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3rd BUILDING DIGITAL TWIN International Congress

Digital Twins for port infrastructure a necessity

Cornelis Versteegt

MACOMI

PIONEERS

ORGANIZED BY:

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THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION´S HORIZON EUROPE RESEARCH AND INNOVATION PROGRAMME – PROJECT 101058541 – DIGICHECKS

Infrastructure challenges

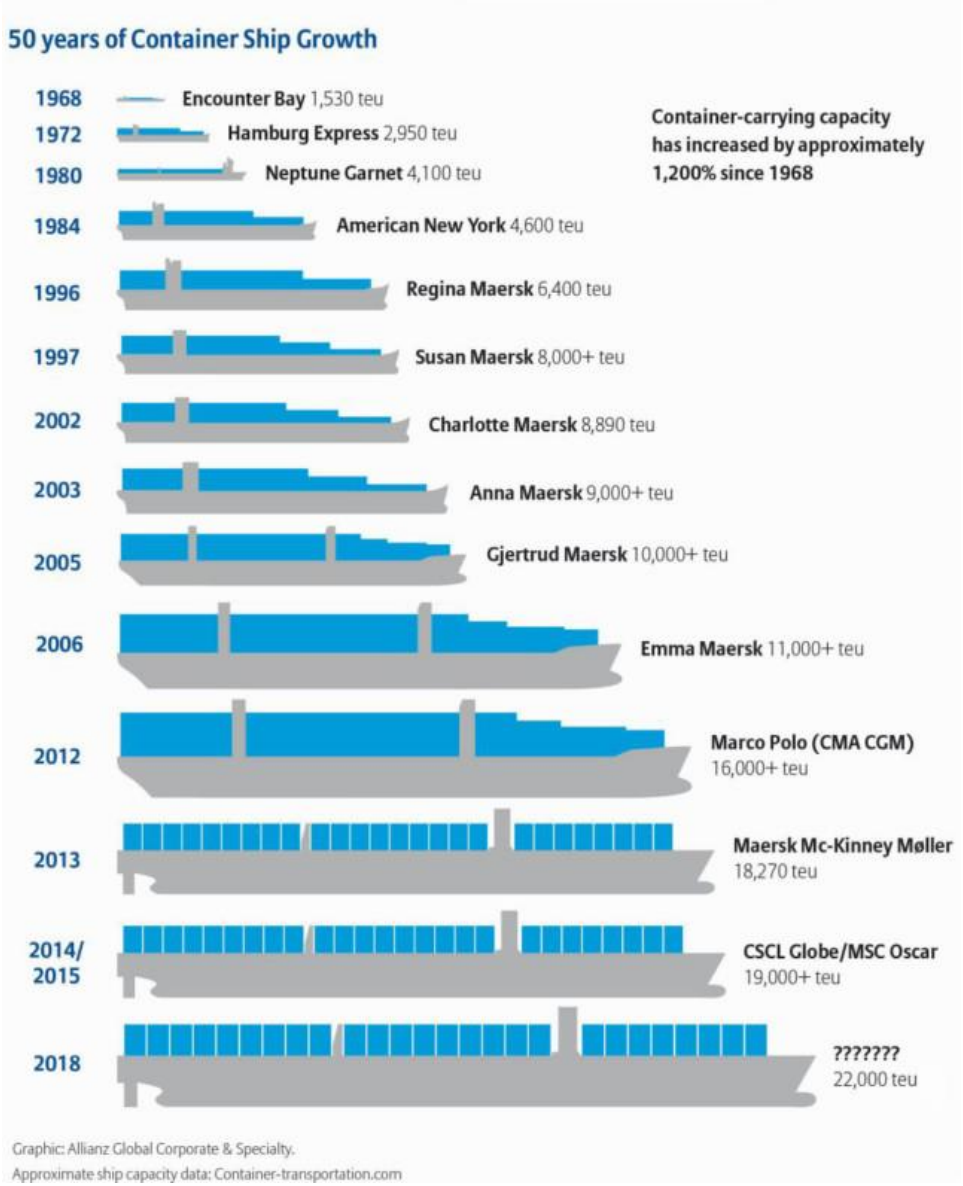
PIONEERS: designing the ports of the future

- Terminals - new ones and expansions
- Nautical access - larger vessels
- Hinterland connection – rail/road: congestion, barges: too little/much water
- Maintenance (costs and impact on operations)
- Environmental pressure

Keep in mind

- High costs
- Complexity – everything is related and all part depends on each other
- Long term decisions (uncertainty)

