THE MDV FISHERY CASE

Circular-sustainability and climate-smart design processes

Fishing vessel MDV-1 represented the design paradigm shift for sustainable North Sea flatfish fisheries. Yet, a design knowledge gap arose when (inter)national climate agreements and socio-political pressure led to new sets of circular sustainability and circular economy requirements. Climate-smart design processes are needed to comply with upcoming circular design drivers 2030/2050 (Rutte III, EU Green Deal, IMO). This requires more of a system design integrator role for naval architects in future-proof socio-technical (agri-food) systems.

Since the innovative MDV-1 was launched (2015) and won the KNVTS Ship of the Year award 2016, two more MDV sister-fishing vessels have been built and twelve follow-up MDV type vessels have been designed and are being built. In the current energy and climate transitions, towards emission-free and fully recyclable, the MDV type newbuilds cannot be cost-efficiently adapted any longer. From the Horizon 2050 perspectives, the MDV too soon became a "design with a promising past". New multiple sustainable system design knowledge had to be developed, a holistic design optimising strategy based on the Dutch fishery (re)design cases (Beamer-2000, MDV-1) and system design methodologies. In agribusinesses, fishermen (and farmers) are constantly confronted with ad-hoc operational/redesign requirements. Today, small and medium enterprises (SMEs) are required to modify their primary capital-intensive goods in circular food value chains, such as fishing vessels (and animal housing/greenhouses).

The new system design challenge is to develop circular-adaptive design concepts, so that designers/SMEs can make the right green choices in early design phases; with limitations of current pieces of green technologies (decarbonisation, re-use/recycling) and emerging green technologies (fossil-free, recyclable materials, robotics). Transition knowledge-based engineering with upcoming circular sustainable design requirements requires smart, modular, flexible and circular-adaptive design approaches. So that in the vessel's lifetime, these designs can easily be adjusted with viable green technologies and SMEs keep positive business models in the long term as well.

A PhD approach started at TU Delft (Prof. Hans Hopman (3mE), Prof. John Stoop (Safety Science); 2017), after two years becoming a co-promotion trajectory with Wageningen University and Research (WUR) as main promotor (Prof. Peter Groot Koerkamp; Smart farming (& fishing)). An obvious step, as at TU Delft there is next to no Dutch beam trawling fishery knowledge and I used to work for RIVO/IMARES-WUR for many years. Besides, at WUR, fundamental knowledge is basically translated into SME applications and/or new government policies (science with impact). This is indispensable to understand the increasingly complex relation between technological and socio-political design drivers. In new climate-smart design

Photo: The MDV-1, once seen as the future of shipping, now a "design with a promising past" (by Flying Focus).

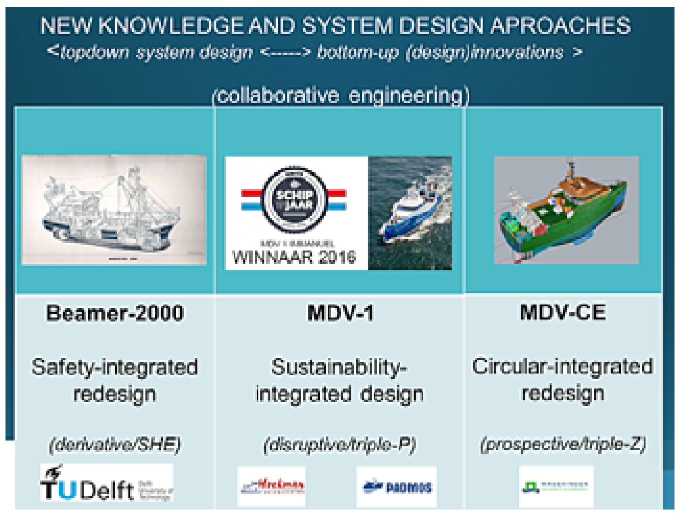
processes, design architects will play a decisive role as system integrators. For a TU Delft trained naval architect (Prof. Constantin Gallin, 1980) it is a challenge to transform maritime, climate-smart design processes into circular food value chain designing.

