanding of what constitutes costs and benefits has evolved substantially beyond the direct monetary costs of using the tool and the direct monetary benefits of what the tool was used to create. Over the last 50 years, the cost-benefit evolution was aided by the environmental movement.

The Broad Context

For the last several decades, dredging has found itself at the centre of a fundamental conflict between supporters of development and the environment. To minimise the adverse effects of dredging activities on ecosystems, environmental regulations were put in place. The environmental regulations put into place intend to eliminate, reduce, or control the impacts of dredging on the environment have produced a range of outcomes, both positive and negative.

It is undoubtedly true that such regulations have helped to reduce negative impacts on the environment, in general. However, it is also true that the amount of environmental benefit produced by such regulation has not been systematically quantified, let alone compared to the social and economic costs and the shift of negative impacts to other systems due to reduced efficiency of the construction works of such regulation. Today, a paradigm shift is increasingly being embraced within the dredging industry, truly changing the traditional engineering approach into a holistic approach in which the ecosystem is leading and values for people, profit and planet are integrated in an interdisciplinary manner.

The Growing Focus on Sustainability

The International Focus

An increasing amount of attention is being given to the concept of sustainability as an approach to informing social, environmental and economic development. In 2015, the United Nations released its Sustainable Development Goals (SDGs) as a part of its 2030 Agenda for Sustainable Development (see Table 1). A total of 17 goals were established and encompass a very broad range interests, values and objectives.

As a means for developing water resources infrastructure, the relationship of dredging to each the SDGs varies from weakly to strongly connected. For example, the use of dredging to construct efficient and productive navigation infrastructure is directly connected to SDGs 2, 7, 8, 9, 10, 11, 12, 13, 15 and 16. As a tool used to provide coastal protection and infrastructure supporting flood risk management, dredging clearly supports SDGs 1, 3, 7, 10, 12 and 14, among others. In the future, one of the challenges that should be addressed by the

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dredging and water infrastructure community is to incorporate these goals into the infrastructure development process and to become effective at communicating how such projects support the SDGs.

The Sector-Specific Focus

On behalf of the dredging sector, the World Organization of Dredging Associations (WODA) – which includes the Central Dredging Association (CEDA), the Eastern Dredging Association (EDA) and the Western Dredging Association (WEDA) – published its principles of sustainable dredging in 2013.

The WODA principles reflect the importance of using dredging to create value across the three pillars of sustainability, considering the system-view of projects including the ecosystem and natural processes operating within the system, and the role of engaging stakeholders including project proponents, regulators and the broader array of interests relevant to a project. Publication of the WODA principles has sparked a range of discussions and actions within the dredging sector in efforts to seek a balance between the economic development that is supported through dredging and environmental considerations and regulation.

Disseminating information throughout the industry

Alongside the growing public awareness of the need for sustainability, there has been an increasing sense of individual and corporate responsibility regarding the consequence of dredging activities on the environment. In 2008, a team of experts brought together by CEDA and IADC compiled their knowledge – as well as information available in less comprehensive, earlier publications – into a single, up-to-date volume. The *Environmental Aspects of Dredging* (Bray, 2008) brought the impacts of dredging to marine environments into industry focus in an effort to inform a project's manifold stakeholders while complying with international legislation. A myriad of methodologies are presented to mitigate the negative effects of dredging on water quality and contaminated soils as well as minimising loss of habitats and fauna.

In the years following the release of the *Environmental Aspects of Dredging*, an update of its information was prepared to ensure it evolved with the industry's practices as well as legislation. After consideration by an editorial advisory board of industry experts, it was collectively agreed upon that a mere revision of the presented information was not enough and an entirely new publication was needed. The principles and methodologies were updated, refined and expanded upon. An updated successor makes its debut as *Dredging for Sustainable Infrastructure* later this year, once again the result of a joint effort by CEDA and IADC.

