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Submerged Floating Tunnels
and
The largest infrastructure project in Norway…Ever…

Mathias Egeland Eidem mathias.eidem@vegvesen.no /Arianna Minoretti arianna.minoretti@vegvesen.no

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Coastal Highway Route E39

Kjersti Kvalheim Dunham
Norwegian Public Roads Administration

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Norwegian Public Roads Administration

The current E39

- E39 Kristiansand-Trondheim
  nearly 1100 km, including 7 ferry connections
- E39 ferry connection Kristiansand-Hirtshals
- Aalborg: The E39 joins the E45 which continues to Italy

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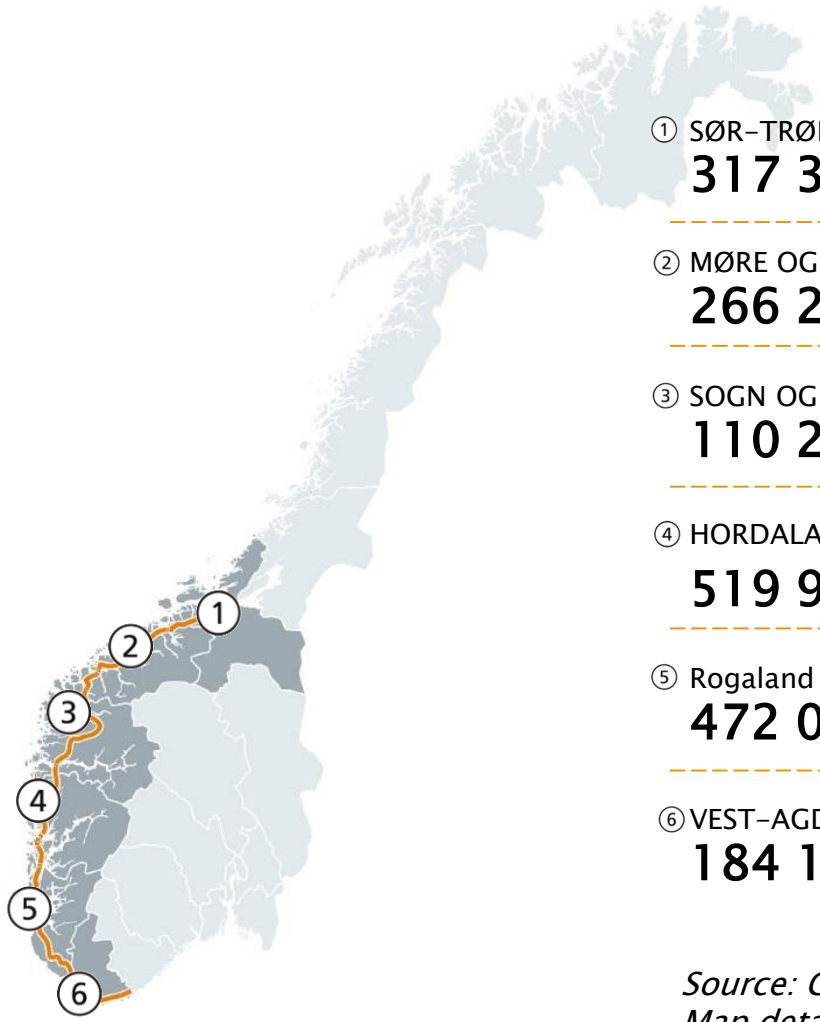
Facts about the counties along the E39

Inhabitants as of 1 Jan 2017

- 1/3 of the country's population
- Approx. 60 % of our export value



① SØR-TRØNDELAG
317 363

② MØRE OG ROMSDAL
266 274

③ SOGN OG FJORDANE
110 266

④ HORDALAND
519 963

⑤ Rogaland
472 024

⑥ VEST-AGDER
184 116

Source: Central Bureau of Statistics (SSB)
Map details: Norwegian Mapping Authority

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The E39 Coastal Highway Route

Challenging fjord crossings

Fiord	Length (km)	Depth (m)
Halsafjorden	2	5-600
Julsundet	1.6	5-600
Romsdalsfjorden ★	16	330
Sulafjorden	3.8	500
Vartdalsfjorden	2.1	600
Nordfjorden	1.4	500
Sognefjorden	3.7	1250
Bjørnafjorden	5	5-600
Langenuen	1.3	500
Boknafjorden ★	27	390

★ = subsea tunnel

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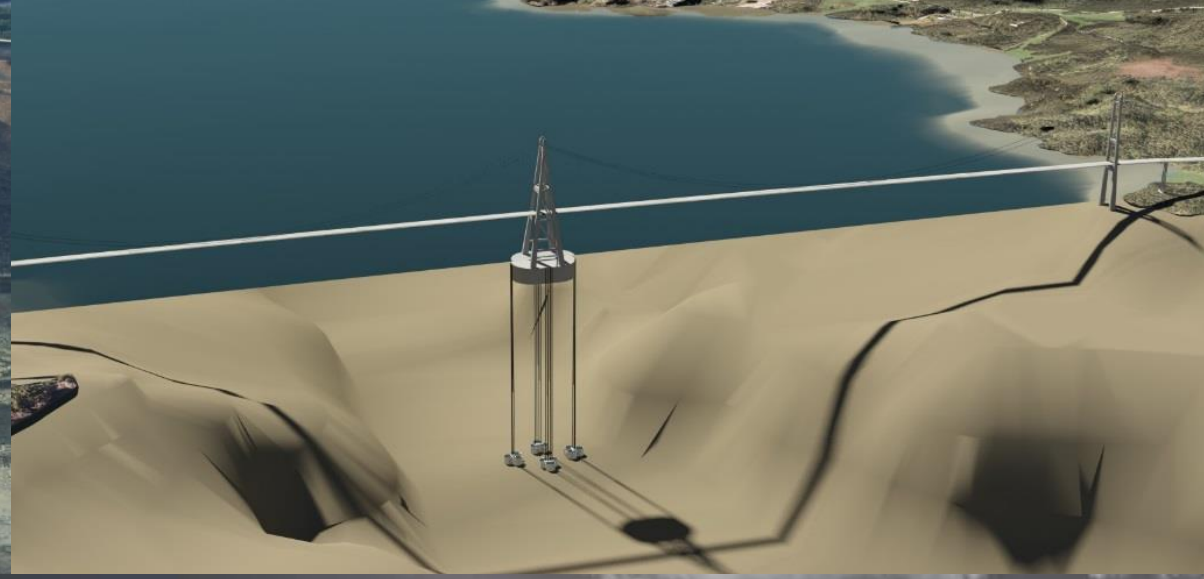
An improved and continuous E39 – what does that mean?

- **Open road 24/7**
  7 ferry connections removed
- Travel and transport time reduced from 21 hours to **11 hours**
- **New solutions** and new competence
  - Similar bridge solutions have never been built before

Illustration: Baezeni/NPRA



RAMBØLL

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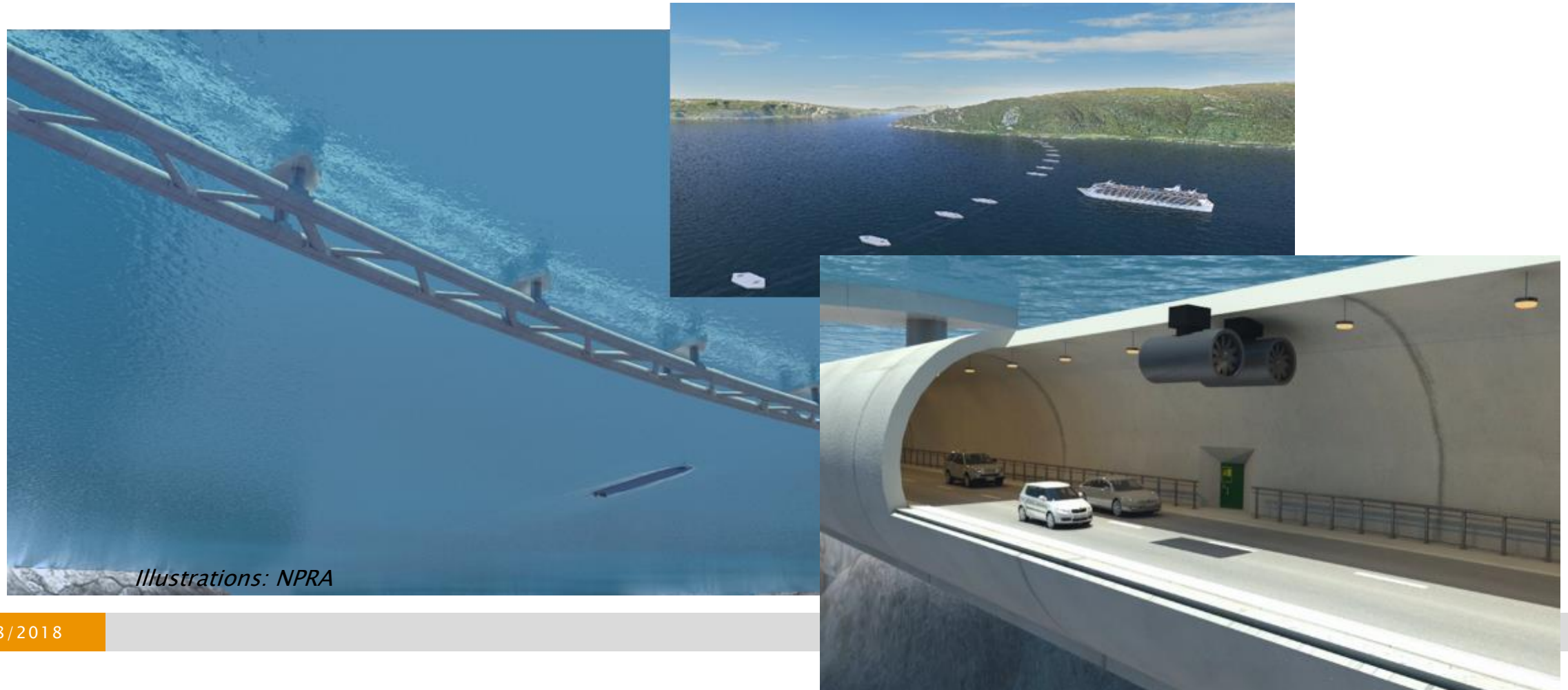
Submerged floating tube bridge anchored to pontoons on the surface



Illustrations: NPRA

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Knowledge helps reduce the cost and find better solutions!