Beam trawling history and (re)design trigger events

As described in many non-scientific publications [1], the North Sea beam trawling fishery history can be characterised by tradition and innovations, over many generations directed by small-scale, family-owned businesses. The central trigger events are government (re) actions with innovation stimulus/redesign responses (v.v.).
The mother of North Sea beam trawling developments was the Zuiderzee closure (1932) and North Sea bottom trawl gear developments. Regional fishermen had to look for new North Sea fishing grounds, new target species and new fishing methods on board customised side trawlers. The first Urk beamer basic concept arose for deep water flatfish fishing with towed bottom-gears at port and starboard outriggers.
When in the 1960-70s innovative navigational aids, catch processing, cold storage and gear handling equipment became available, the frontrunners could explore fishing grounds further offshore and explore how to land good quality fresh flatfish after one week fishing. Similar to the Zuiderzee fishery culture, one was firstly looking for gear improvements, adapting existing fishing vessels accordingly, in the beginning with poor stability features. The traditional culture was men at sea, competitive towards fellow fishermen with best fresh fish catches and their wives at home, (co-)controlling the SME accountancy and (re)investment plans. At the time, ministerial consultations were regularly held, often by former fishermen.
Together with the development of Urk's fresh fish market and flatfish processing industry, a new North Sea flatfish fishery chain was rapidly emerging (> 1970s). Yet, the daily practice initially concerned short term problems, often neglecting long term issues. Till 2010, beam trawler (re)designing was always subordinate to gear developments. The traditional (re)design drivers were catching flatfish as much as allowed, reducing operational costs with a *mare liberum* approach. For more than fifty years, technological innovations have been very helpful to adapt the basic concept to a maximum extent. However, during the 2008 economic crisis, increased EU technological measures and socio-political awareness, fishermen with ageing vessels were looking for new designs and input of design knowledge, such as first applied in the 1990s (Beamer 2000 safety integrated redesign approaches; [2-3]). At the time, a Task Force Sustainable North Sea fisheries advised the Dutch Ministry of Agriculture, Nature and Food Quality and sector to roll out a government sponsored Visserij-Innovatie Plan (VIP, 2006-2010) and the establishment of Visserij-Kenniskringen (Knowledge Groups). The goal was to enhance practical knowledge transfer, green technologies and sustainable fishing plans.

The MDV design was the major goal and for the first time new fishing gears were subordinate

The Urk Knowledge Group "SMART fishing" focused on more sustainable fishing vessels. Then the bottom-up idea arose to renew



System fishery design cases (1990-2020).

Policy making	**-------------------> nature-inclusive**
1. Paris	Climate conference (2016)
2. IMO	Reduction greenhouse gas emissions (2017)
3. Rutte III	Climate agreements (2018)
4. LNV	Circular farming/fisheries (2019)
5. EU	Green Deal

Targets	**-------------------> design specifications**
1.	2100 global warming 1-2 degrees
2., 3.	2030 CO_2 49% ↓ ; 2050 CO 100% ↓
4.	2030 waste 50% ↓
5.	2050 EU climate-neutral

Climate-inclusive and resilient 21st century.

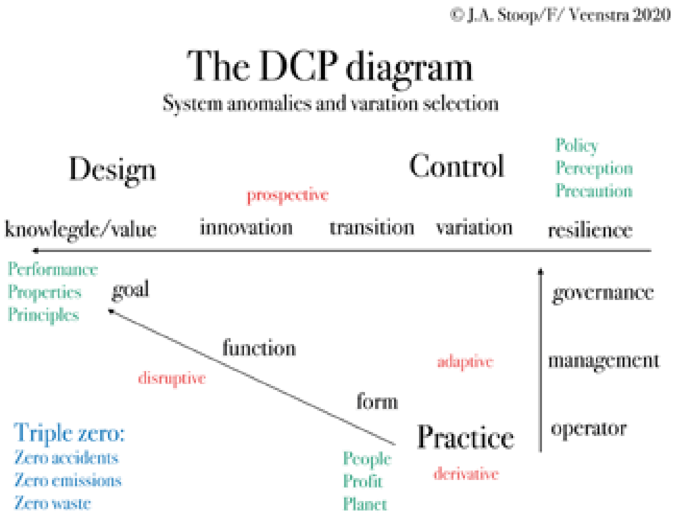
the flatfish fishing fleet with sustainable out-of-the box designs. The foundation Masterplan Duurzame Visserij (MDV, 2010-present) was established. It sought to initiate ecologically and economically sustainable developments in the North Sea flatfish fisheries through the design and launch of a proven sustainable pilot fishing vessel. A disruptive innovation process, because the "thinking outside of the box" MDV design was the major goal and new fishing gears were subordinate for the first time. Although the MDV-1 was the sustainable design paradigm shift for the North Sea flatfish fisheries [4], soon a design knowledge gap arose. The (inter)national climate agreements led to a new set of long term design requirements, which the MDV-type vessels could not cost-efficiently be adapted to any longer.