Applying the concept of sustainability to water infrastructure development

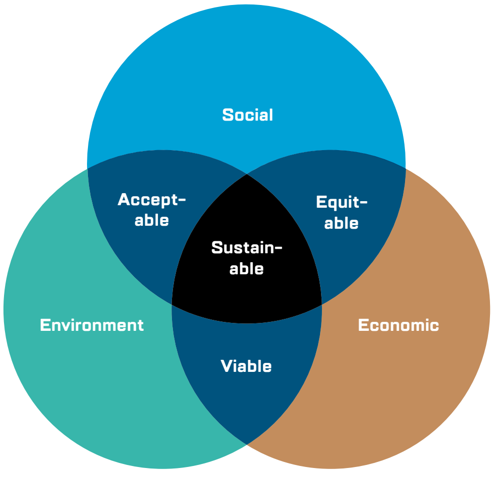
The concept of sustainable development is based on the premise that the design for an action – in this case a development project that involves the use of dredging – will be informed by a full consideration of the values and costs of the proposed action across the three pillars of sustainability. The outcomes expected from the action may be categorised as social, environmental and economic outcomes (see Figure 1).

The concept of sustainable development recognises the need to consider the full range of benefits and impacts related to human actions and the distribution of these benefits and costs across the social, environmental and economic domains. The relationships among these value domains are reflected by the goal to take actions – such as developing projects – that will balance the distribution of benefits and costs so as to produce socially equitable, environmentally acceptable, and economically viable outcomes. This balance is achieved through active and consistent engagement with the stakeholders which will be affected by the proposed project. Stakeholders may include local, regional and national members of the public, government authorities, private sector interests and special interest groups as well as perspectives that are relevant to the project.

In order to aid the discussion of sustainability in the context of infrastructure development and dredging, the following operational definition is proposed:
Sustainability is achieved in the development of an infrastructure by efficiently investing the resources needed to support the desired social, environmental and economic services generated by the infrastructure for the benefit of current and future generations.

FIGURE 1

The three principles of sustainability.



Dredging for Sustainable Infrastructure

The new publication is an authoritative guide on delivering dredging projects that enhance the natural and socio-economic systems, and will be an invaluable resource for those responsible for delivering projects with longevity which need to do more than just the basics. Project owners, regulators, consultants, designers and contractors looking for an up-to-date reference should find it to be a useful tool. The team of expert authors represents international institutes, dredging contractors, consultants and project owners. Edited and published by CEDA and IADC, *Dredging for Sustainable Infrastructure* will be available in a print and e-book edition. A special conference and course will be held on the subject. Information will be available at http://sustainabledredging.com.

Here, the word infrastructure is used to refer to the diverse range of structures, features and capabilities that are developed through the use of dredging such as navigation channels and waterways, ports and harbours, levees and dykes as well as nature-based infrastructure such as beaches and dunes, islands, wetlands and many other forms of habitat.

In practical terms, the sustainability of an infrastructure project is increased by:

1. increasing the overall value of the project through the range of services it provides,
2. reducing costs associated with the project, where the word costs is being used in the broadest sense to include all of the monetary and non-monetary – such as environmental impacts – costs and resources consumed by the activity and
3. balancing the distribution of the value and costs among the social, environmental and economic domains over time.

Some practical implications for dredging

The importance of vision and value creation

For the vast majority of the history of dredging, the nearly exclusive focus of the activity was to generate the economic benefits produced by infrastructure. The incorporation of environmental and social factors – the other two pillars of sustainability – into the decision making and governance process is a relatively recent development, mostly concentrated within the last 50 years. During the last few decades, significant technological and operational advancements have been made that have improved the dredging process in relation to the environment. That said, one of the biggest opportunities for increasing the overall sustainability of the water infrastructure sector is for project proponents, dredging contractors and other stakeholders to invest more time and energy in upfront visioning to identify ways of creating more project value across all three pillars of sustainability.

Such visioning will not diminish the importance of generating economic benefits from infrastructure, rather, it is more likely to reveal opportunities for creating additional economic value. By devoting more effort to identifying and developing positive values for social – such as recreational, educational and community resilience – and environmental – such as ecosystem services, habitat and natural resources – perspectives, dredging and infrastructure projects will be able to avoid unnecessary conflict with stakeholders while simultaneously developing a larger number of project proponents, advocates and partners.