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Technology days October 30th–November 1st 2018
Clarion Hotel and Congress, Trondheim

Bridge constructions and Impacts on Society

- https://www.vegvesen.no/Teknologidagene

Programme Manager Kjersti Kvalheim Dunham

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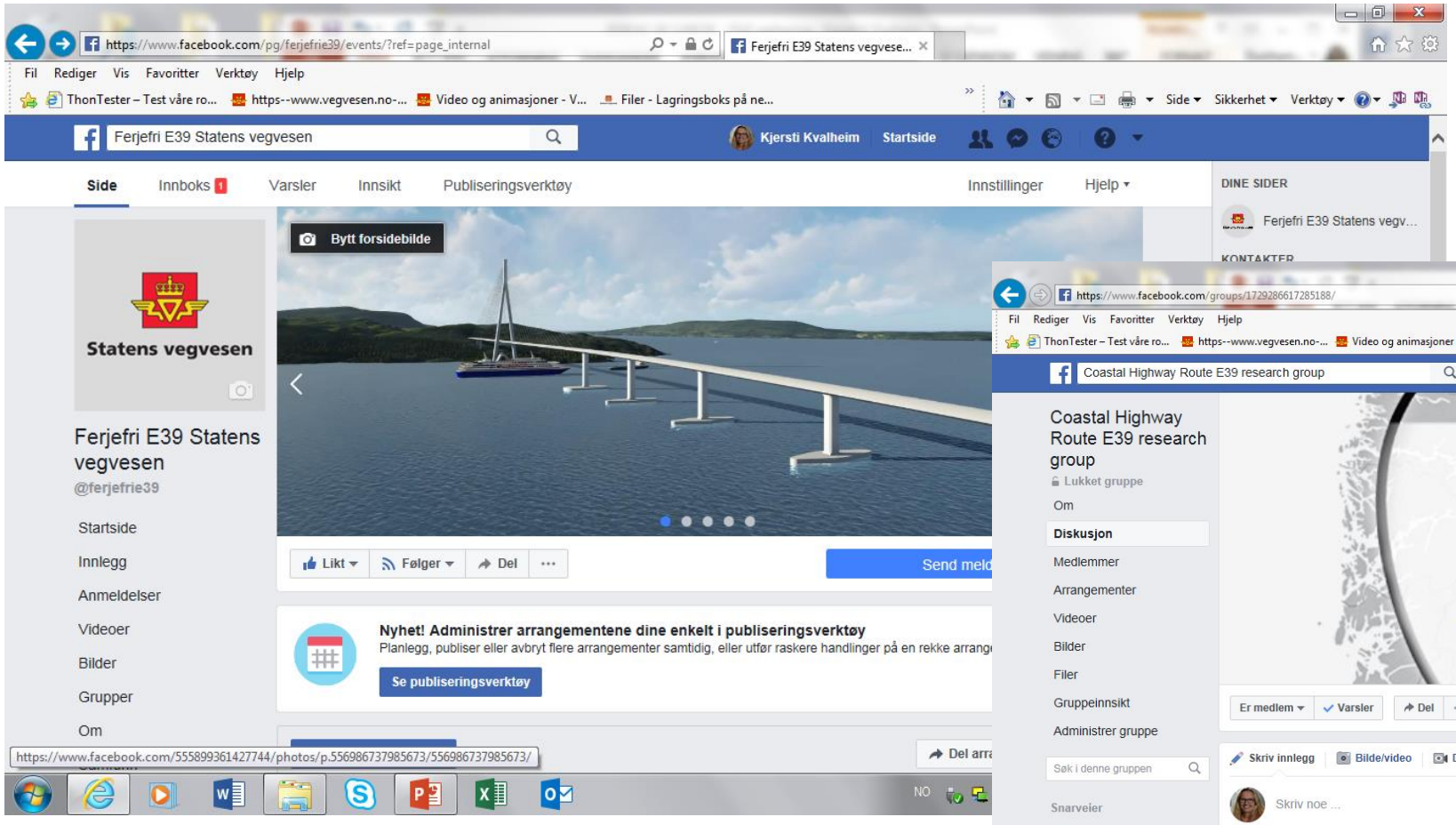

- The Coastal Highway Route E39

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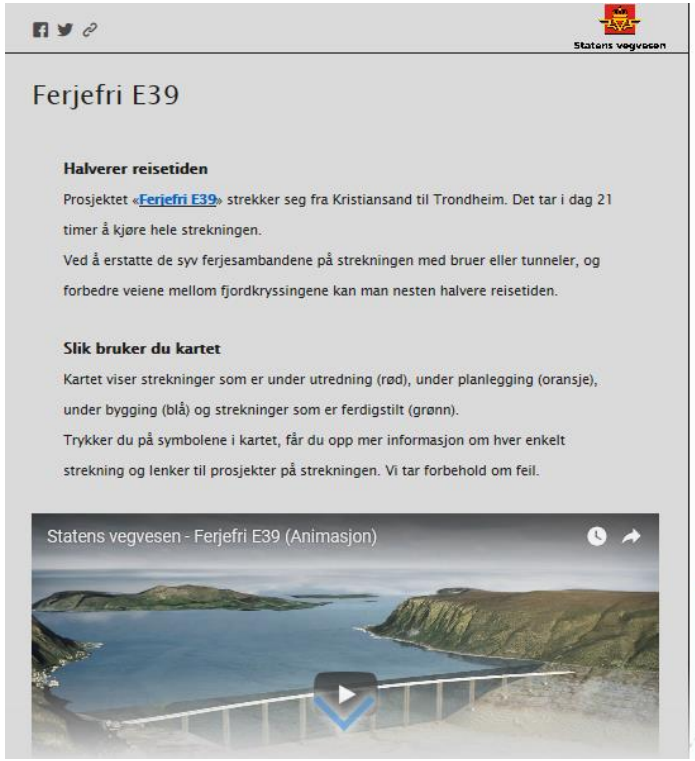
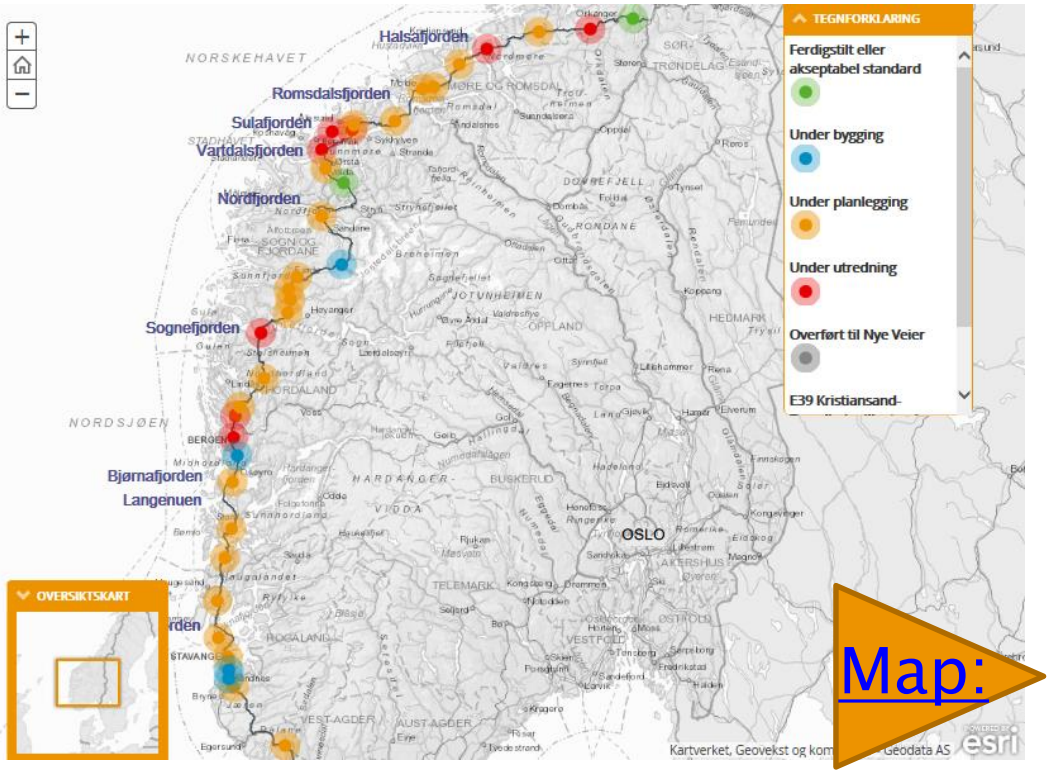
Interactive map with information on status and progress





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THANK YOU
FOR YOUR ATTENTION!