Sustainable methodologies and holistic design processes

Since the 1970s, the Dutch fishing vessel owners and researchers have been dealing with three major socio-political changes in sustainability transitions. Firstly, single sustainability, focusing on decreasing the number of (fatal) accidents on board (Safety & Health Environment (SHE/Arbo, 1980s), then triple-P sustainability, focusing on the impact of fishery not only on income (Profit), but also on society (People) and the environment (Planet; Corporate Social Responsibility (CSR, 2000). Currently, we are looking for circular sustainability with the focus on climate-neutral fisheries without impacting the ecosystems of the sea and wasting raw materials (Circular Economy principles (CE, 2020)). After the data driven, single sustainable design methodology (Beamer-2000, proof of concept, 1990) and business-goal based driven, triple-P sustainability design methodology (MDV-1, Ship of the Year, 2016), a holistic-value based driven, circular sustainable design methodology (MDV-CE, proof of concept, 2019) has been developed in the PhD framework (2017-present). The single towards multiple sustainability system design shifts have increasingly been approached from the economic, environmental as well as socio-political perspectives, from evidence based to future-proof SME business goal based.
In the case of the sustainability transitions towards safer ships (1980s), for the first time human values had to be accounted for in the maritime design spiral (Gallin, 1970s). Personal safety and well-being aspects were explicitly integrated: the safety system problem solving methodology ([2], Kindunos, 1990s). This created a maritime design shift by integrating hard and vague requirements in a systematic way and dynamic socio-technical systems. A benchmark was created for further integration of multiple sustainability aspects and holistic design drivers (2017).
An increased demand for design knowledge was needed to find answers to the new socio-political realities and to integrate and provide connection, links and alignment with multi-actor combinations and perceptions of the general public/NGOs. Linear transitional design processes evolved from craftmanship (1930/50s) through mechanisation and upscaling (1960/70s) towards industrialisation and more design aspect optimisations (1980/90s) are currently inadequate with a too limited 3D (re)design scope.
The maritime (and agribusiness) sector must also deal with multi-space use and biodiversity production issues, reconsidering their mono-value chains on food value chain design levels. A new multiple actor design methodology had to be developed, originating from cross engineering domains such as mechanical (Van de Kroonenberg [5]), aircraft (Vincenti [6]) and safety systems (Stoop [2]). In addition, WUR scientists developed the Reflexive Interactive Design process (RIO, 2008 [7]), involving multi-actors, including animal welfare in sustainable animal housing concepts.
But traditionally, the shipping industry works with basic design concepts, modifying them as long as possible. Before outstretching these "parent vessels" into unacceptable "grandparent vessels" with additional operational and safety risks, it is time for new design knowledge with clear multiple sustainability targets. For this, new triple-Zero design indicators have been determined: Zero accidents (SHE), Zero emissions (CSR) and Zero waste (CE). The best way to predict the future is to design it, controlled by design architects with insight (users, culture), oversight (designers, system design processes) and foresight (administrators, future-proof business models).
In addition, the triple-P key design drivers have been upgraded into three dimensional triple-P drivers, integrating business design perspectives (People, Planet, Profit) and socio-politic design perspectives (Policy, Perception, Precautionary) as well as designers' per-

MDV cases	Task-specific	Artefact	Predetermined purpose
Beamer 2000	Single sustainability (personal safety & well-being (SHE))	Redesign fishing vessels & equipment (flatfish beam-trawling, 90s)	Improving personal safety through systematic problem solving approach, evidence-performance based & human, economy impact factors on sustainable North Sea flatfish fisheries
MDV-1 2015	Triple-P sustainability (people, planet, profit, CSR)	New design fishing vessel & equipment (flatfish twin-rigging, 2008)	Co-designed positive business models, functional properties based & human, economy and ecology impact factors on sustainable North Sea flatfish fisheries
MDV-CE 2020	Circular sustainability (Circular Economy principles, CE)	New concept design fishing vessels & climate-inclusive equipment (new flatfish bottom-gears, '20)	Foresight variation selection modelling, socio-value principles based & human, economy, climate, socio-values and geo-political impact factors on sustainable North Sea flatfish fisheries

Sustainable flatfish fishery design methodologies, 1990-2020.