Larger vessels



1956: 58 containers on the Ideal-X

2023: 24,346 TEU
On the MSC Irina

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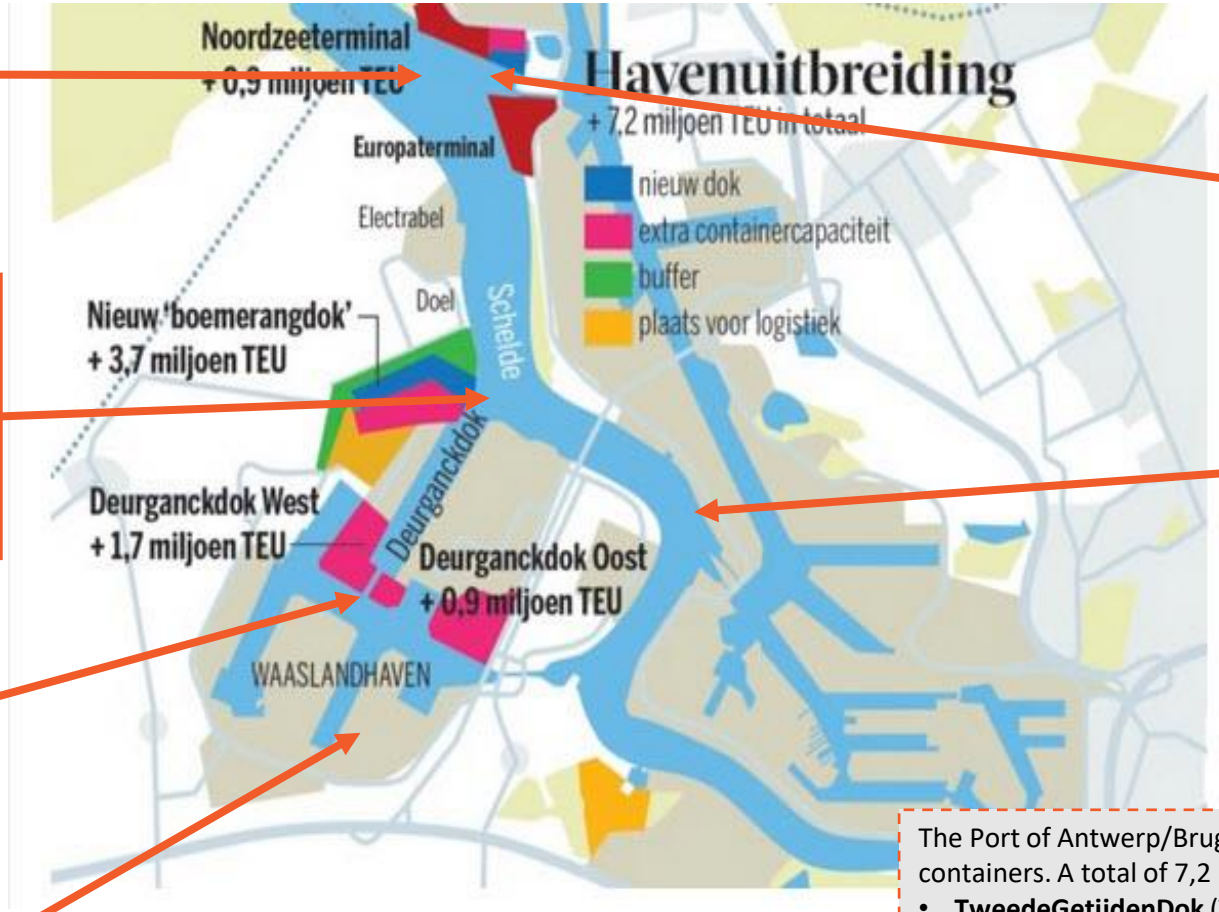
Project: extra container capacity PoAB

Tide restrictions
- Bigger ships (depth) have small windows for departure/arrival
- Sometimes windows of only minutes

Turning basin
- Used for both Deurganckdok and TweedeGetijdenDok. Does the basin have enough capacity?
- Larger container vessels (400 m) take 20-30 minutes
- Traffic rules – impact on other traffic?

Kieldrechtsluis
- Busy area, passing Deurganckdok

Critical resources
- Pilots (Dutch, Belgian – river/dok)
- Tugboats



Terminal and locks
- Vessel to/from Zandvliet/Berendrecht-locks pass moored vessels at NordzeeTerminal very closely

Small passage area
- The Scheldt river is not very wide at certain locations.
- Issue for passing vessels? Traffic rules?

The Port of Antwerp/Bruge has an ambitious plan to extend the capacity to handle containers. A total of 7,2 Million TEU will be added
- **TweedeGetijdenDok** (TGD): new terminal (3,7MTEU)
- **Europaterminal**: new quay wall (most expensive infrastructure) and more yard area
- **Noordzeeterminal**: new quay wall and more yard area
- **Deurganckdok**: extension behind the Kieldrecht lock

PortGenie a Digital Twin for Ports

The challenges are great….ports need to take well informed decisions….that is were Digital Twins come into the picture!

PortGenie: Digital Twin used by PoAB

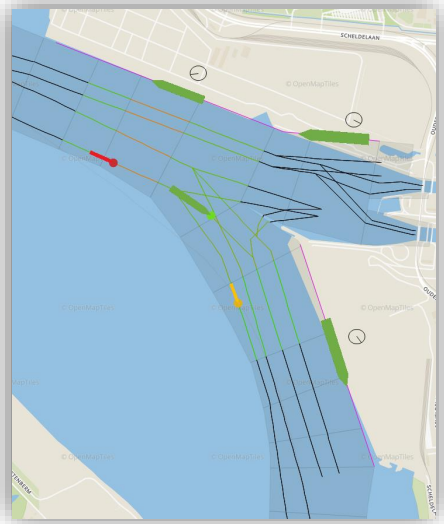
PortGenie is a Digital Twin, a digital copy of the real (or future) system that can be used for experimentation and ultimately better decision-making.

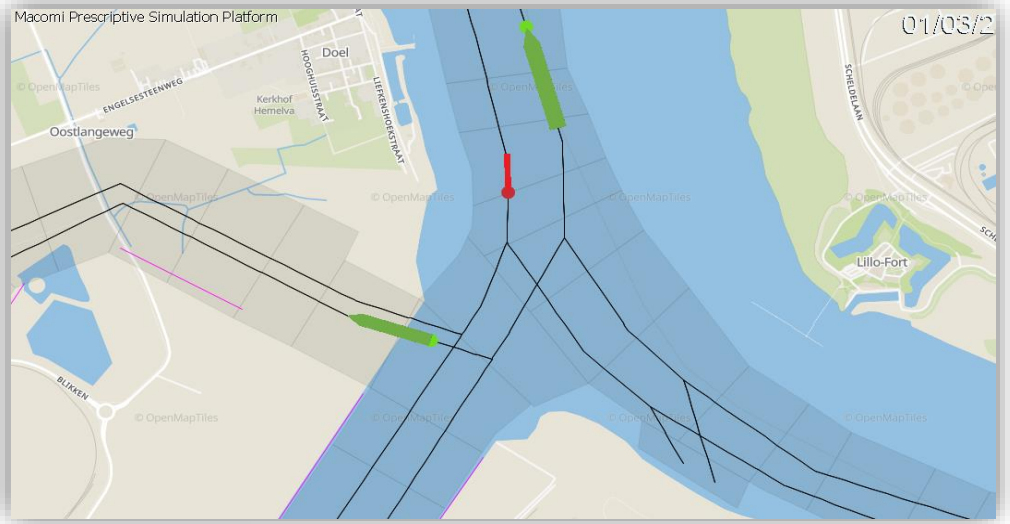
PortGenie is one of the applications connected to APICA

