IW-NET

Exploring bottlenecks on inland waterways to improve traffic flow using simulation

Simulation-based optimisation of IWT flows on River Weser

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Application Scenario: River Weser

Corridor

- Hinterland connections of **Bremerhaven and Bremen** via the River Weser (TEN-T North Sea – Baltic)

Key Challenge

- Existing infrastructure bottlenecks for larger vessels

IW-NET Solution

- Traffic Flow Simulation

Application Scenario: River Weser

Key industry challenge

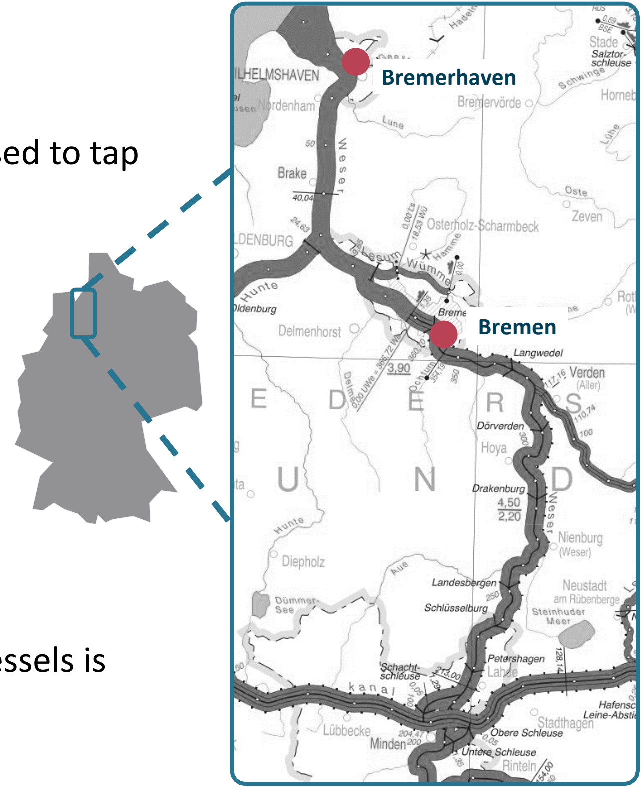
- IWT is in strong competition with other means of transport
- Use of larger, **more efficient** vessel types in corridor needs to be increased to tap the full potential of IWT in terms of costs, GHG emissions and thus competitiveness

Mittelweser Adaption Directive (1987/1997)

- Mittelweser only navigable by small vessels up to 1980s
- Since 2017: Clearance for Large Motor Vessels (GMS)
  Fairway adaptions still ongoing or cancelled
  → no-passing/no-encounter sections and draught restrictions
- barriers to IWT profitability due to **infrastructure bottlenecks**

Consequences

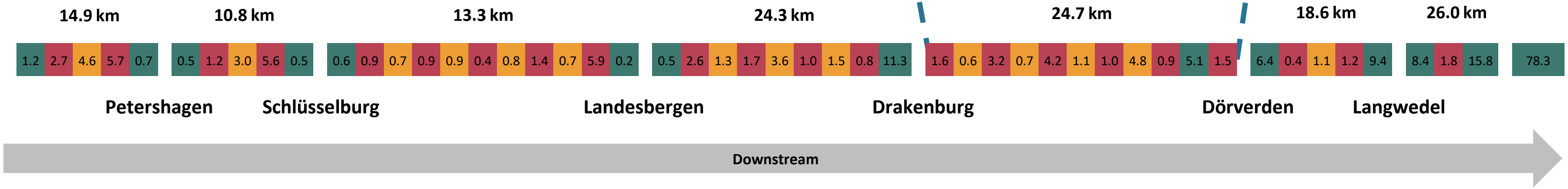
- Lack of predictability and reliability → Even though traffic with larger vessels is physically possible, it may be **operationally inefficient**