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Hilsen fra

Styret i NFF

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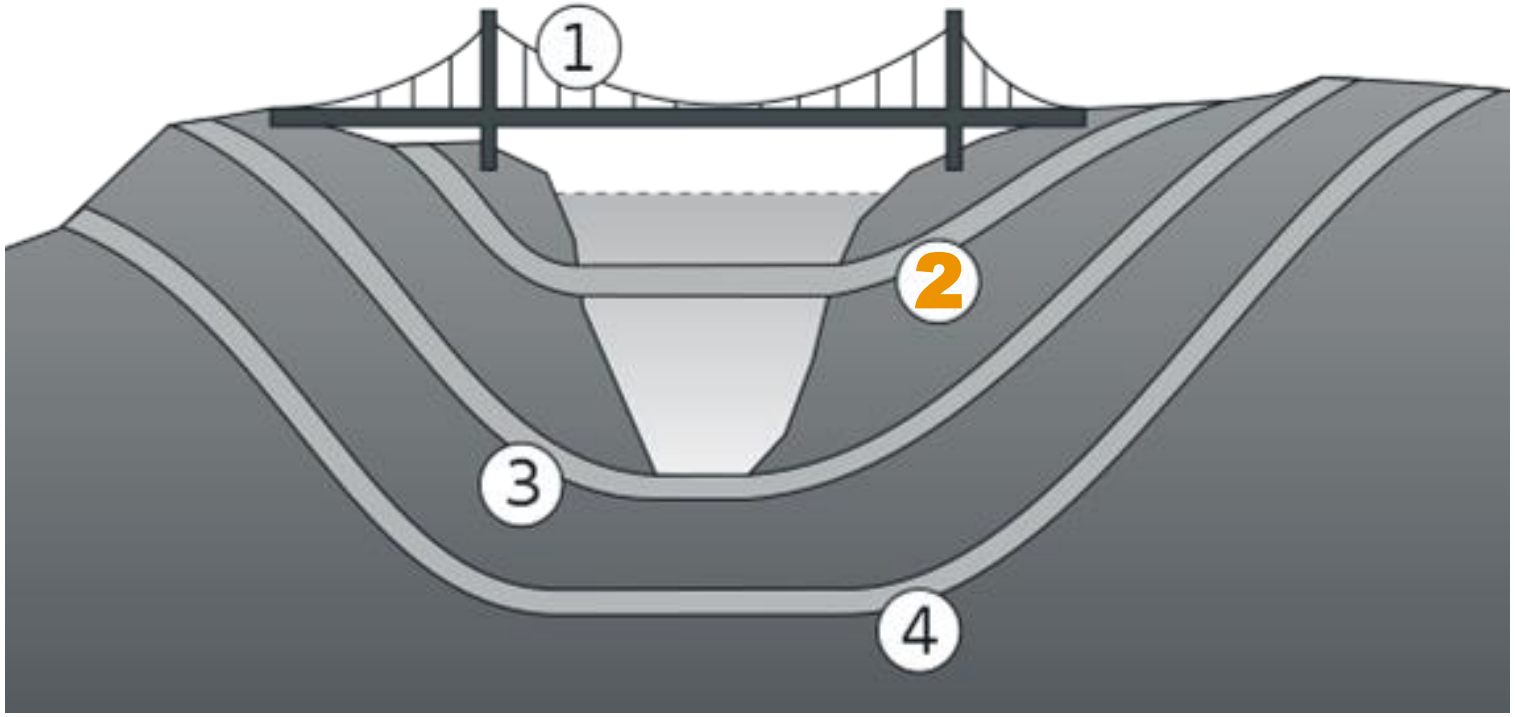
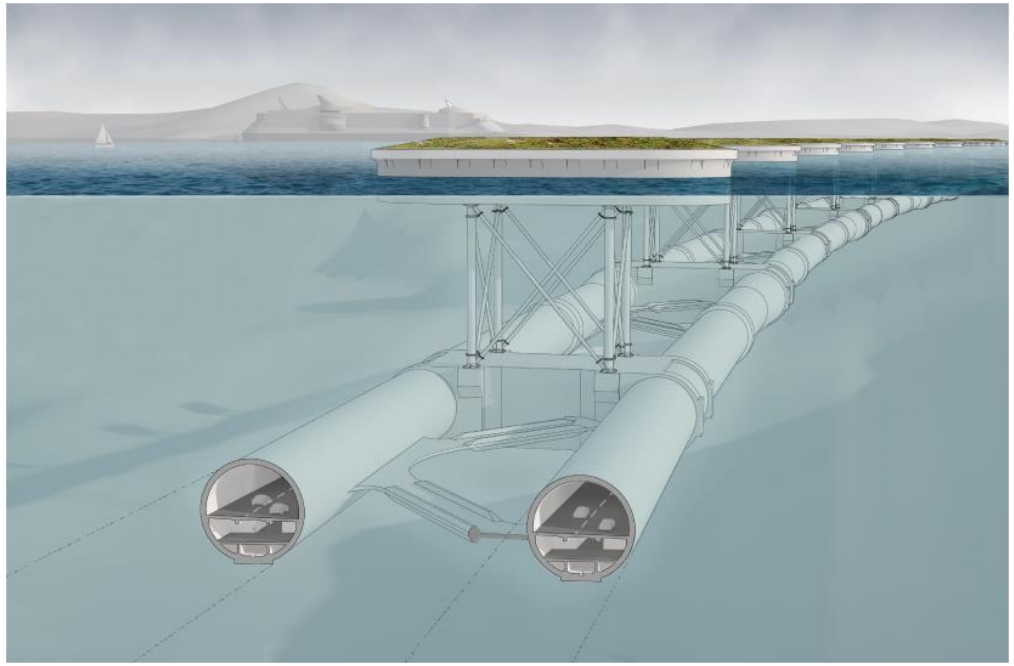
What is a Submerged Floating Tunnel(SFT)?

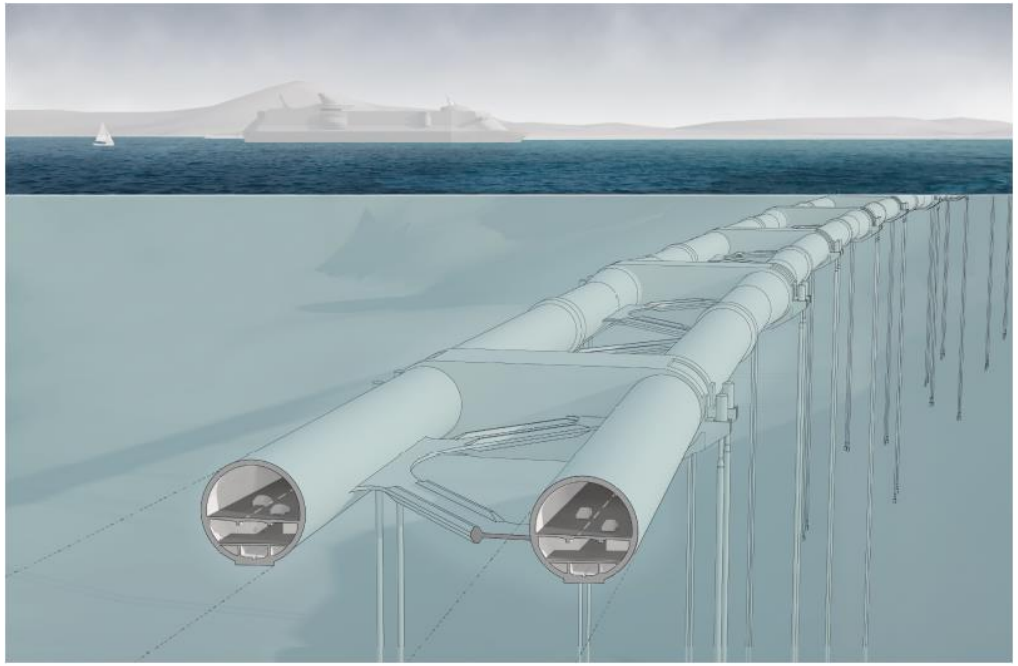


1. Bridge
2. Submerged Floating Tunnel (SFT)
3. Immersed Tunnel (IT)
4. Rock Tunnel/Bored Tunnel

Vertical stabilization



SFT with pontoons – NPRA



SFT with tension legs anchoed to the seabed – NPRA

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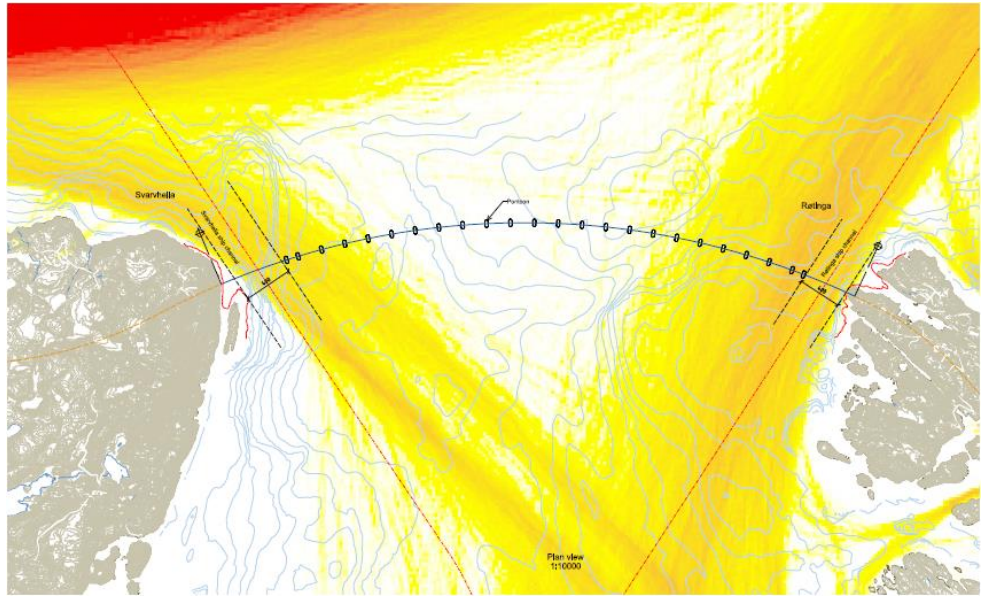
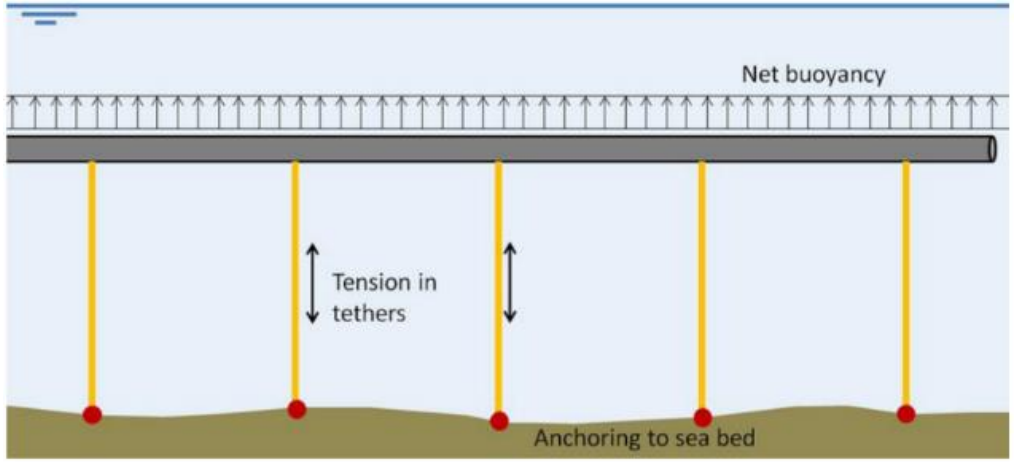
Pontoons: Pros and Cons