Adapting projects to nature, rather than the reverse

Dredging is used to change or manipulate the physical structure of the environment to produce a feature or a function that nature didn't and wouldn't create on its own. For centuries, ports and waterway networks have been produced by creating a design for these systems and then imposing that design on the natural environment, but with mixed results. Traditional designs were assessed also for their effects on nature. However, in many cases those effects could not be fully assessed because of a general lack of knowledge.

In this historical approach, the design functionality and investment cost were dominant factors and effects on nature were a follow-up consideration. Effects on nature and impacts in the coastal zone and rivers have in many cases been underestimated or partly ignored because of this lack of knowledge. However, in more recent decades, important lessons have been learned.

Stakeholders' Role in Port Expansion

The new 2,000 hectare expansion of the Port of Rotterdam is a top location for port-related industry. From the onset of Maasvlakte 2's development, sustainability and innovation were the key drivers in the development of a world class port area which also improved the liveability of the region. There were far-reaching agreements with the key stakeholders about sustainability objectives as well as continuous attention from the outside world, with nearly 120,000 annual visitors. The stakeholder inclusive approach is an important driver for the sustainable development and innovation of the Port of Rotterdam.

In 2018, Pieter van Oord, Van Oord's CEO, received the honour Port Man of the Year 2017 (Havenman van het Jaar 2017) in recognition of the dredging contracting company's outstanding contributions towards the development of the Port of Rotterdam and for spearheading the energy transition taking place across the Netherlands. Pieter says: 'It's clear offshore wind has become a mainstream energy source. Offshore wind could give our home base of Rotterdam a fantastic boost, specifically across the region and in the port'. The company's tagline of Marine Ingenuity permeates all aspects of Van Oord's activities. He explains: 'we create innovative solutions that are valuable to our clients, our partners and other stakeholders. Marine ingenuity means, among others, creative thinking'. Case in point, the company is one of the founding partners of PortXL – a startup labelled the first World Port Accelerator – which has a collective aim of creating value for stakeholders and companies of the global port industry.

Lack of knowledge in regards to sediment flows and relief changes, and the importance of sediment flows and relief changes for (eco-) system functioning and related eco-flows – nutrients, biota and so on – have presented challenges. In the past, engineering solutions often focused on hydrology and less on ecology. Long-term effects were not fully understood. Common engineering solutions in order to manage the hydraulics involved the use of hard interfaces between fresh and salt water and wet and dry areas. Rivers were trained to manage navigation and hydro-power dams became abundant. The structures regulated the water as needed. Sediment disruptions – which were longer-term effects – were addressed through repairs or taken for granted. However, later it became more and more evident that next to the sedimentological processes, biological processes had been disrupted, leading to long-term effects on sediment balances as well as ecosystem functioning and ecosystem services such as agriculture and fisheries. The traditional engineering solutions certainly have had major positive effects on economy, safety, welfare and the well-being of the human populations affected by them but the detrimental longer-term effects become more and more visible and may in the future overshadow the initial positive effects. Additionally, in many cases the negative effects probably will be amplified by the adverse effects of climate change.

Nature can be a stubborn and uncooperative collaborator, especially when it is not adequately considered and consulted during the process of design. Winds, waves, and tides deliver force, water, and sediment

TABLE 1

The Sustainable Development Goals (SDGs) are a collection of 17 global goals set by the United Nations.

Sustainable Development Goals

1 NO POVERTY	End poverty in all its forms everywhere.
2 ZERO HUNGER	End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
3 GOOD HEALTH AND WELL-BEING	Ensure healthy lives and promote wellbeing for all at all ages.
4 QUALITY EDUCATION	Ensure inclusive and quality education for all and promote lifelong learning.
5 GENDER EQUALITY	Achieve gender equality and empower all women and girls.
6 CLEAN WATER AND SANITATION	Ensure access to water and sanitation for all.
7 AFFORDABLE AND CLEAN ENERGY	Ensure access to affordable, reliable, sustainable and modern energy for all.
8 DECENT WORK AND ECONOMIC GROWTH	Promote inclusive and sustainable economic growth, employment and decent work for all.
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	Build resilient infrastructure, promote sustainable industrialisation and foster innovation.
10 REDUCED INEQUALITIES	Reduce inequality within and among countries.
11 SUSTAINABLE CITIES AND COMMUNITIES	Make cities inclusive, safe, resilient and sustainable.
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Ensure sustainable consumption and production patterns.
13 CLIMATE ACTION	Take urgent action to combat climate change and its impacts.
14 LIFE BELOW WATER	Conserve and sustainably use the oceans, seas and marine resources.
15 LIFE ON LAND	Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss.
16 PEACE, JUSTICE AND STRONG INSTITUTIONS	Promote just, peaceful and inclusive societies.
17 PARTNERSHIPS FOR THE GOALS	Revitalize the global partnership for sustainable development.