Application Scenario: River Weser

Traffic Regulation on Mittelweser

- No traffic regulation area
- Traffic regulation area – no passing (depending on vessel type)
- Traffic regulation area – encounter allowance (depending on vessel type)



	km
Total length of waterway system	211.384
Total length of waterway (Mittelweser stretch)	137.384
Total length of traffic regulation area	72.03
Length of no passing areas involving GMS	46.67
Length of no passing areas involving ES and lower	7.399
Length of general no passing	4.14

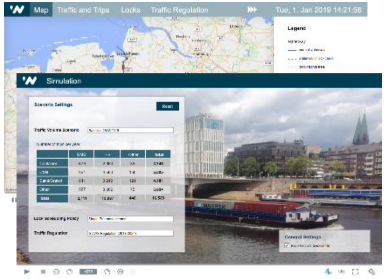
IW-NET Approach: Traffic Flow Simulation

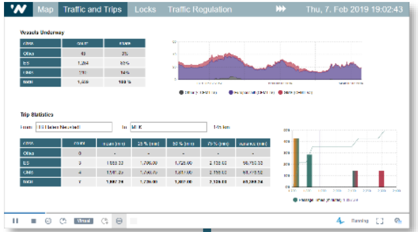
How do infrastructure management strategies affect traffic flows?

IW-NET Approach: Traffic Flow Simulation

How do infrastructure management strategies affect traffic flows?

real system



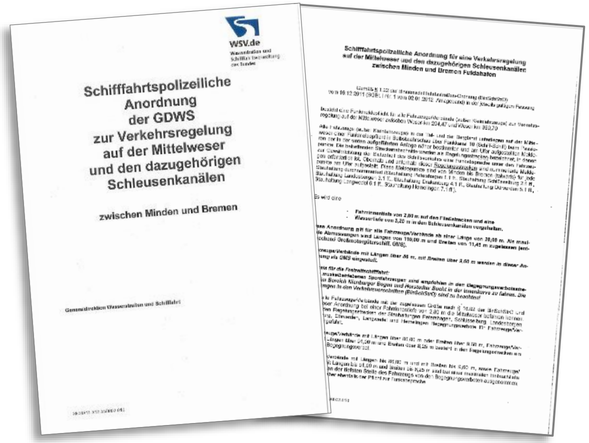


Requirements Gathering

Requirements Gathering → Concept Proving → Scenario Activation → Scenario Deployment → Final Scenario Assessment

Identification of functional and usage related requirements

- Provide a simulation model that allows to analyse traffic flows given
  - infrastructure conditions
  - traffic flow management regimes
- Necessary and sufficient model details
  - Waterway Network
    - Fairways (rivers & canals)
    - Locks
    - Traffic regulation areas
  - Bottleneck and current state analysis
    - Trip durations
    - Traffic patterns (origin/destination per vessel type)
    - Lock cycle duration
- Flexible configuration and control of experimental conditions


WSV.de

Schifffahrtspolizeiliche Anordnung der GDWS zur Verkehrsregelung auf der Mittelweser und den dazugehörigen Schleusenkanälen

zwischen Minden und Bremen

Schifffahrtspolizeiliche Anordnung für eine Verkehrsregelung auf der Mittelweser und den dazugehörigen Schleusenkanälen zwischen Minden und Bremen Foldahaton

Federal Ministry for Digital and Transport

WSV.de Wasserstraßen- und Schifffahrtsverwaltung des Bundes

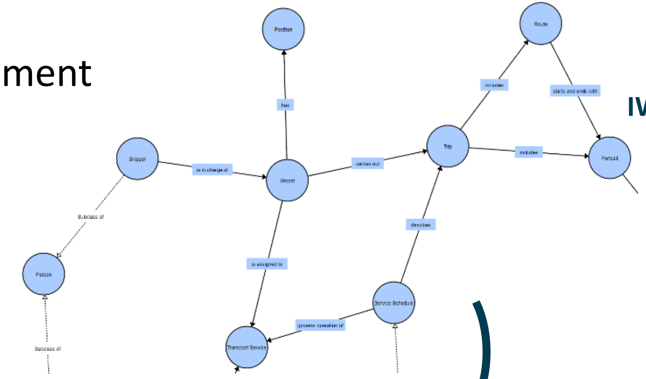
Advisory Board members with strong support