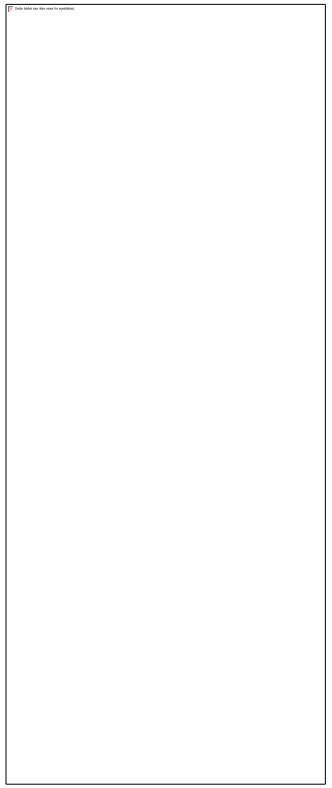
Estimated ship routes for the Bjørnafjord – NPRA

Proposal for pontoons as «floating islands» – NPRA

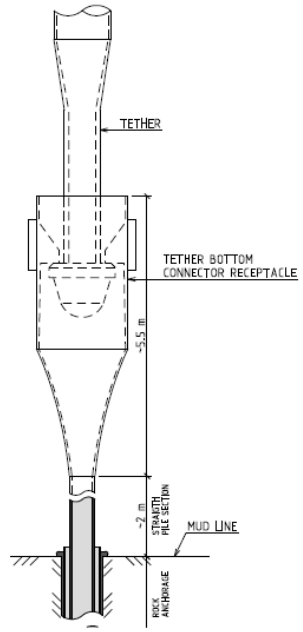
Tension leg anchoring: Pros and Cons



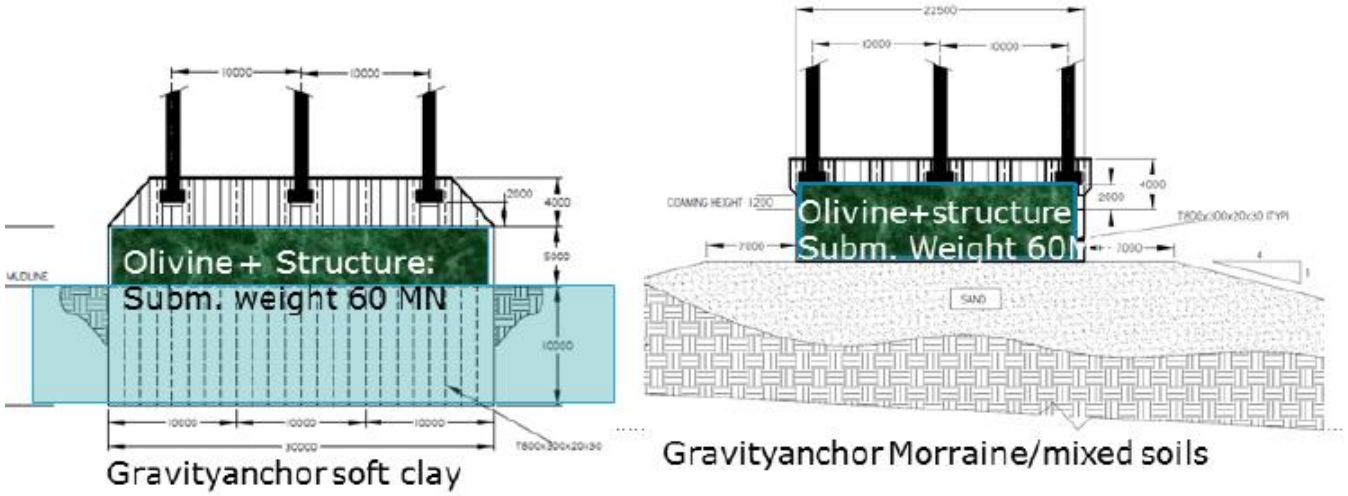
Load bearing principle of tension leg anchored SFT – NPRA