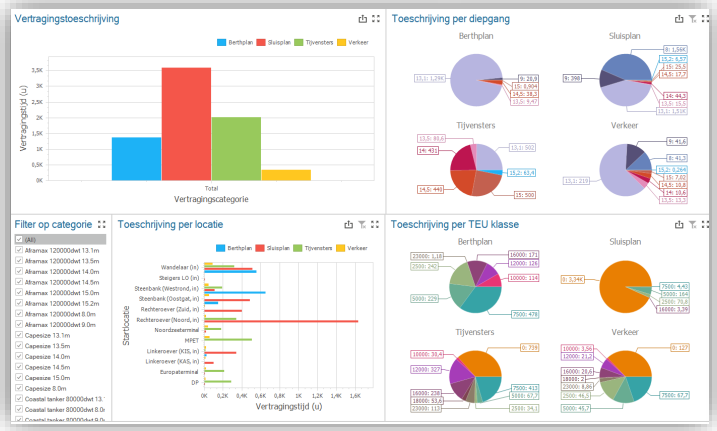
PortGenie adds the operational aspects in Digital Twins

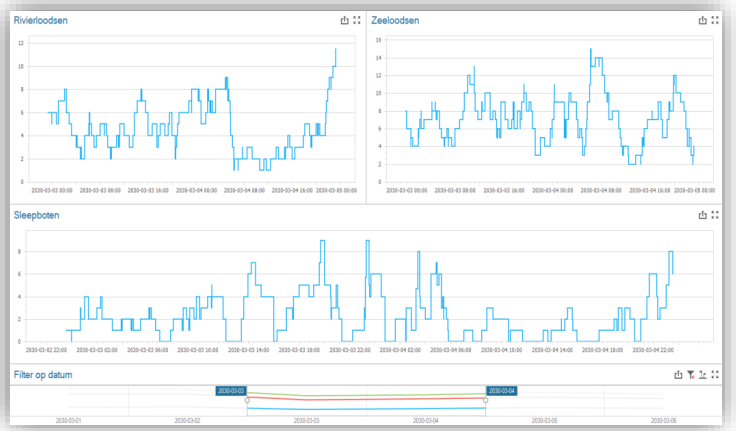
PortGenie has several time-horizons:

- Past – analyse what happened and be better prepared next time.
- Current – what is going on now?
- 0 - 24 hours ahead – improve operational planning. What should I do the next hours?
- 1 week ahead – resource planning
- More than a year ahead – investment planning



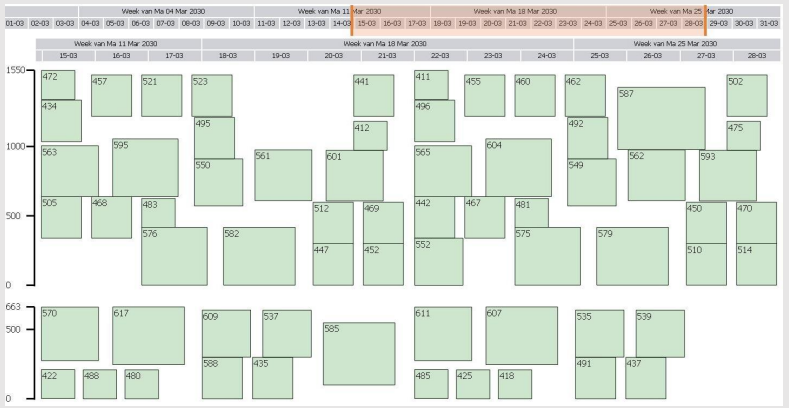






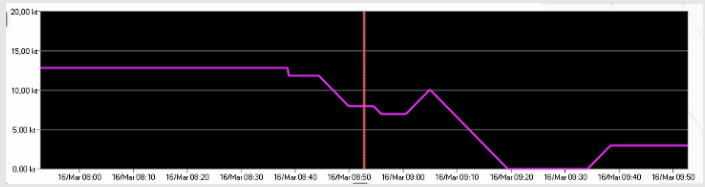
Many parts combined for PoAB

Berth planning for terminals



Database of vessel

- Vessel characteristics
- Vessel behaviour
- AIS data (patterns)
- Forecasts arrival patterns

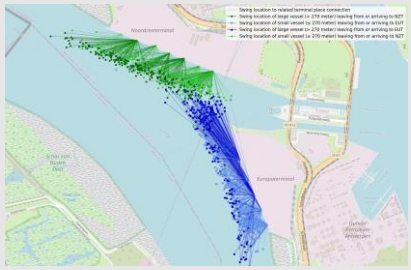


Vessel movements (historical and present)

- AIS data (is lacking information elements)

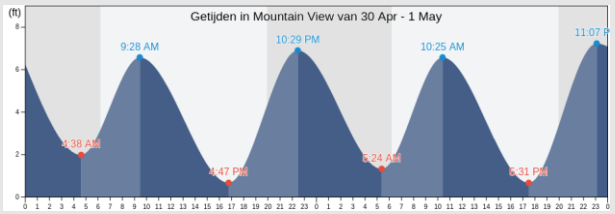
Vessel movements (future)