against the products of a design with endless energy, which prompts additional effort, time, and money to be spent in reaction to nature's onslaught. The lesson has been learned countless times: taming nature can be an expensive proposition. Integrating the concept of sustainability into infrastructure projects will in turn lead to identifying opportunities to cooperate and collaborate with natural process, rather than seek to control and counter. By working in this way, the design will adapt the port to the coastal ecosystem, the ship to the river, and the local community to cycles of low and high water.

As a philosophy, working with nature emphasises the need to enhance nature instead of impacting nature, both in the short term and to be cost-effective in the long term. Nowadays, tools are being developed to value the so-called ecosystem services, which means that in a project evaluation the effects on nature and the resulting effects on its services – such as ecosystem functioning, water and food supply, minerals, cultural services and so on – will be assessed.

Taking the long view

Water infrastructure projects – due to the level of investment they require – are long-term propositions. While the state of scientific and engineering practice continues to advance, uncertainties remain regarding the behaviour of natural and engineered systems over the long-term. Nevertheless, pursuit of sustainable infrastructure requires taking a broad and long term view of a project's life cycle. Taking this broad, system view is necessary in order to determine whether the project can be expected to be sustainable over the long term. One way this can be done is to judge whether the total value of the project over the three pillars of sustainability is sufficient in relation to the investment required to create that value.

Performing such sustainability analyses could mean that some proposed projects will not be built, or that existing projects will be decommissioned and abandoned in favour of more sustainable projects. For example, ports or waterways which cannot be efficiently sustained over time due to the effects of physical processes, coastal conditions, sedimentation, environmental impacts and so on would receive reduced levels of investment in favour of ports and waterways situated in a more sustainable condition. When investment decisions are being made on the basis of the overall sustainability of the asset or project, then it can be ensured the concept of sustainability has been successfully incorporated into the governance of infrastructure systems.

Three guiding principles of dredging for sustainability

Number 1
Comprehensive consideration and analysis of the social, environmental and economic costs and benefits of a project is used to guide the development of sustainable infrastructure.

Dredging is but one component of an infrastructure project, and any one piece of infrastructure functions as a part of a larger network of infrastructure as well as the surrounding ecosystem. Therefore, understanding the full set of costs and benefits of a project requires taking a system-scale view of infrastructure and the functions and services that infrastructure provides. The costs – in the broad sense – of a project include all the resources, material, and negative impacts associated with executing the project and/or producing and operating the system over time. Likewise, the benefits generated would include all the values, services, and positive outputs generated by the project and/or system over time. Defined in this way, costs and benefits will include both monetisable and non-monetisable quantities. While traditional economic analysis can be used to develop an understanding of the more readily monetised costs and benefits, for other values within the social or environmental domains different methods should be used to develop credible evidence about costs and benefits. Finally, one of the key opportunities for increasing the overall sustainability of water infrastructure is to seek opportunities to increase the total value of projects by identifying and developing benefits across all three pillars of sustainability.

Number 2
Commitments to process improvement and innovation are used to conserve resources, maximise efficiency, increase productivity, and extend the useful lifespan of assets and infrastructure.

Innovations in technology, engineering, and operational practice provide opportunities to reduce fuel and energy requirements related to dredging and the operation of infrastructure. These same innovations can provide the means to reduce emissions – including greenhouse gases and other constituents – and conserve water and other resources. By lowering the consumptive costs associated with dredging and infrastructure the sustainability of projects is enhanced. In addition, using technology or improvements in operational practice in order to extend the useful lifespan and functional performance of an asset in a manner that lowers overall life cycle costs will increase the sustainability of infrastructure, such as a navigation channel or offshore island that supports coastal resilience.