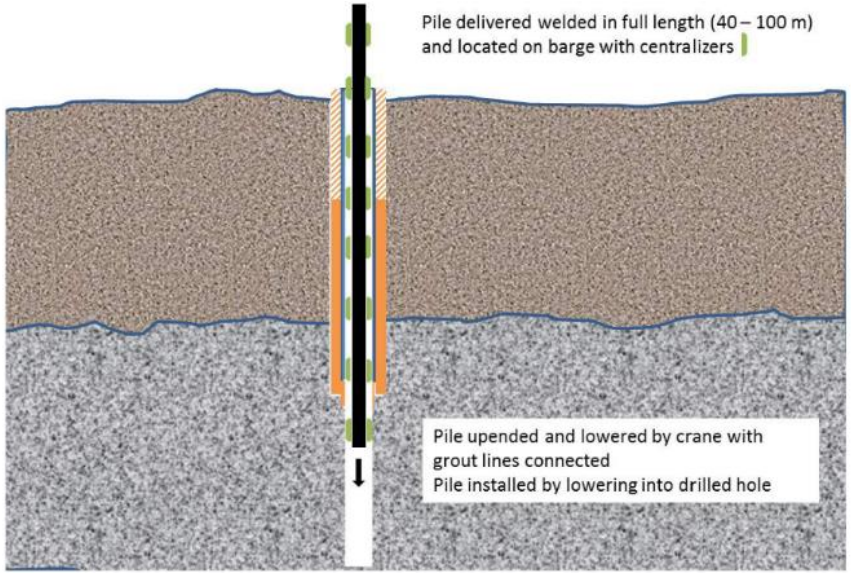
Tension Leg – NPRA



Foundations for tension legs



Gravity/Suction based anchores- NPRA

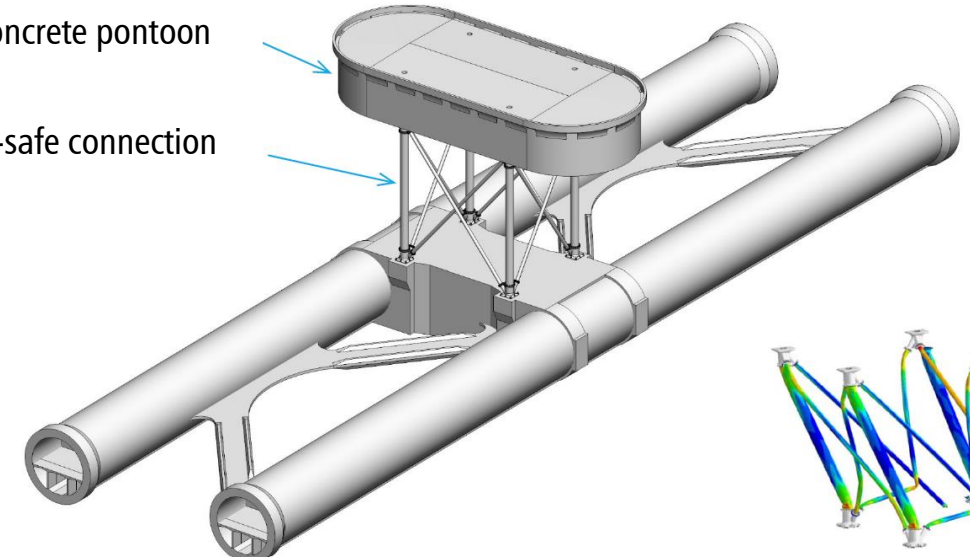


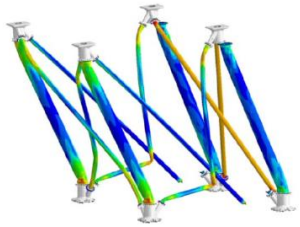
Rock anchores - NPRA

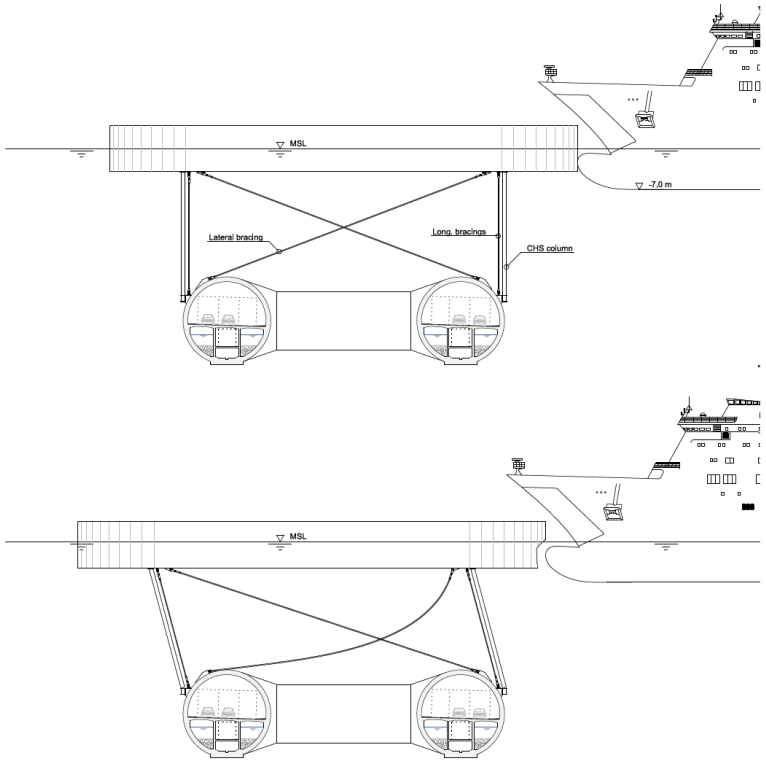
Ship Impact

Concrete pontoon

Fail-safe connection







Principle of fail safe connection for a pontoon subjected to ship impact

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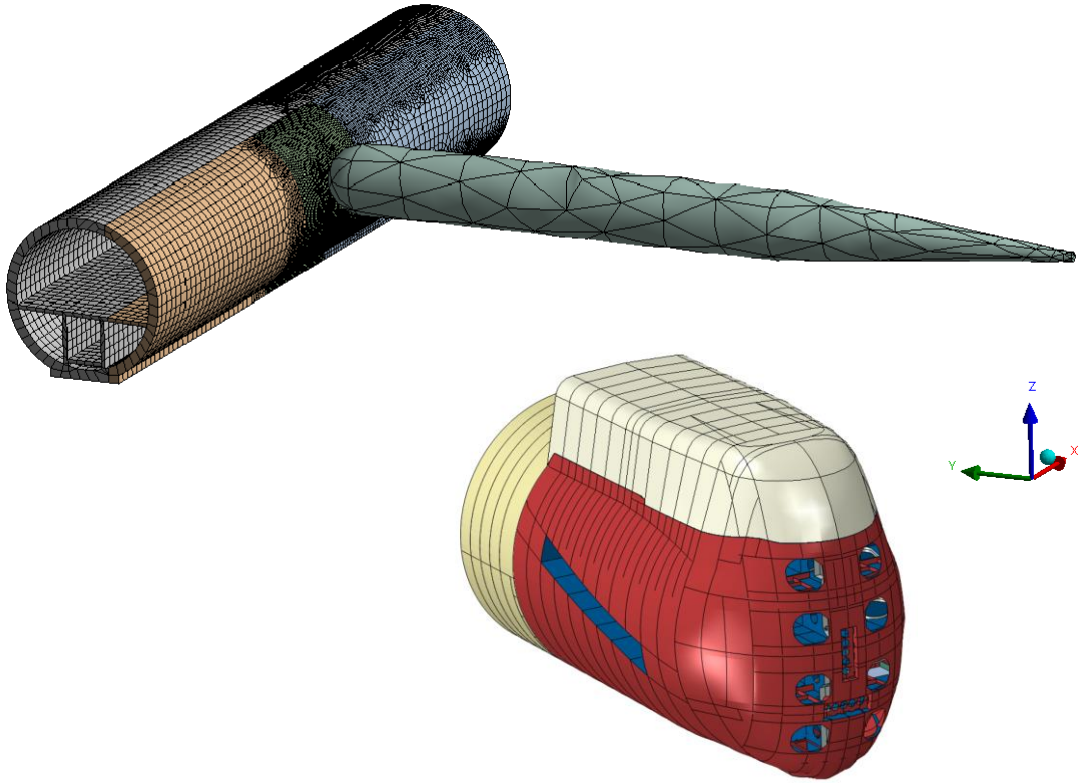
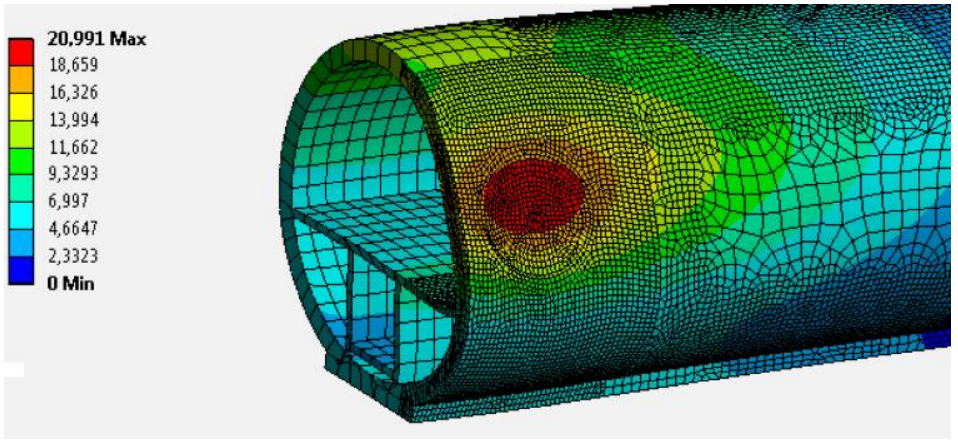
Submarine impact



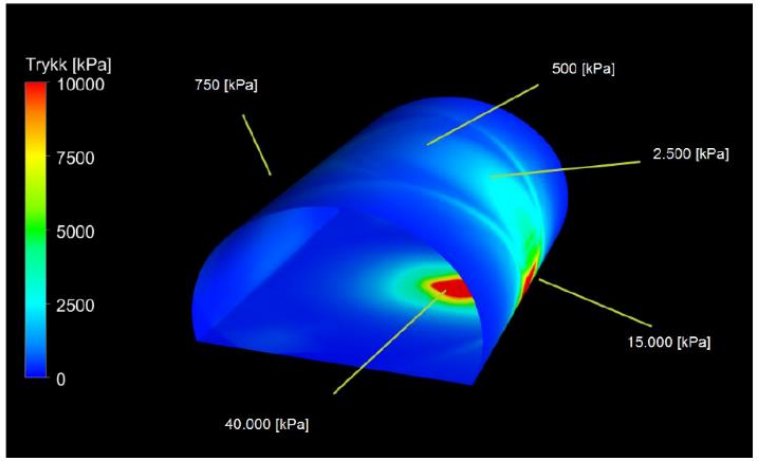


FEM model for submarine impact on SFT – NPRA

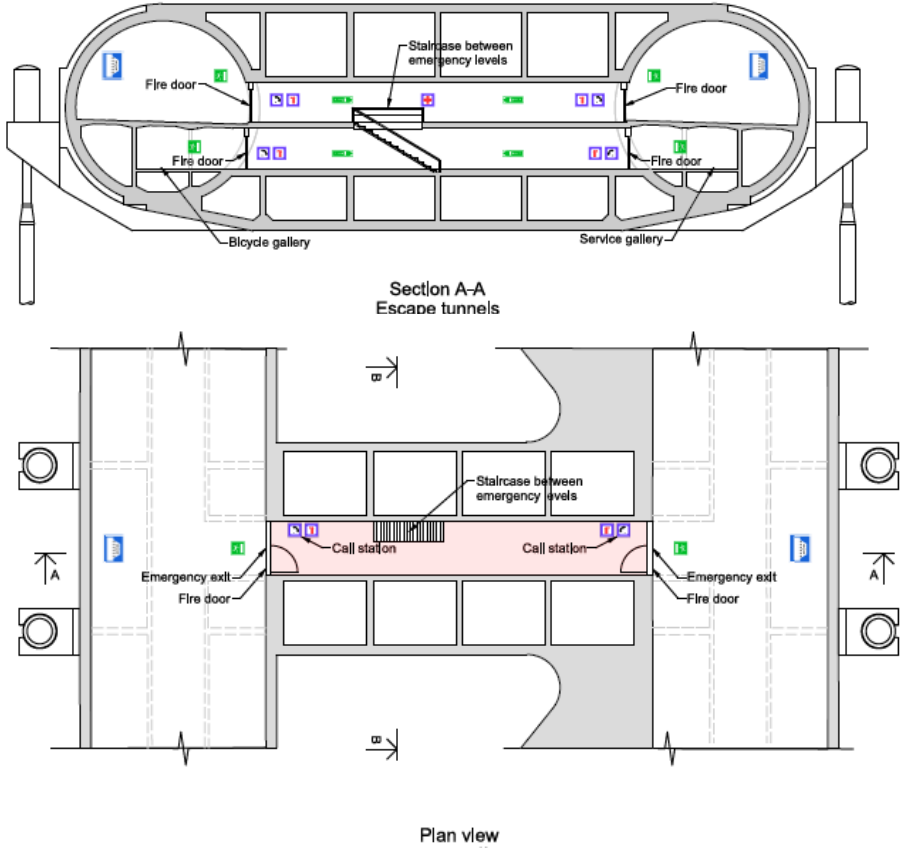
Fire and explosion

Fire:
NPRA handbok designload: 300 MW for 2 hours

Explosion :
Gasseksplosjon most likely
Designload: 300 kPa



Max pressure from TNT detonasjon



Escaperoutes in the SFT – NPRA

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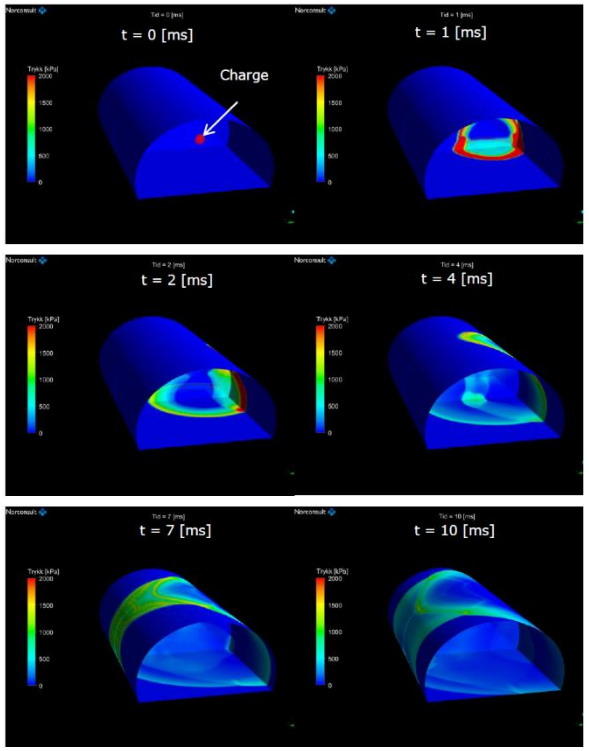
Robustnes:
– The structures ability to withstand the unexpected