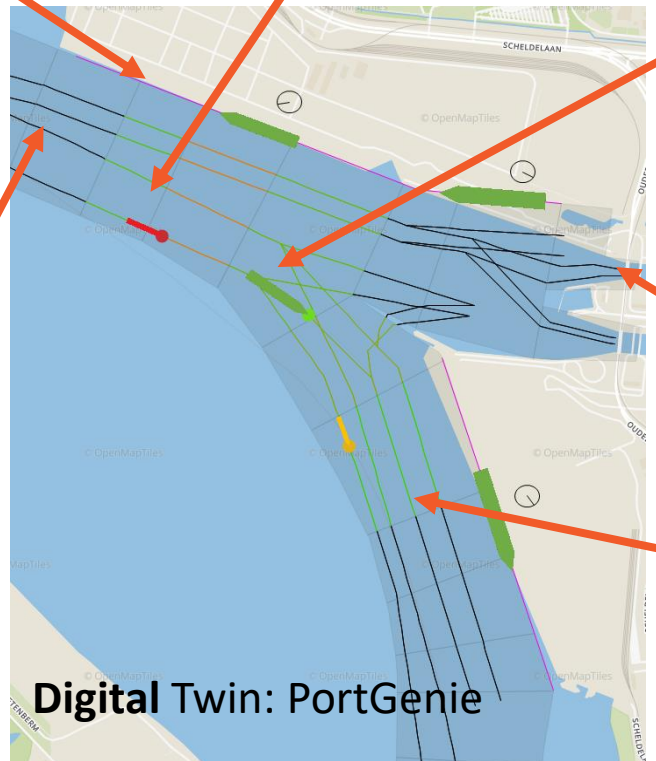
- Single vessel: mathematical
- Interaction between multiple vessels, locks, and berths: prediction model based on neural networks (AI)



Tides and access/departure windows

- Astronomical tide tables
- Vessel categories (depth, weight and cargo load)
- Combined into access/departure windows for specific locations

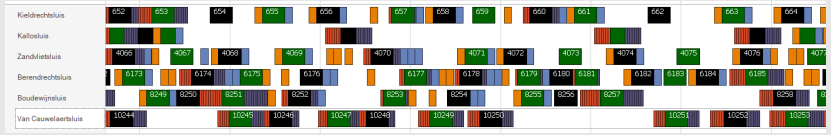




Digital Twin: PortGenie

Lock planning

- Rules for lock planning. What vessels can go together?
- Optimize (waiting times for vessels or number of cycles for lock or both?)



Safety

- Margins around vessels
- Width of Scheldt rivier

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Some conclusions

The complexity of port and port operations ask for Digital Twins

There are many individual initiatives on Digital Twin in ports

- Mostly focus on small specific areas/parts of the port.
  - Ports consists of many interacting components
  - A look at the bigger perspective (the entire port) is required
- Initiatives could be better coordinated between ports
- Standards within Digital Twins are missing and/or need to be further developed

Some conclusions

Data is in the center of Digital Twins

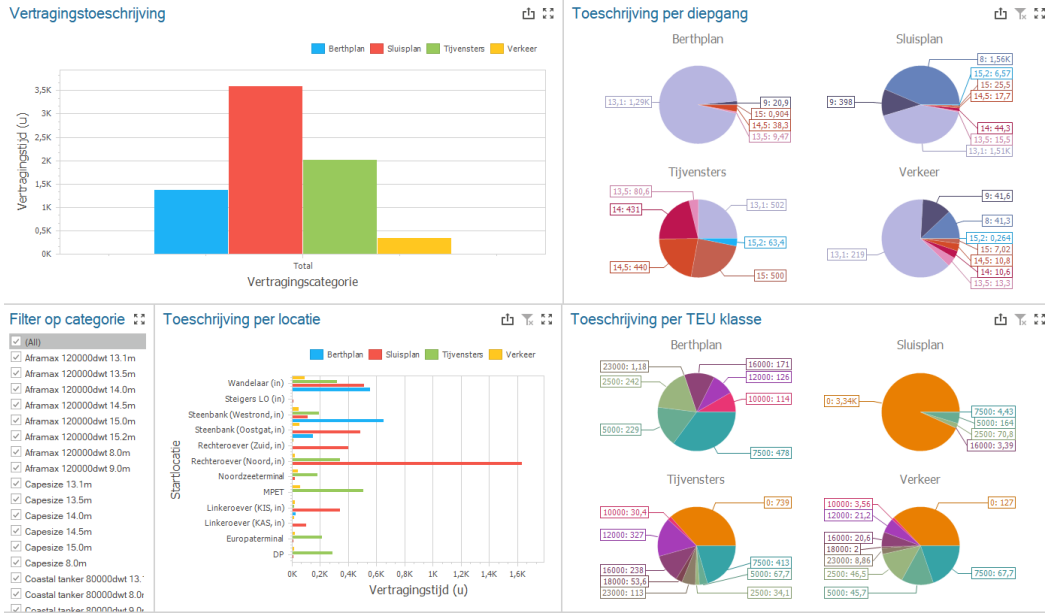
- Digital Twins require a lot of data
- A lot of data is available, but….
  - Data is highly distributed among different parties
  - Data collection/gathering is time consuming
  - Data cleansing and making data usable also requires large effort
  - Data is not always reliable