Number 3
Comprehensive stakeholder engagement and partnering are used to enhance project value.

Stakeholder engagement plays an important – even critical – role in the governance of infrastructure projects. The level investment and sophistication employed in the engagement process directly contributes to the degree of success achieved through the engagement. Early investment in stakeholder engagement should be used to inform the conception and design of a project. Such engagement will provide important information about the values of interest among stakeholders and how those values can be generated by the project, in respect to the three pillars of sustainability. Furthermore, early engagement can help identify project partners who are interested in making contributions or investments toward particular values the project could produce. One example of this strategy is to partner with an NGO to perform ecosystem restoration as a part of the project.

Pursued in this manner, stakeholder engagement can produce opportunities to increase the overall value of a project and to diversify the benefits produced across all three pillars of sustainability. This approach to stakeholder engagement is different than the historical use – which has been more focused on reducing conflicts over project costs – which in the context of this discussion includes the negative impacts – whether social, environmental or economic – associated with a project. For example, stakeholder engagement has been used as a means to proactively engage environmental interests concerned about port infrastructure, flood protection and dredging in order to minimise the risk of project delays and litigation. The information and knowledge that is produced through active and sophisticated stakeholder engagement provides a basis for increasing the overall sustainability of the project. When the information leads to actions that increase overall project value, sustainability is enhanced. When these actions lead to reducing total project costs – including all monetary costs and non-monetary impacts – while producing the same level of benefit, the result is a more sustainable project and system. Likewise, actions that increase project value – in terms of social, environmental, and economic benefits – for the same (or lower) costs, the result is a more sustainable project.

Traditionally, dredging projects have been focused on a single functionality, whether land reclamation, port basins and channels, coastal development, flood protection or pipeline trenches. A design was made and the effects on the environment and other functionalities were assessed and where possible, mitigated and, if needed, compensated. Stakeholders came in late, during the permitting stage, where they were informed but usually not able to influence or change the design. Increasingly, this has led to lengthy procedures and frustration, for the developer as well as stakeholders. Nowadays, more and more projects are developed in a stakeholder-inclusive way. At first, the focus on stakeholders was driven by aims to reduce the risk of project delays and lengthy procedural conflicts, but more recently this approach has evolved to include the mindset of co-creation. In this mode of stakeholder engagement, values are created not only with regard to the prime-intended functionality, but as well with regard to stakeholder interests and values. This approach leads to value sensitive and value added design and responsible innovation, which aims for projects that are beneficial both to business and society. For co-creation to work, an interdisciplinary approach is needed, where from the start of the project there is a broader scope which will be more complex to develop. Ultimately, this approach will also reduce project risks and delays.

Taming nature can be an expensive proposition.

FIGURE 2

Landsat imagery displaying island location of dredged material (DM) placement and subsequent formation, establishment, and growth from strategic dredged material placement from December 2010, 2011 and 2012. Imagery provided by USACE MVN

Horseshoe Bend Dredging on the Atchafalaya River, Louisiana, United States

In 1999, options for managing dredging material from the navigation channel near Horseshoe Bend on the Atchafalaya River near the Gulf Coast of Louisiana, USA were nearly exhausted. Sites for additional wetland creation or upland disposal along the banks of the river were limited. Operations managers and engineers with the USACE decided to use strategic sediment placement as a means of managing the dredged material by placing the sediment – via cutterdredge pipeline – in the middle of the river just upstream of a natural shoal (see Figure 5 and Suedel et al., 2015).

Project engineers expected the placed sediments to be moved by the river to the natural shoal and that these strategically placed sediments would contribute to the formation of an island habitat at the location of the shoal. Beginning in 2002, between 0.4 and 1.4 million cubic meters of sediment were placed in this manner every 1 to 3 years, as determined by the schedule of maintenance dredging. Over the following dozen years, this change in operational practice resulted in the formation of a 35 hectare island that includes a diverse combination of habitats and ecosystem services (see Figure 4 and Suedel et al., 2015).