- Skipskollisjon med en pontong
- Øyeblikkelig tap av en pontong. Full trafikkbelastning
- Sinkende skip som treffer rørene
- Eksplosjon i rørene i kombinasjon med andre belastninger
- Oversvømmelse i et av ballastkamrene
- Tap av et strekkstag



TNT detonation in the tunnel.

arianna.minoretti@vegvesen.no

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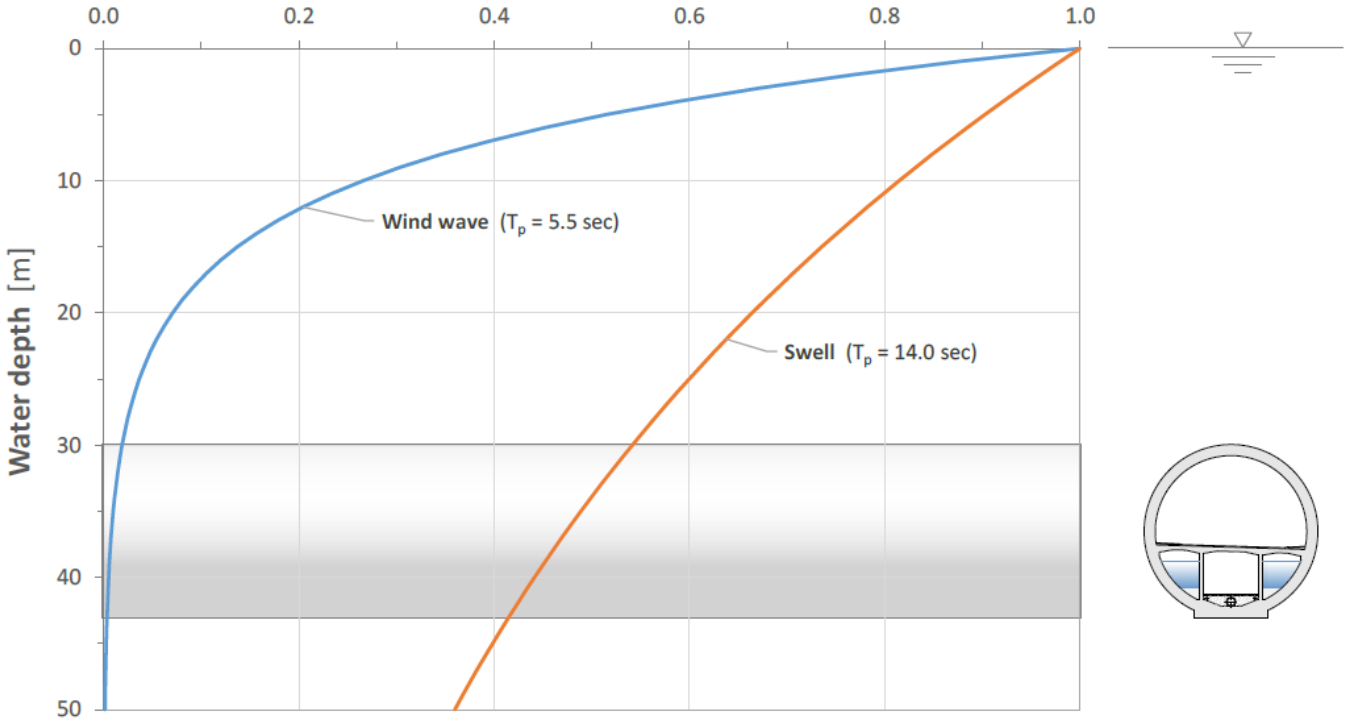
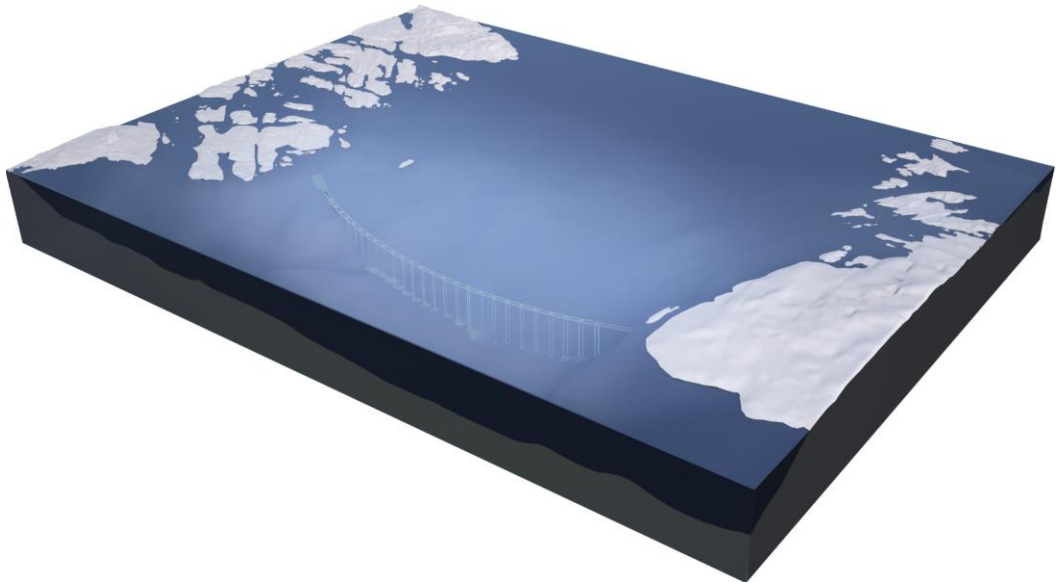
Natural reduction of wave loads



Zero downtime due to weather!

Waveloads depending on depth(normalized) for the Bjørnafjord – NPRA

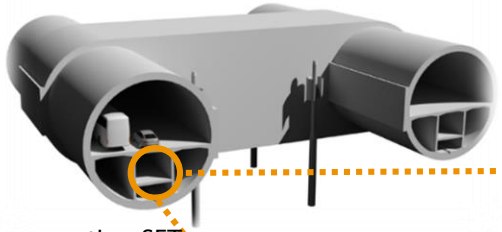
Landscape and noise



A teathered solution is invisible – NPRA

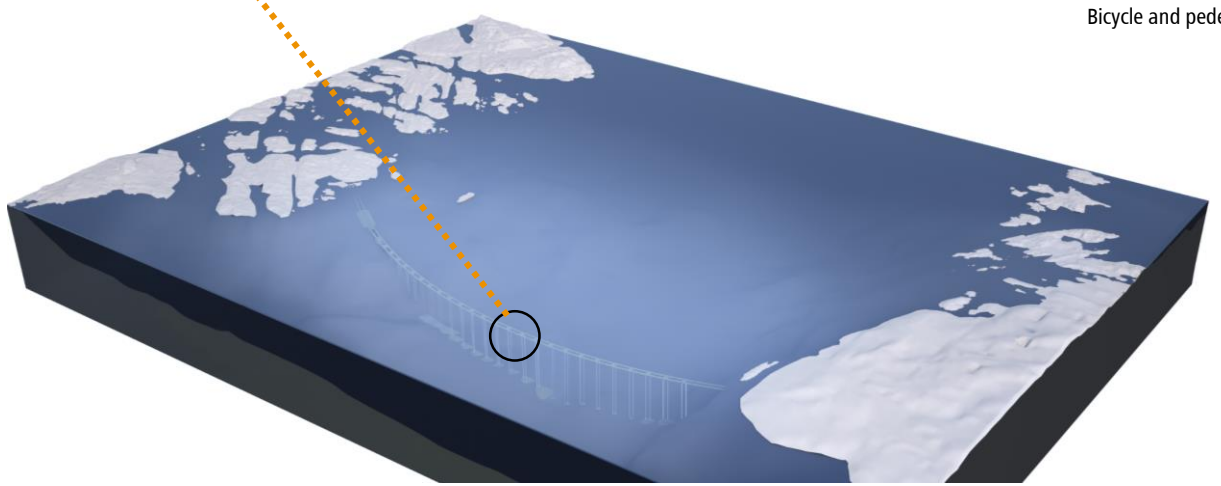
A pontoon solution is visible, but still free from noise pollution – NPRA

Bicycle and pedestrian path?



Cross-section SFT

Bicycle and pedestrian path in SFT - NPRA



SFT for the Bjørnafjord – NPRA

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Why has an SFT not been buildt yet?

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Feasibility study:

Høgsfjord-crossing

Sognefjord-crossing

SFT for crossing the Sognefjord - NPRA

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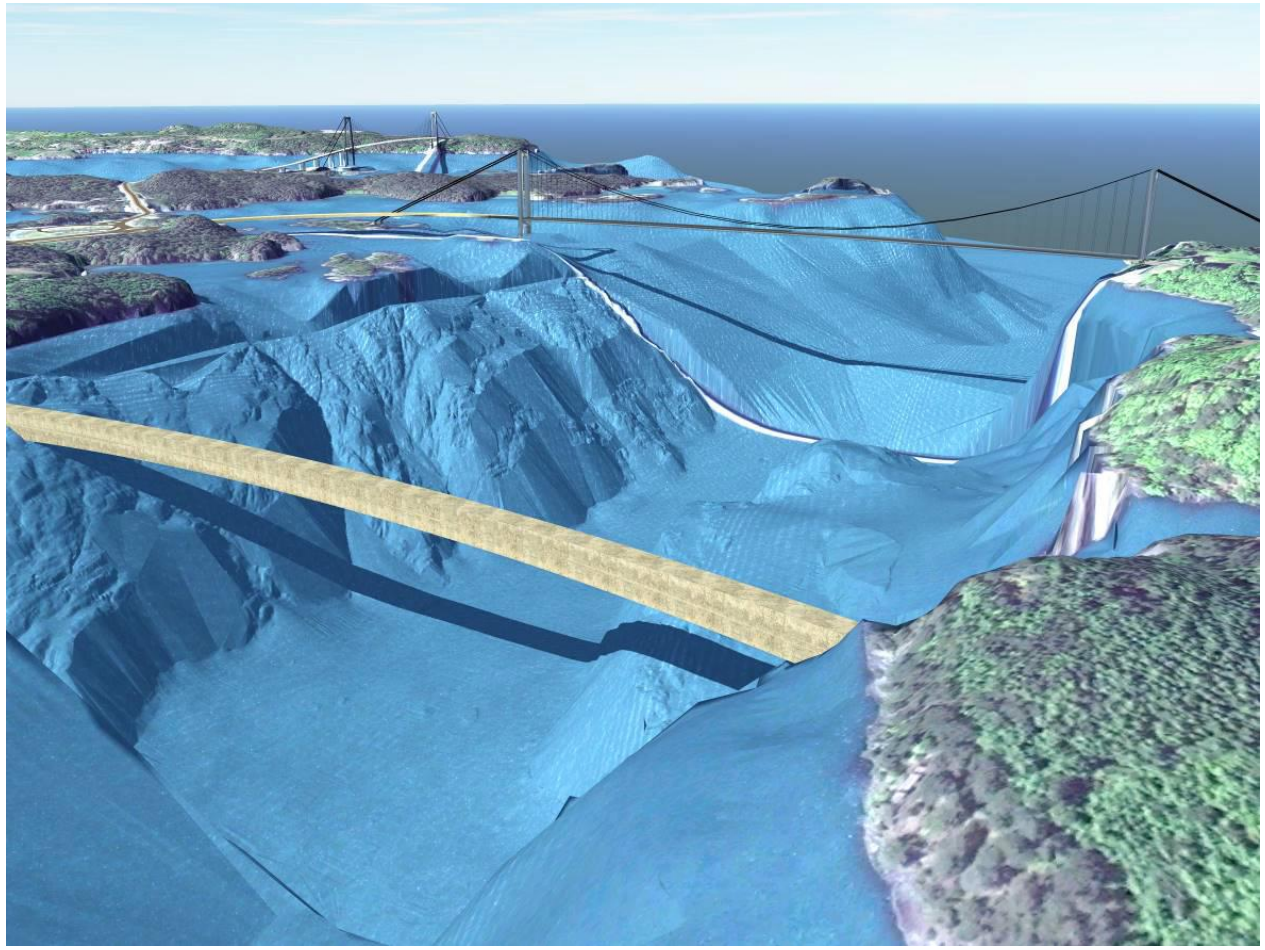
Bjørnafjord-crossing

Digernessund-crossing

Sulafjord-crossing



Study for crossing the Digernessund - NPRA

Publications:

Development of a submerged floating tube bridge for crossing of the Bjørnafjord; Multi-Span Large Bridges; Porto 2015

Vertical stiffness for tube bridges: Comparing pontoons and tethers; IABSE; Geneve 2015

E39 - nuove tipologie strutturali per l'attraversamento dei fiordi norvegesi; Trasporti e cultura; Italia 2015

The use of wind tunnel facilities to estimate hydrodynamic data; Experimental Fluid Mechanics; Prague 2015

Mega bridges for the fjord crossing in Norway; Bridge design & Engineering; 2015

The Submerged Floating Tube Bridge: The invisible bridge crossing the Bjørnafjord; IABSE; Stockholm 2016

The Submerged Floating Tube Bridge: Design Philosophy and Concept Development; IABSE; Stockholm 2016

Hydrodynamic loads on a submerged floating tunnel bridge induced by a passing ship or two ships in maneuver in calm water; OMAE; Busan 2016

Basic design for a Submerged Floating Tube Bridge across the Digernessund; IABSE; Vancouver 2017

A submerged floating tube bridge concept for the Bjørnafjord crossing – marine operations; OMAE; Trondheim 2017

Simplified hydrodynamic design procedure of a submerged floating tube bridge across the Digernessund of Norway; OMAE; Trondheim 2017

Global Analysis of Submerged Floating Tube Bridge (SFTB): The Design Case of Crossing the Bjørnefjord in Norway; World Tunnel Congress; Bergen 2017

Submerged floating tunnels subjected to internal blast loading; Transport Research Arena; Vienna 2018

The Submerged Floating Tube Bridge as an alternative for a crossing: pros and cons; IABSE; Nantes 2018

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ITA Working Group 11
for Immersed and Floating Tunnels

Owners guide for SFT – ITA AITES (International Tunneling and Underground Space Association)

fib CEB-FIP

WG 1.2 Concrete structures in marine environment – FIB (International federation for structural concrete)

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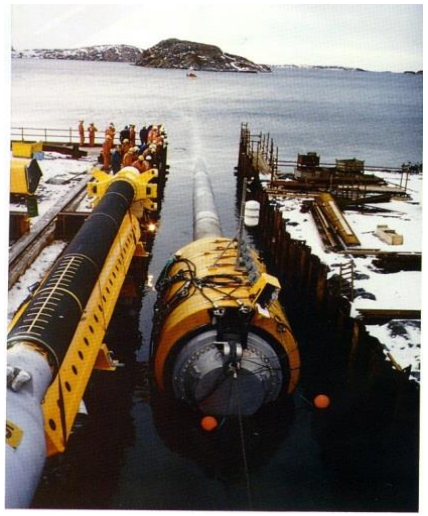
Development of offshore structures



Heidrun tension legs towing and installation – Holwech & Engebretsen

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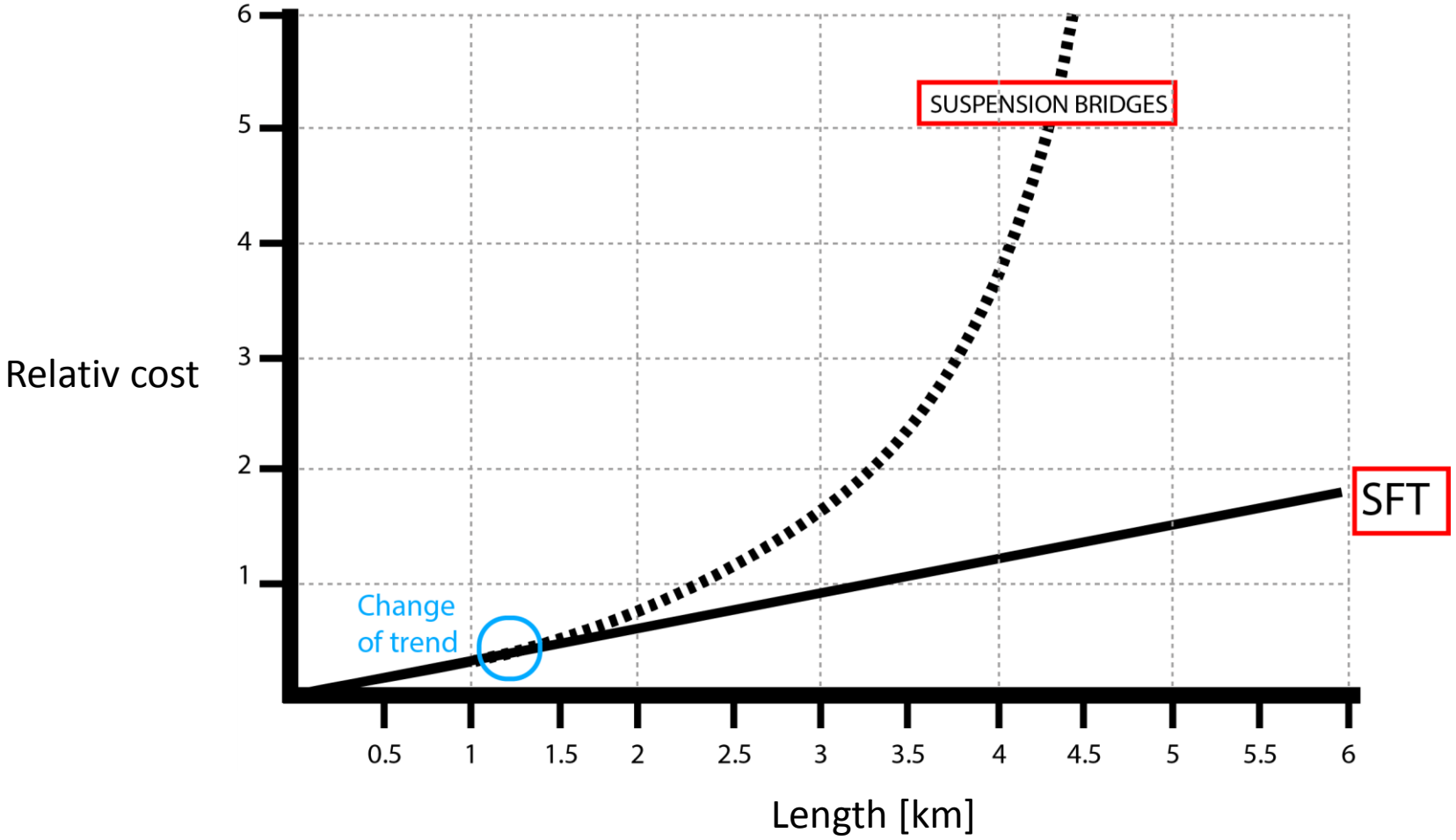
Cost comparison