Conceptualization

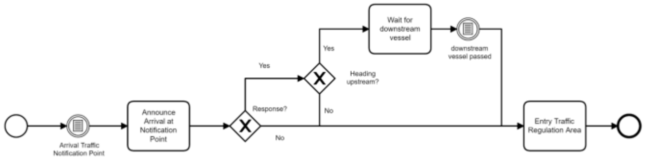
Requirements Gathering | Concept Proving | Scenario Activation | Scenario Deployment | Final Scenario Assessment

Agent-based & DES simulation approach

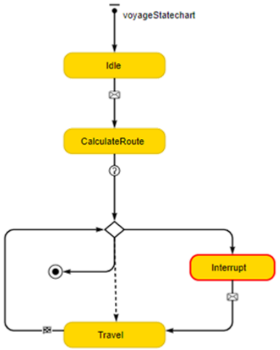
- Implementation using AnyLogic environment
- Waterway network
  - Nodes (incl. origins and destination)
  - Sections (incl. regulations)
  - Locks
- Trip coordination
- Traffic regulation
- Lock scheduling
- Inland vessels



IWT modeling ontology



descrete-events

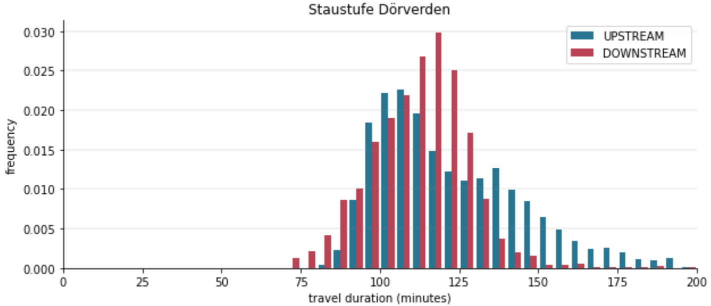


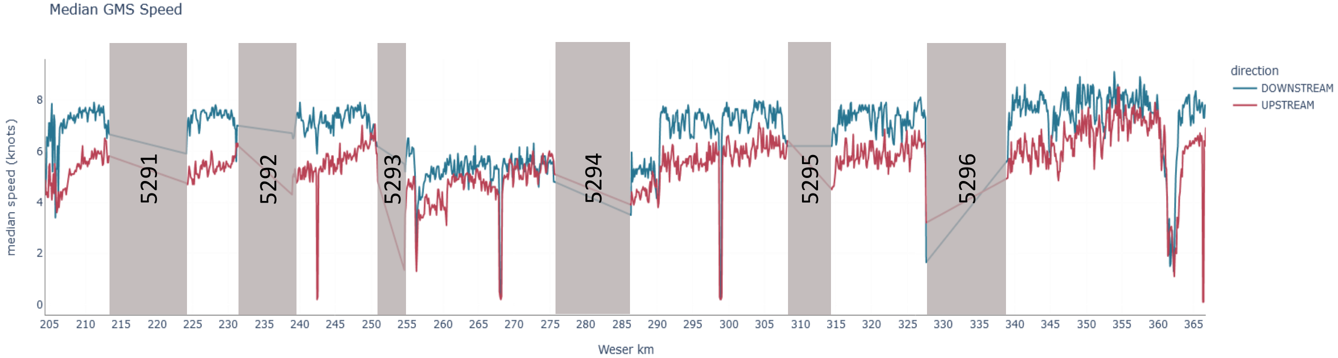
agent behaviour

Activation and Deployment

Gathering of input data

- Setup of network based on data provided by German Waterway and Shipping Administration and OSM.
- Generation of traffic patterns based on anonymized AIS data
  - Speeds
  - Travel durations
  - Lock cycle times
  - Vessel types





