

Exploring bottlenecks on inland waterways to improve traffic flow using simulation

Simulation-based optimisation of IWT flows on River Weser





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

ightarrow 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 re Traffic regu Traffic regu	egulation area lation area – no lation area – er	o passing (depending on vess ncounter allowance (dependi	el type) ng on vessel type)				
14.9 km	10.8 km	13.3 km	24.3 km	1	24.7 km	18.6 km	26.0 km
1.2 2.7 4.6 5.7 0.7 0	1.2 3.0 5.6 0.5	0.6 0.9 0.7 0.9 0.9 0.4 0.8 1.4 0.7	5.9 0.2 0.5 2.6 1.3 1.7 3.6 1.0 1.	5 0.8 11.3 1.6 0.6 3.2	0.7 4.2 1.1 1.0 4.8 0.9 5.1 1.	5 6.4 0.4 1.1 1.2	9.4 8.4 1.8 15.8 78.3
Petersha	gen Schlüss	selburg L	andesbergen	Drakenburg	Dö	rverden La	angwedel
			Downstream				
					km		
		Total length of w	aterway system		211.384		
		Total length of w	aterway (Mittelweser stretch)		137.384		
		Total length of tra	affic regulation area		72.03		
		Length of no pass	ing areas involving GMS		46.67		
		Length of no pass	ing areas involving ES and lov	ver	7.399		
		Length of general		4.14			



IW-NET Approach: Traffic Flow Simulation

How do infrastructure management strategies affect traffic flows?



IW-NET Approach: Traffic Flow Simulation



Requirements Gathering



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

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	PROJECT
Designed with bulkers (41)	



Advisory Board members with strong support

Conceptualization



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



Staustufe Dörverden

UPSTREAM DOWNSTREAM

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



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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)



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

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12/10/2023



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

			AI	6		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			

Example: AIS vs Baseline simulation travel durations within regulation areas





Workflow of simulation experiments



- Quantitative data analysis
- Qualitative adaptions
- Model calibration

12/10/2023

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



Final Scenario Assessment



Discussion of possible ways towards future deployment in practise



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 \rightarrow 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 \rightarrow resilience-based analyses



Thanks for your attention!



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