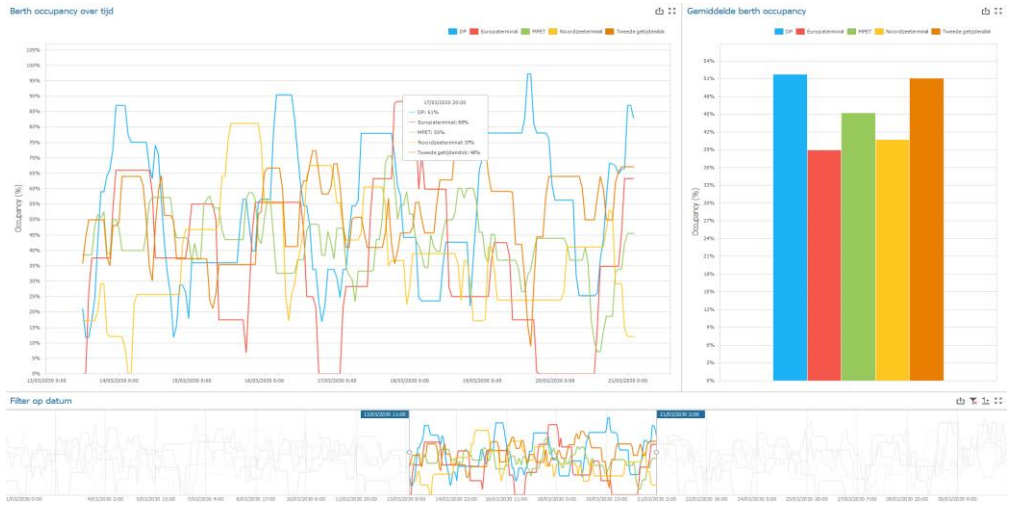
PortGenie at Port of Antwerp

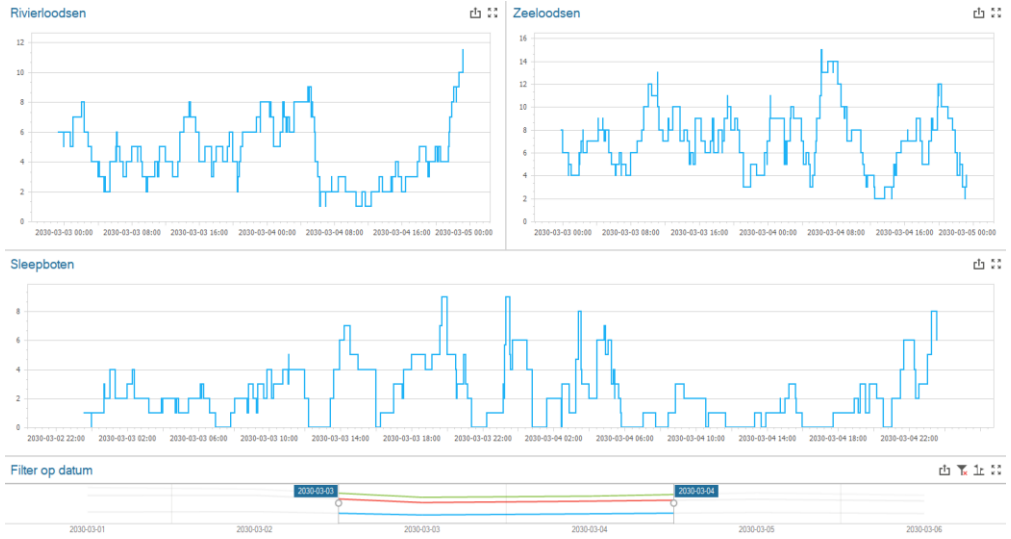
Off-the-shelf dashboards include:

- In-depth attribution of delays to traffic, tide windows, lock or berth plan, etc.
- Berth utilization graphs over time
- Overview of berth and lock planning
- Lock capacity utilization over time
- Resource utilization pilots and tugboats

But the most important is the animation / visualization







Port of Antwerp – Lock scheduling

Port of Antwerp Bruges

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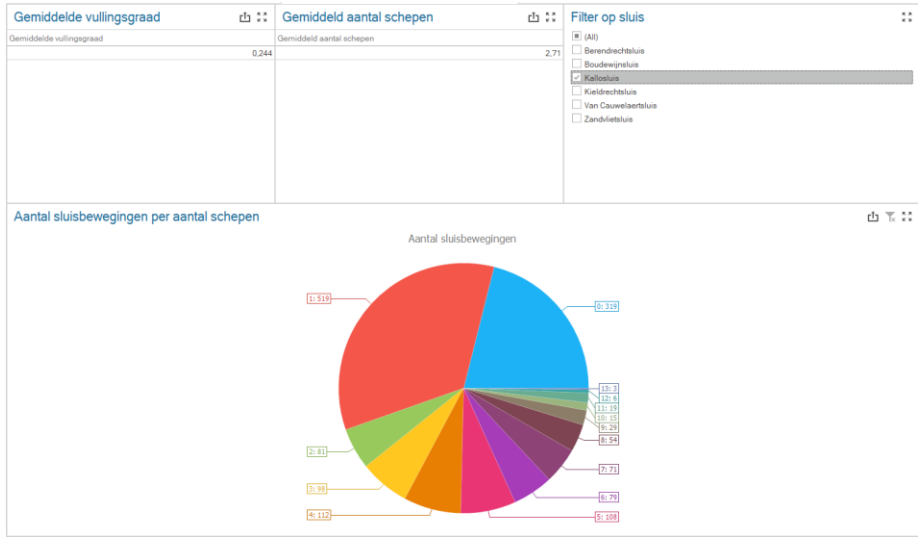
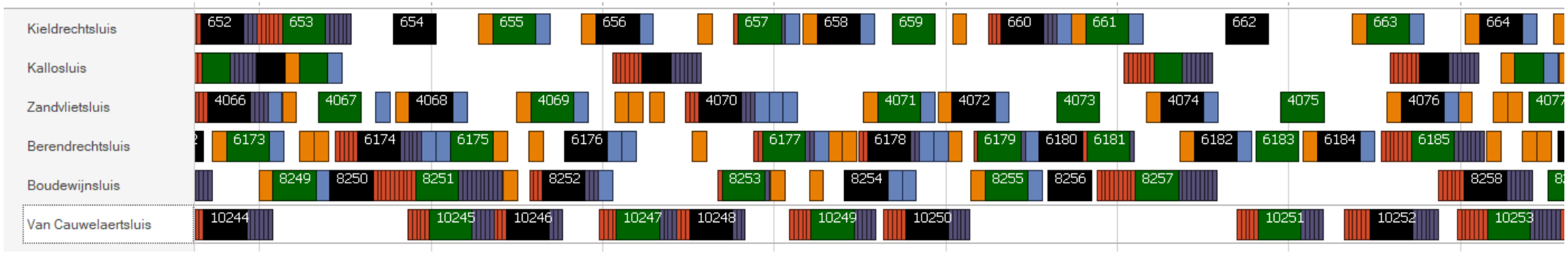
Lockage planning

- The lock planning is aware of future lockage demand by vessels and will plan a preliminary place for upcoming vessels in a rolling forecast
- Planning a vessel in a lockage happens by considering several proposals, for example amending an existing lockage or creating a new one. The best proposal is chosen.
- By employing neighborhood search (i.e., making small adjustments to the current planning), the rolling forecast is constantly working on improving, by both reducing total lockages and reducing vessel delays
- Nearing the moment of execution, the lock planning can handle external disruptions to the vessel and adjust the planning by recovery.
- Several parallel and/or sequential locks can be simulated and optimized together. Port of Antwerp employs 4 locks servicing the same area. PortGenie can make split-second decisions on assigning a vessel a different lock based on short term disruptions.