The Design-Control-Practice diagram contains all holistic design drivers.

spectives (Performance, Properties, Principles) with the triple-Zero targets as a circular-adaptive design integrator. All holistic design drivers are shown in the Design-Control-Practice diagram (DCP) with three group-specific system variables, namely for users (Practice: people, planet, profit performance indicators), for administrators (Control: policy, perception, precautionary value chain indicators) and for designers (Design: performance, properties, principle design indicators). It is the revised role of the naval architect to communicate and coordinate these variables across their boundaries. Complex design variation selections require synthesising solutions in order to establish a shared solution, based on the credibility, feasibility, compatibility and selection of preferred alternatives in order to create consensus among all multi-actors involved in accepting the solutions. Then complexity is defined as the interdependences of values, variables, choices, design assumptions and modelling simplifications.

To support the circular fishing vessel transition process, in addition a new designer's tool has been developed, the Circular Economy value Design Index (CEDI). This was done because existing design tools, such as EEDI and LCA, do not integrate all the CE key design factors. The CEDI is not a blueprint, but a design tool to assist ship designers and skippers in making the right green technology choices in an early phase of the design process [8]. To what extent can emerging non-fossil technologies, recyclable materials and automated/robotic fish processing equipment be cost-efficiently applied in the MDV type vessel's lifetime?

Design indexes in shipping
Environmentally sustainable algorithms

EEDI: gramme CO_2 per tonne-nautical mile (ß)
LCA index: (material) eco-impact in vessel lifetime (ß & y)
CEDI: all-circular economy principles (ß, y & α; © F.A. Veenstra 2018)

Maritime design indexes, (SME) supportive design tools.

Innovation and sustainability performance foresight

Since the 1980s, EU, national and since 2000, NGO/public perceptions have become major (re)design change drivers, upon which the sector responded with innovative technologies, to which the government responded with restrictions, and so on. This ended derivative component optimisations (end of basic concepts, Beamer-2000) and the disruptive design optimisations were blocked early (new CE-regulations; MDV-1).

Now, circular adaptive concepts (MDV-CE) are needed, which can be transitionally/cost-efficiently modified in the vessel's lifetime towards the Horizon 2050 sustainability goals.

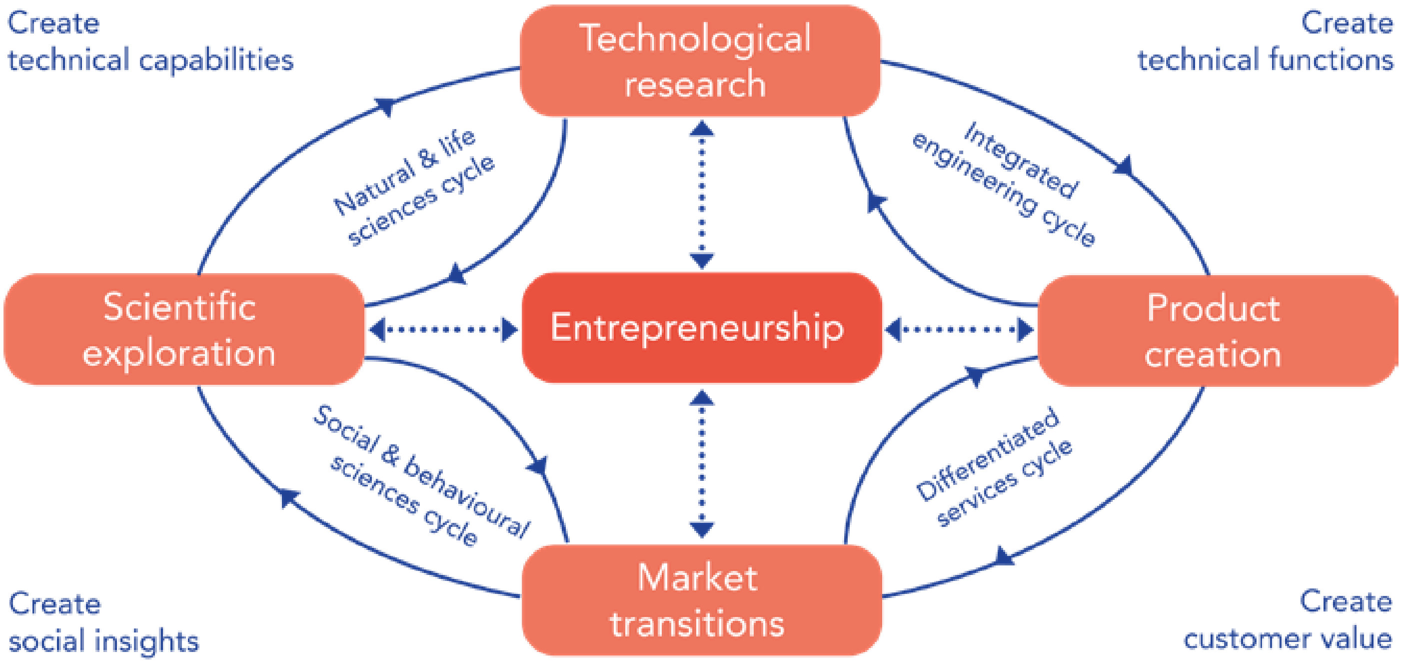
Three-dimension modelling concepts obviously have a more system integrating role for design architects. They are to guarantee the dynamics between multi-stakeholders and system design processes, based on holistic system variables and value change agents as described in the MDV fishery cases.