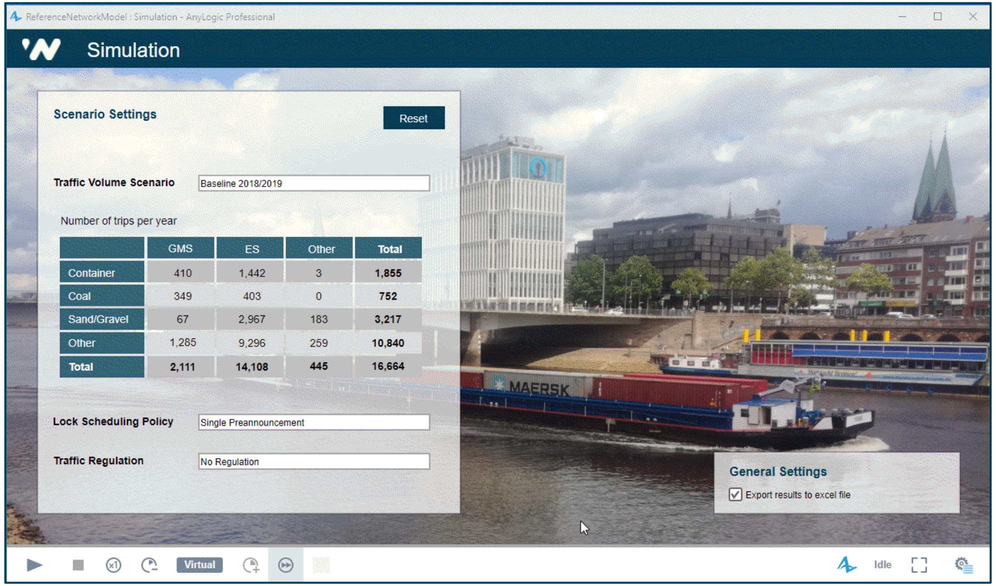
Minden **Bremen**

Activation and Deployment

Requirements Gathering → Concept Proving → **Scenario Activation** → **Scenario Deployment** → Final Scenario Assessment

Implementation of simulation model

- Implemented using the AnyLogic simulation environment
- Can be deployed locally (without installation) or within cloud
- Graphical user interface for input, visualisation and monitoring
- Possibility to use excel-based inputs and generate outputs
- Flexible and adaptable (Java-Components)



	GMS	ES	Other	Total
Container	410	1,442	3	1,855
Coal	349	403	0	752
Sand/Gravel	67	2,967	183	3,217
Other	1,285	9,296	259	10,840
Total	2,111	14,108	445	16,664

Activation and Deployment

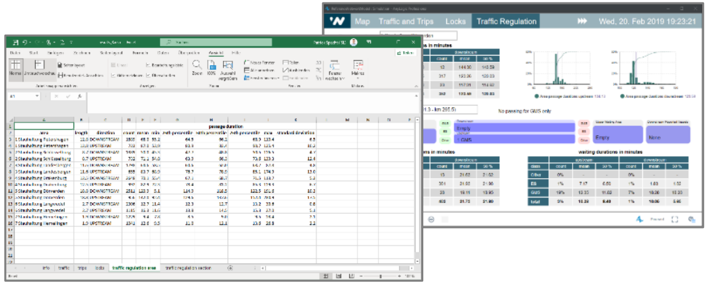
Requirements Gathering → Concept Proving → Scenario Activation → Scenario Deployment → Final Scenario Assessment

Simulation Input

- Network
  - Nodes (terminals, locks)
  - Speed limits
- Traffic regulations
  - Encounter sections, reporting locations
  - Encounter rules
- Traffic volumes on origin-destination-pairs
  - monthly/weekly/hourly
  - Percentage of vessel types
- Locks
  - Characteristics: Opening hours, Capacity and processing times
  - scheduling policies
    - FIFO
    - Preannouncement
    - Priority-based

Simulation Output

- Passing durations e.g. per section, regulation area
- Travel durations from port to port
- Waiting occurences e.g. in lock areas, within regulation areas
- Waiting durations
- All events and processes can be logged