Dashboards to quickly get an overview of each lock's performance in both number of vessels per lockage and space used



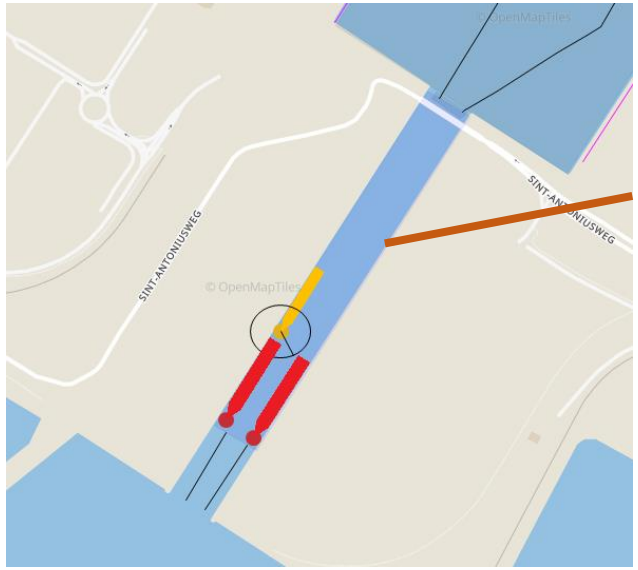
Detailed view of realized lock planning, including exact moments of vessels entering and exiting and period of water equalization. Available after each simulation.

Port of Antwerp – Lock scheduling

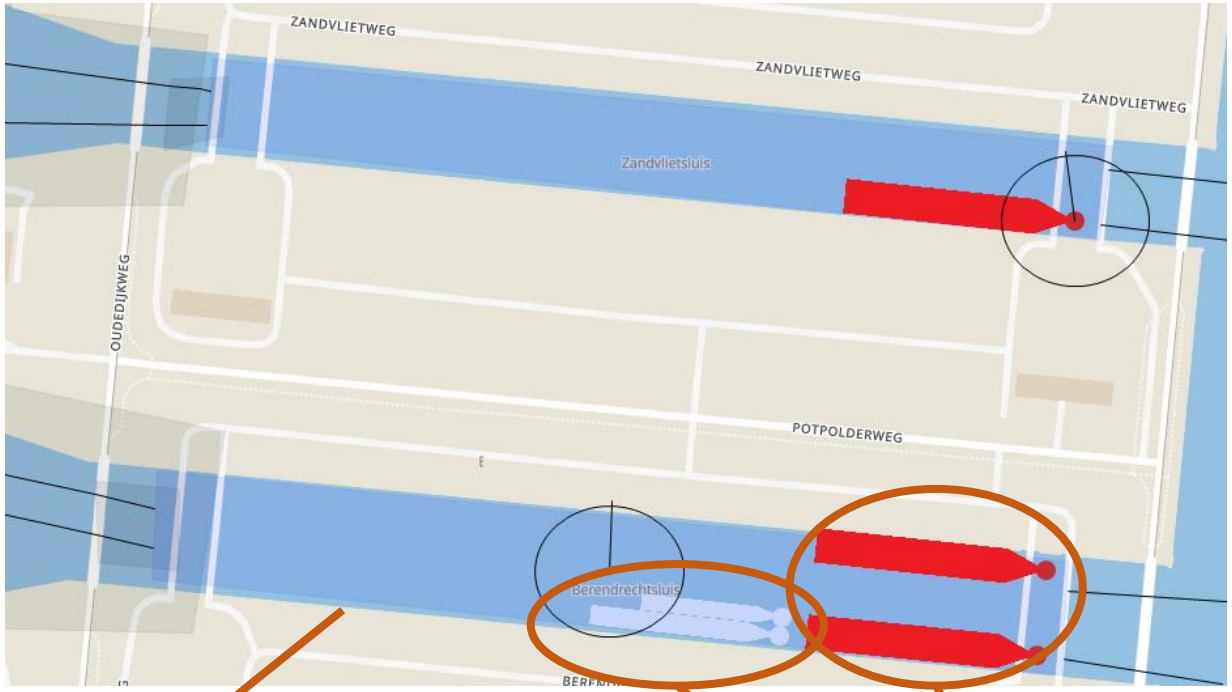
Port of Antwerp Bruges

- Vessels are placed in the lock based on dimensions and order of entry
- The lock planning algorithm dynamically calculates lock utilization and prevents illegal situations
- Vessels can attach to the wall, and barges also to each other
- Vessels respect a certain amount of buffer to each other and the wall. This buffer can be varied based on the vessel's dimensions
- The vessel placement logic is entirely modular and can be modified to each port's needs

Port of Antwerp employs some of the two largest locks in the world;



Kieldrecht lock: Second largest lock in the world. 500 meters long, 68 meters wide, 17.8 meters deep



Berendrecht lock and Zandvliet lock

Sea vessels attach to the lock wall

Barges can also attach to each other, and leave some buffer with regards to the sea vessels

Port of Antwerp – Berth planning

Port of Antwerp Bruges

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Optimizing the berth plan

The optimization of the berth plan works using two steps:

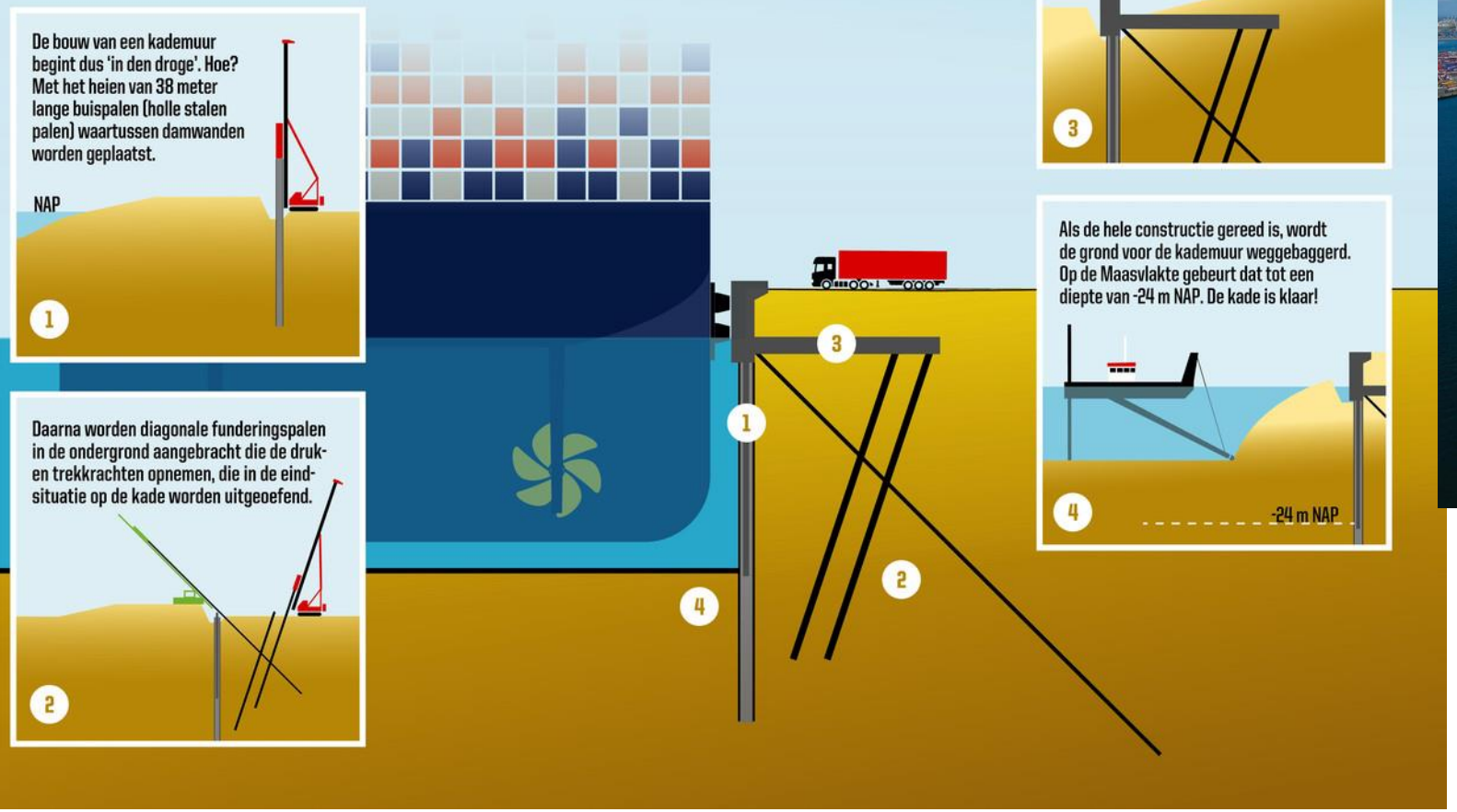
- Before simulation, a theoretical berth plan is constructed using the yearly arrivals of vessels, their expected handling times, and detected weekly patterns leading to a predictable weekly pattern in the resulting plan. This is optimized using Simulated Annealing.
- During simulation disruptions such as delays during traveling or longer handling times are encountered. The planning recovers from such disruptions using local recovery based on Constraint Programming.