To further understand successful CE-design innovations and sustainability performance foresights, it makes sense to look at other science domains as well. Both to test if the MDV design variables match essential variables in other science theories and if system design variables are missing. Based on design knowledge literature reviewed (1920-2020) and stimulating system design discussions with prof. John Stoop, two scientific theories have been found, which could be supportive. Firstly, in the consumer commodi-

> The best way to predict the future is to design it with insight, oversight and foresight

Essential variables for successful MDV (ship)innovations	Technology (1)	Business (2)	Markets (3)	Science (4)	Circular-Adaptive (CA)	Technology Readiness Level (TRL)
Beamer -2000 concepts	x (existing)	- (ST)	-	x	-	1 - 4
MDV-1 new design	x (proven)	x (MT)	-	x	-	4 - 6
MDV-CE transition concepts	x (semi-proven)	x (LT)	x	x	x	6 - 8

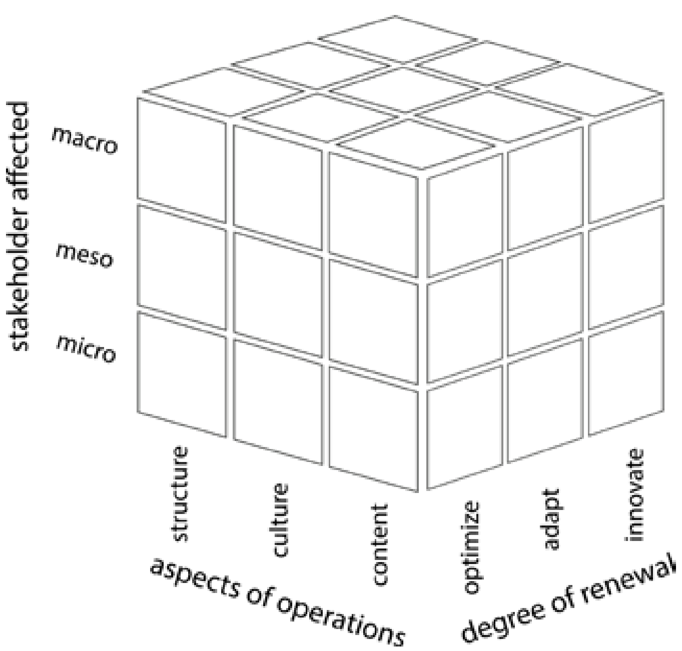
Fishing vessel change drivers with success factors (CIM 1-4) plus CA/TRL, 2.0/fv/August 2020.



CIM modelling, Berkhout, 2007.

MDV-CE ESReDA review	Multi-stakeholders	Operational actors	Renewal
1st level	Micro: fishermen/SME	Culture: tradition	Optimising: performance
2nd level	Meso: business models	Content: capital intensive goods	Adapt: functional
3rd level	Macro: licence2fish	Structure: value chain	Innovative: principles

Fishing vessel design variables in Esreda cubic system framework 1.0/fv/20 June 2020.