Risk or opportunity

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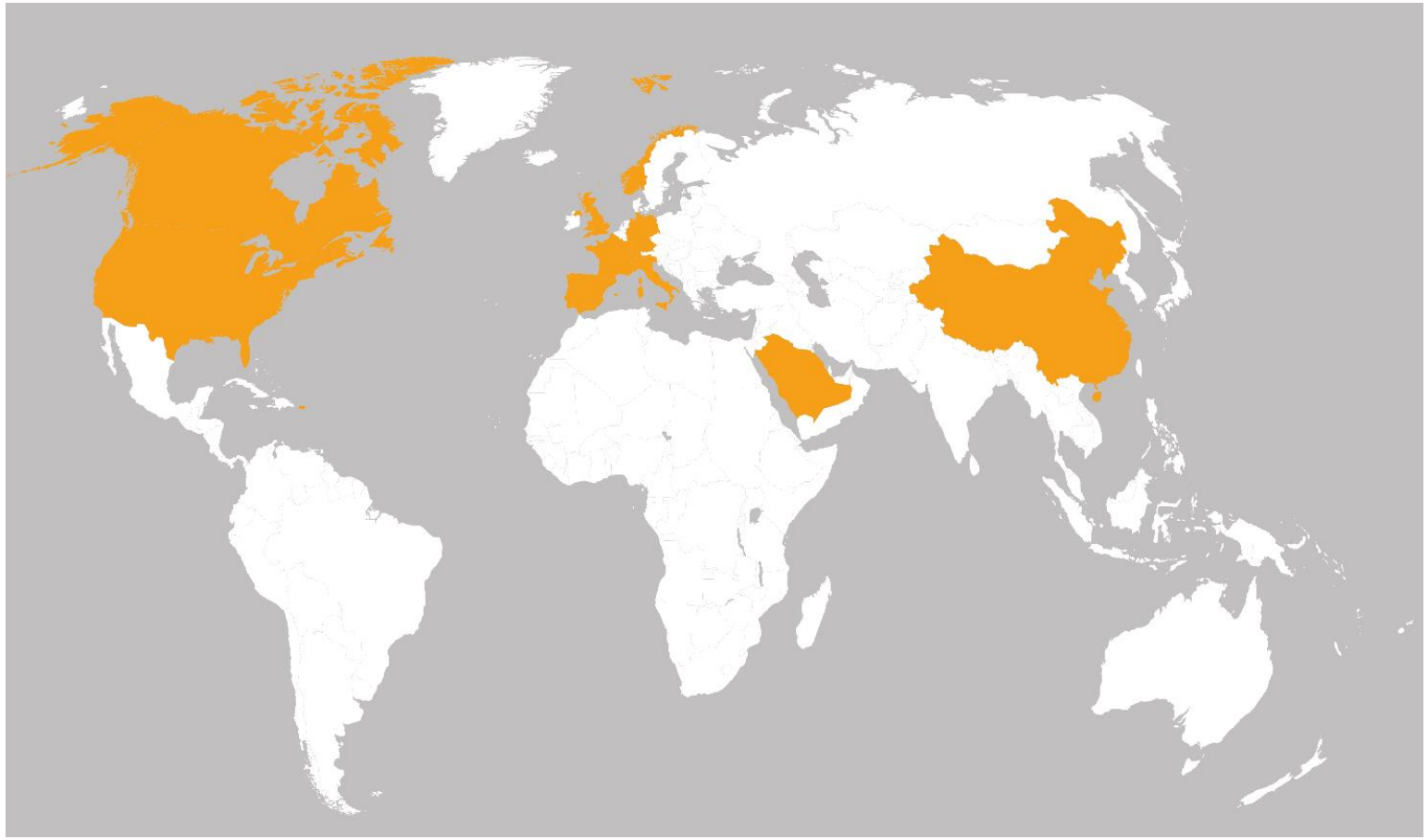
Interest for Subemerged Floating Tunnels World Wide



Map 1: Articles

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Interest for Subemerged Floating Tunnels World Wide

WIRED

AARIAN MARSHALL TRANSPORTATION 07.14.16 12:00 PM

YES, A 'SUBMERGED FLOATING BRIDGE' IS A REASONABLE WAY TO CROSS A FJORD

TRATION

Forbes

Could Norwegian Engineers Really Build A Floating Tunnel In A Fjord?

HUFFPOST

ACTUALITÉS 26/07/2016 17:20 CEST | Actualisé 05/10/2016 16:44 CEST

Entre le tunnel sous-marin et le pont, la Norvège pourrait expérimenter les tunnels flottants

Nadège El Ghomari Le HuffPost

ifanr 爱范儿

挪威人疯了，打算让海底隧道“浮”起来

新创

2016-07-26 12:26

BBC

ACTUALIDAD

LA STAMPA

futurezone TECHNOLOGY NEWS

...

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Daily Mail

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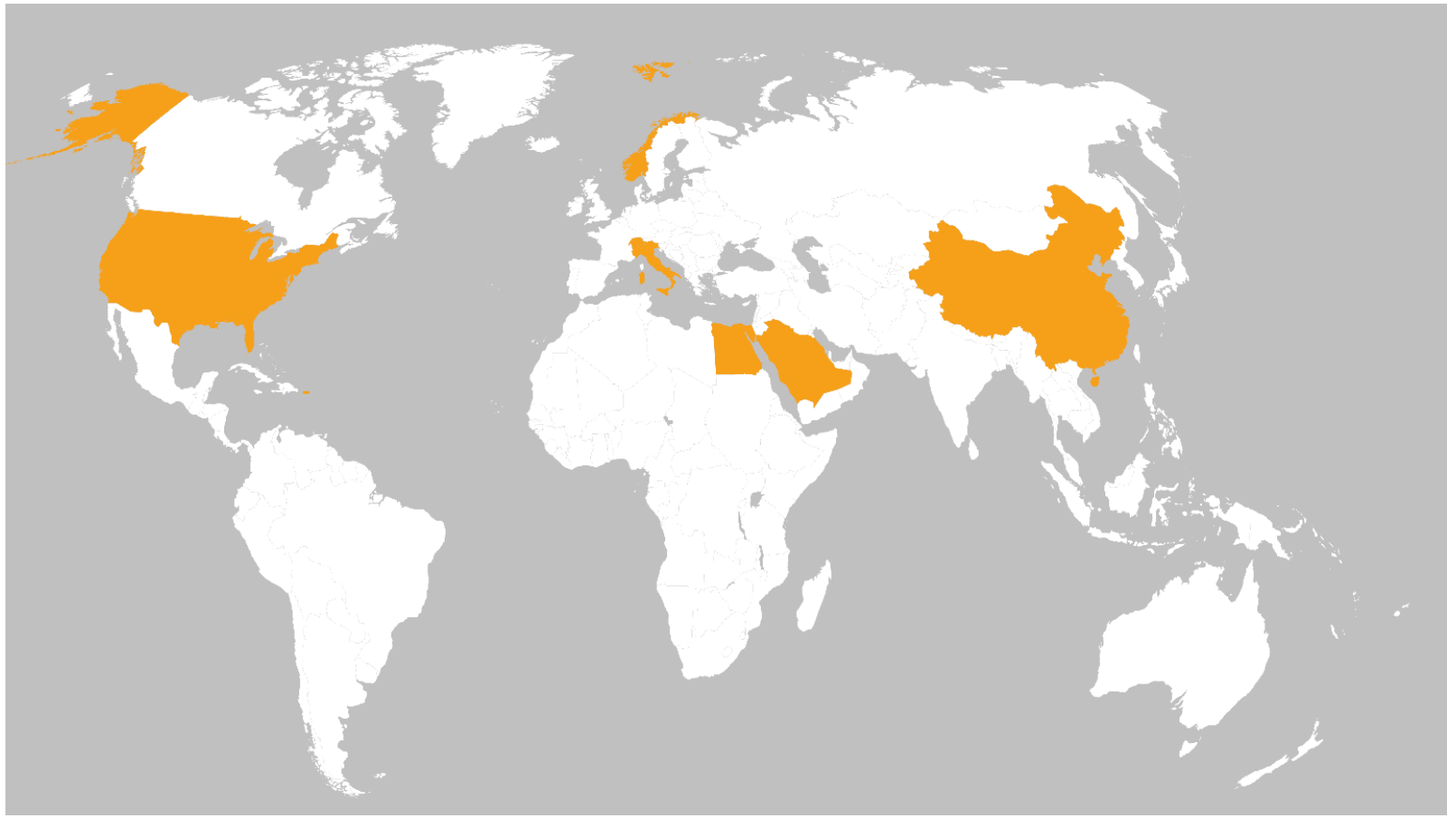
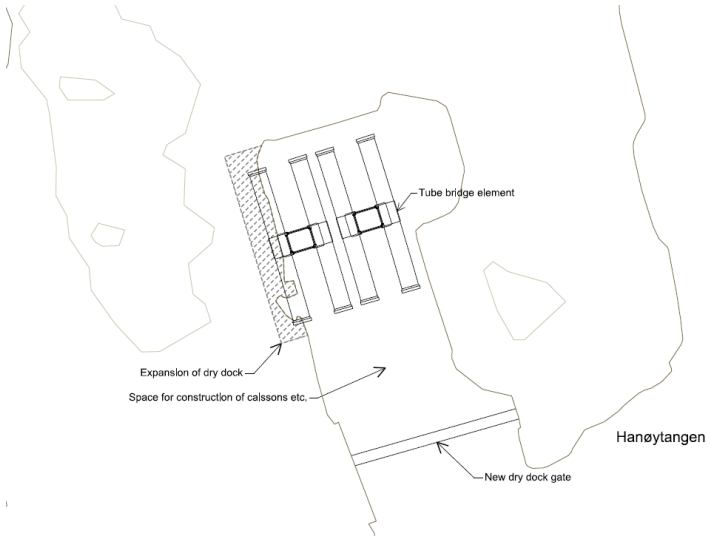
SFT-studies in recent years

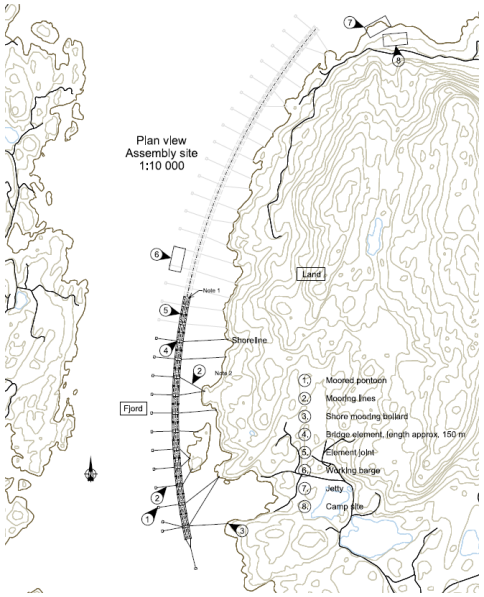


Map 2: Feasibility studies

A BIG opurtunity



SFT: Construction in dry dock - NPRA



SFT: Assembly phase - NPRA

Towing of the Troll platform

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The question is not if, but when…

SFTB across the Sognefjord – NPRA