Activation and Deployment

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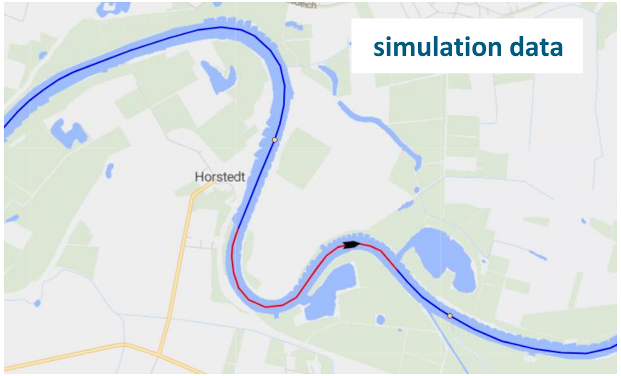
Calibration of model based on historic data

- Creation of baseline scenario (2019)
- Mapping KPIs of baseline simulation results against AIS observations
- Limited resolution of AIS data causes inaccuracy

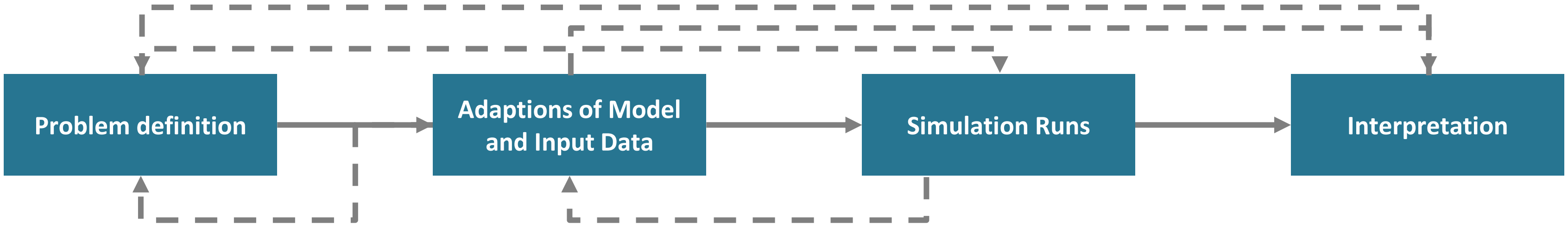
Example: AIS vs Baseline simulation travel durations within regulation areas

		AIS				Simulation			
regulation area	**direction**	**mean**	**Q1**	**Q2**	**Q3**	**mean**	**Q1**	**Q2**	**Q3**
…	…	…	…	…	…	…	…	…	…
4 Drakenburg	UPSTREAM	66,88	55,0	65,0	75,0	80,2	77,4	78,8	80,7
5 Dörverden	DOWNSTREAM	111,50	100,0	114,8	120,0	123,3	118,5	119,9	122,4
5 Dörverden	UPSTREAM	121,69	105,0	115,0	135,0	131,8	126,4	128,4	134,2
6 Langwedel	DOWNSTREAM	12,69	10,0	13,4	15,0	13,1	12,9	13,2	13,4
…	…	…	…	…	…	…	…	…	…



Activation and Deployment

Workflow of simulation experiments



Defining research questions
- Identification of relevant scenarios
- Definition of suitable KPI
- Observation period

If required, model adaptions
- Lockage strategies
- Adaptions of traffic regulation regime
- Implementation of KPI

If required, input data adaption
- Quantitative data analysis
- Qualitative adaptions
- Model calibration

Use of Model
- Scenario configuration
- Conduction of simulation runs
- Supervision and control

Checking the plausibility

Derivation of recommendations for action

Documentation

Activation and Deployment

Requirements Gathering → Concept Proving → **Scenario Activation** → **Scenario Deployment** → Final Scenario Assessment

Possible simulation scenarios have been outlined with local waterways and shipping office