ESReDa cubic 2.0, 2019.

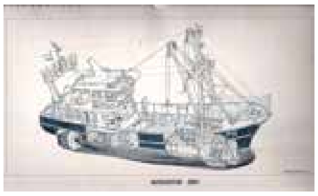
ty domain, Berkhout et al developed a Cyclic Innovation Model (CIM, 2007 [9]) and secondly, in the system safety investigation domain, Stoop et al are developing Foresight ESReDa cubic modelling (2019 [10]). Both models identify and communicate about all essential change variables and change drivers in complex and dynamic socio-technical systems.

The CIM model is an iterative process with four major change drivers, comparable to the iterative maritime design spiral and PhD used sustainability design drivers. The business focus is on productivity chains while markets concern product (quality) developments. The CIM model appeared to be a supportive communication tool for innovative system designing as well, for better understanding of the dynamics between multi-stakeholders and potentially successful innovation factors, preventing too many Valley-of-Death product development (business) cases.

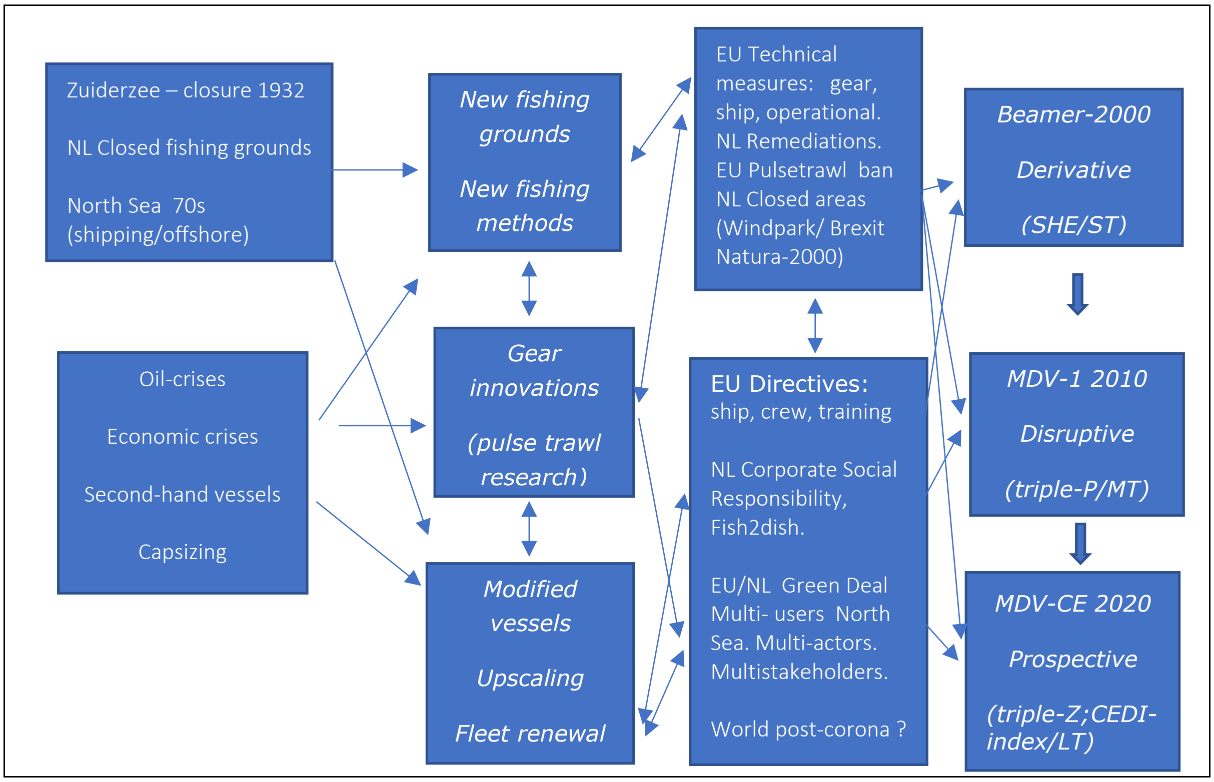
Indeed, the 3D ESReDa model can be used as a tool to demonstrate and communicate feasible, credible and plausible system changes and adaptations. From a system designer's point of view, it is to better aim and integrate all essential design variables, including hard and vague requirements. This model explores links between multi-system design components in a systematic design way to gain foresight in the designer and SME search for multi-sustainability optimisations and reduction of business uncertainties in the long run.