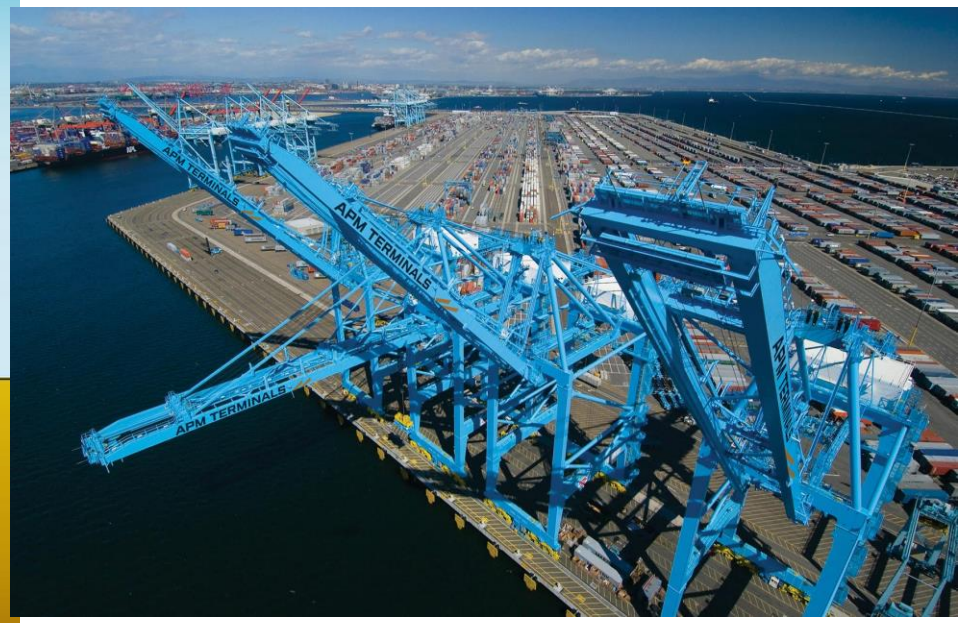
On the x-axis, a scrollable time bar

On the y-axis, the length of the quay wall, possibly divided into multiple walls

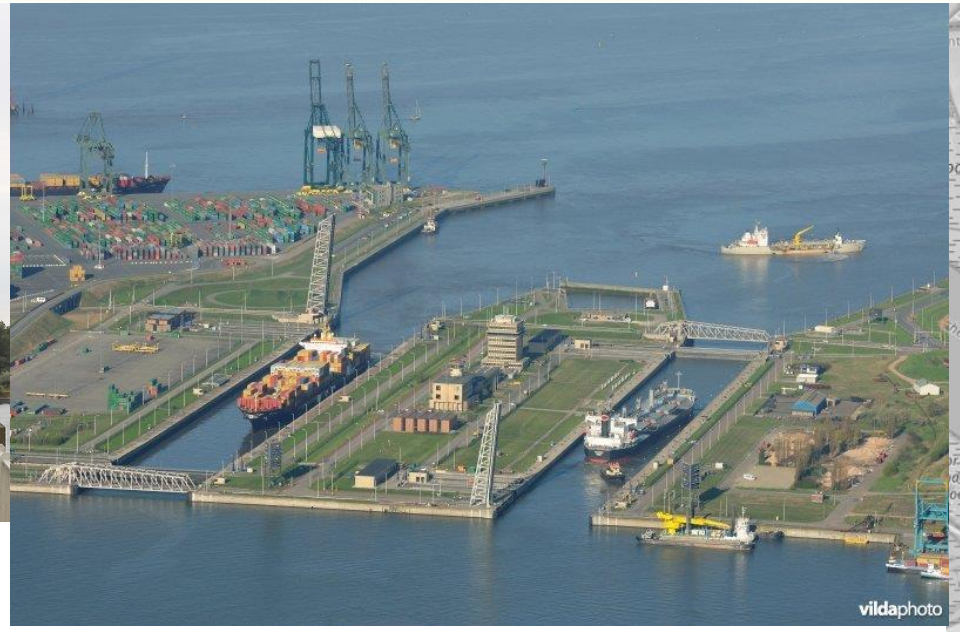
Zo bouw je een kademuur

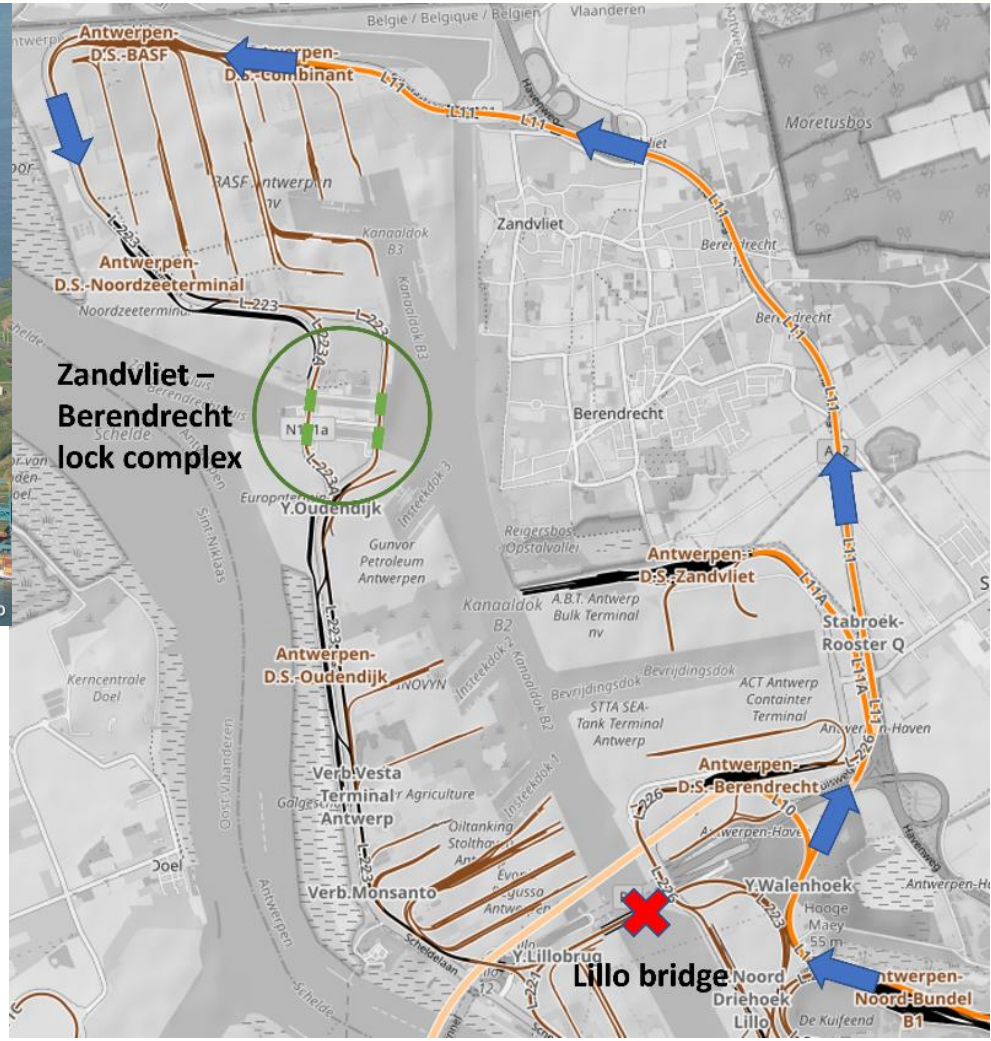
De haven van Rotterdam heeft zo'n tachtig kilometer kademuur. En er komen er nog steeds bij: voor de vestiging van een nieuw bedrijf op Maasvlakte 2 wordt een nieuwe kademuur gebouwd. In tegenstelling tot wat je misschien verwacht, wordt een kademuur gebouwd 'in den droge'. Hier zie je hoe.





Case study maintenance: Lillo bridge





Lillo bridge is at the end of its technical life. Does it need to be replaced?

Trade off between

- Costs of replacing bridge (investment)
- Rerouting of trains over lock complex (waiting times for trains)