The USACE Engineering with Nature program has supported studies, including ecological surveys that have documented the rich species diversity and ecological functions (including nutrient cycling and carbon sequestration) provided by the island. In addition, these surveys have revealed evidence that the island is being used for recreational purposes, thus providing social benefits to the local population (see Figure 3 and 4). Strategic placement of the dredged material in the river also avoids the need for transporting the material to the open bay for disposal, which would result in much greater fuel usage and emissions (including carbon dioxide).

In addition to the broad range of environmental benefits associated with the island, the project is also producing practical engineering and economic benefits. As a result of the island's formation, the navigation channel shifted its position in the river from the west to the east side of the river, due to hydrologic influence of the island on the flow of the river (see Figure 2). This 'naturally' realigned channel provides a better, safer transit path around Horseshoe Bend for commercial navigation. The realigned channel has also required less dredging due to more efficient hydraulics and sediment transport in the channel. The USACE estimates that *more* than US$1 million has been saved over the last ten years in reduced maintenance dredging at Horseshoe Bend.

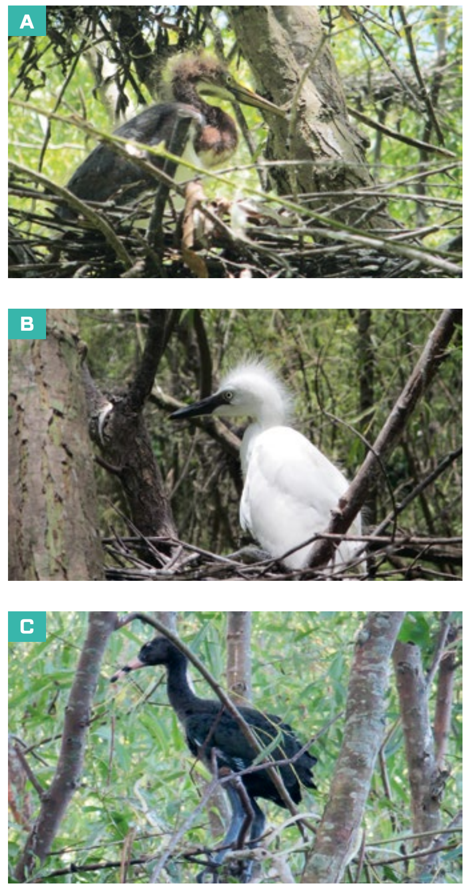


FIGURE 3

A diverse assemblage of native plant and animal life has colonised on the island. During nesting season in July 2014, a juvenile tricolored heron (A), juvenile snowy egret (B) and an ibis chick (C) were observed in nests on the island.

FIGURE 4
Variation in surface elevation on the island supports a mixture of habitats, including ponded areas, emergent wetlands, and forested wetlands that are all influenced to some degree by river stage and duration of flooding.

FIGURE 5
The river island at Horseshoe Bend on the lower Atchafalaya River, Louisiana is being self-designed by dredged sediment strategically placed upriver, allowing the river's energy to disperse the sediment, which contributes to the natural growth of the island. Photo Wings of Anglers

Summary

Three guiding principles are set forth to guide the sustainable development of marine infrastructure projects. For marine infrastructure projects, the importance of vision and value creation, adapting projects to nature from the onset, and viewing a project and its impacts over the long term are key to success. The insights presented in *Dredging for Sustainable Infrastructure* result from a wealth of up-to-date knowledge pooled by a team of practicing industry experts. Written by professionals, the publication's information has been moderated by an Editorial Board. Chaired by Polite Laboyrie from Witteveen + Bos and the Central Dredging Association (CEDA), the board includes Stefan Aarninkhof from Boskalis and Delft University of Technology, Mark van Koningsveld from Van Oord, Marcel Van Parys from Jan De Nul, Mark Lee from HR Wallingford, Anders Jensen from DHI, Anna Csiti from CEDA and René Kolman from the International Association of Dredging Companies (IADC). The principles and case study set forth in this article are foundational concepts in the publication and were authored by Todd Bridges from the US Army Corps of Engineers.

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