INFOGRAPHIC BEAMTRAWLING GEAR DEVELOPMENTS AND SHIP (RE)DESIGNING 1970 -2020

5.0/fv Frans Veenstra PhD WUR-TU Delft/ June, 2020



ACTION	REACTION	ACTION	REACTION
LNV/Shipping-Inspectorate/IMO	SECTOR/RIVO	EU/LNV/NGO	TU DELFT-IMARES/SECTOR
rules & regulations (policy makers)	*users + applied science* *(co-creation)*	rules & regulations (public perceptions)	*design scientific knowledge* *(multi-disciplinary)*



1930 -------------> 1970 - 1990	1970 - 1990	1990 - 2020	2020 -----------> 2050
Zuiderzee North Sea	North Sea	North Sea	North Sea Food Chains
New fisheries	*Gear developments* *(Trial & Error approach)*	*(Re)designing* *(Integral system approach)*	*dual TRIPLE-P designing* *(Smart, modular & flexible)*
	Product -----------> *(gears/basic-concepts)*	Product -------> (ships/Δ basic-concepts)	*Means of Production in Circular (Fish)Food Chains* *(ships/transition concepts)*

4.0/fv/May 13, 2020

Side-trawler1960

Beamtrawler 1980 - 2020

MDV-type twin-rigger 2015 -2020

Through intertwining all change agents and change drivers, the design process can be made clear with multi-stakeholders', operational and renewal perspectives on three levels. The cube pictures the complexity and dynamics of modern socio-technical systems and is able to indicate foresight potentials for future-proof business models. The ESReDa safety investigative approach appeared to be a supportive tool for system design architects as well. All design aspects can be addressed. This helps to better understand, discuss and show all the essential variables and to weigh major and minor design aspects in successful sustainable system designing, in particular for new business developments in the near future.

Future-proof markets require transitional thinking

Post-PhD and post-corona research recommendations

Finally, it may be concluded that in about thirty years' time, fishery design developments, the two-dimensional Kindunos (safety integrated design process,1990) and the 3D ESReDa variables (foresight safety performance modelling, 2019) have strongly contributed to system design thinking in the Dutch fisheries.

Both system design theories have strongly contributed to knowledge based engineering towards sustainable industrial fishing with firstly focus on the human aspects (SHE), then the environmental aspects (CSR) and thirdly on circular value chains (CE). The system design developments have gone from successful derivative designing (Beamer-2000 concept) via successful disruptive designing (MDV-1, Ship of the Year) to scientific prospective designing with practical adaptive applications (MDV-CE concept). Based on these scientific system design methodologies, new North Sea use business strategies with currently intended climate-neutral food value chains can be better dealt with. These strategies take into account multi-offshore businesses with their conflicting interests, governmental precautionary principles and in particular socio-political perceptions as given in the DCP diagram and foreseen in the recently established "Maatschap Triple Zero" with sustainable design strategies (Stoop, Veenstra; circular sustainable and post-Covid (re) design strategies).

Instead of traditional management thinking with focus on a purely physical product, future-proof markets require transitional thinking into capital-intensive means of production in circular food value chains with viable return of investments through new North Sea business models. Multi-use North Sea discussions have a tendency to close more fishing grounds, could this even be a fully bottom-trawl fisheries ban and/or general fleet buy-out?

New North Sea fish-food value chains and complicated, "mixed" business models are becoming imminent; not only in "mixed" fishery operations (new fishing cum-sea farming) but also in "mixed" use of North Sea spaces (fishing, wind, natura-2000, transport). The fishery system boundary is becoming the "fish2dish" value chain, at which multi-design and space aspects must be fully taken in consideration, in socio-economic, socio-ecological and socio-technical context. By doing so, system boundaries are not physically exclusive activities, but indicators for specific values in shared and resilient spaces (resilience engineering [11], self-explaining roads [12]).

Ir Frans Veenstra
Former seafarer, naval architect and technical fishery researcher, currently MDV fishery innovation manager, Senior PhD WUR-TU Delft and partner in Maatschap Triple Zero, veenstrafishco@gmail.com

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