- Strategic 1: Implications of traffic volume changes
  - A: realistic
  - B: tipping points
- Strategic 2: Implications of fleet configuration changes
- Strategic 3: Fairway adaptions within Dörverden regulation area
  - A: Effects of existing fairway adaptions within Dörverden regulation area
  - B: Effects of future fairway adaptions within Dörverden regulation area
- Tactical 1: Closure of Dörverden lock canal
  - A: for several consecutive days (as part of maintenance)
  - B: every day from noon on
- Tactical 2: Closure of Schlüsselburg lock every day from noon on
- Tactical 3: Implications of extending lock operations during night time
- Tactical 4: Lock Management
  - A: Implications of expanded lock preannouncement range
  - B: Implications of priority-based lock scheduling (GMS preferred)

- Dörverden regulation area to be considered as most dominant bottleneck with respect to waiting occurences
- Traffic regulation accounts for **4%** of average passage duration, i.e. 5 minutes
- Maximum travel times (upstream) around **35%** higher than without travel regulation.
- Effect measureable also for downstream passages (due to waiting effects at lock harbour)

Final Scenario Assessment

Discussion of possible ways towards future deployment in practise

user / customer

Problem definition

Defining research questions

- Identification of relevant scenarios
- Definition of suitable KPI
- Observation period

researcher

Adaptions of Model and Input Data → **Simulation Runs** → **Interpretation**

If required, model adaptions

- Lockage strategies
- Adaptions of traffic regulation regime
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If required, input data adaption

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Use of Model

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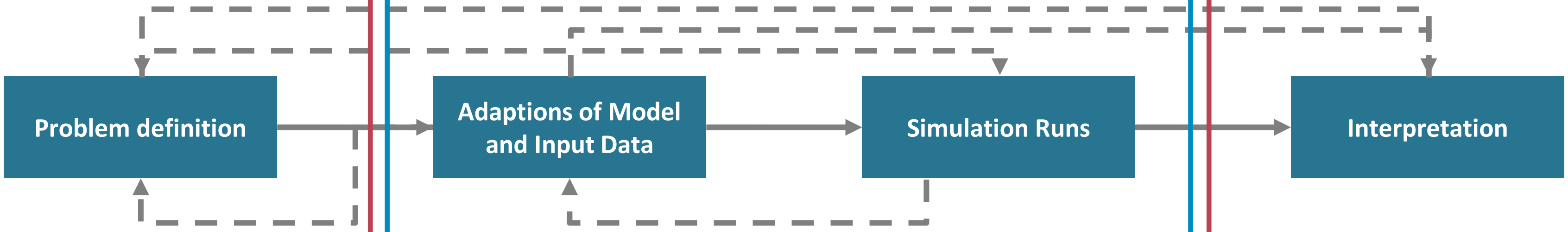
Documentation

Final Scenario Assessment

Requirements Gathering → Concept Proving → Scenario Activation → Scenario Deployment → **Final Scenario Assessment**

Discussion of possible ways towards future deployment in practise

user / customer | **researcher** | **user / customer**



user / customer

Defining research questions

- Identification of relevant scenarios
- Definition of suitable KPI
- Observation period

researcher

If required, model adaptions

- Lockage strategies
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- Quantitative data analysis
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Use of Model

- Scenario configuration
- Conduction of simulation runs
- Supervision and control

user / customer

Checking the plausibility

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Results and Outlook

Currently exploiting possibilities for uptake of results beyond the project

- Interest shown by local Waterway and Shipping Office to continue collaboration and extend capabilities of model
- Data-driven decision support → results more important than providing GUI
- Use tool for tactical and strategic use
  - Impact of planned construction work or maintenance activities
  - Prioritisation of further expansion of certain waterway sections

Extend model capabilities

- Additional details like adaptive vessel speeds
- Integrate further vessel characteristics
- Extending IWT model library

Application of modelling components and experience in other corridors

- E.g. tactical impact of low water bottlenecks → resilience-based analyses

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Thanks for your attention!

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