Climate change and inland navigation

The transport network analysis of the Rhine and Danube rivers

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EC Meeting, Rotterdam, 11.12.2012

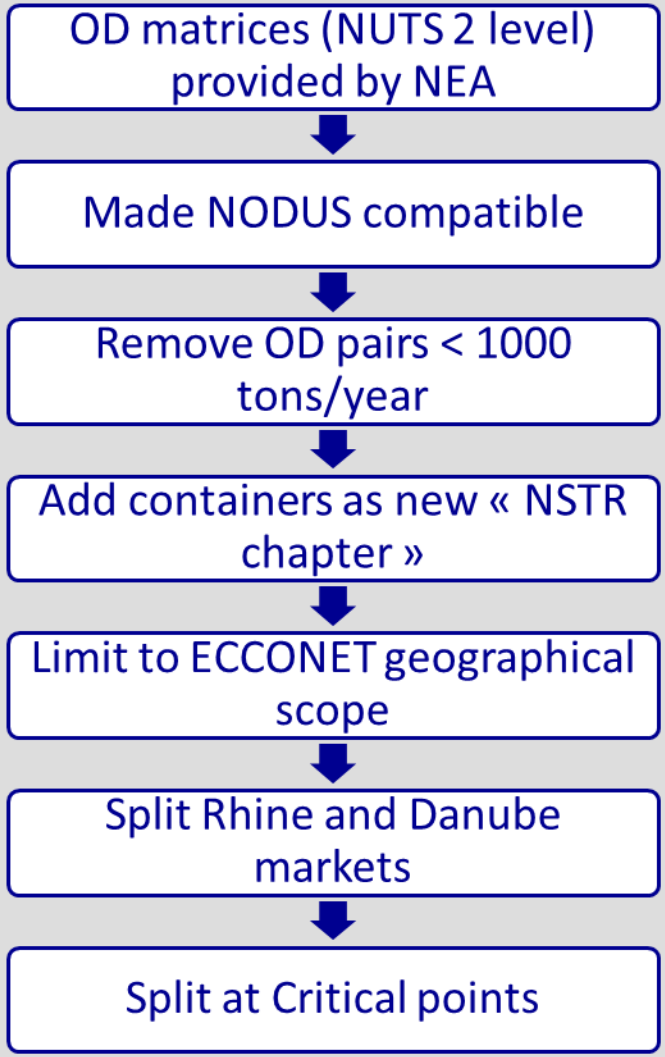
The GTM-NODUS transport model

- The usual transport models proceed in four steps for assigning the transport demands on a network: **generation, distribution, modal split and routing**.
- **NODUS allows a three steps approach**
- **It creates a complete virtual network** where all transport operations are represented by virtual links: loading/unloading, moving, use of a specific vehicle or vessel, transfers, operation of locks, etc.
- The assignment to (complex) transport solutions for each origin-destination is made through **minimization of the generalized transport cost** with respect to the choice of modes, means and combinations.
- Hence, the two steps of modal split and routing are joined together

Its results rely on inputs …

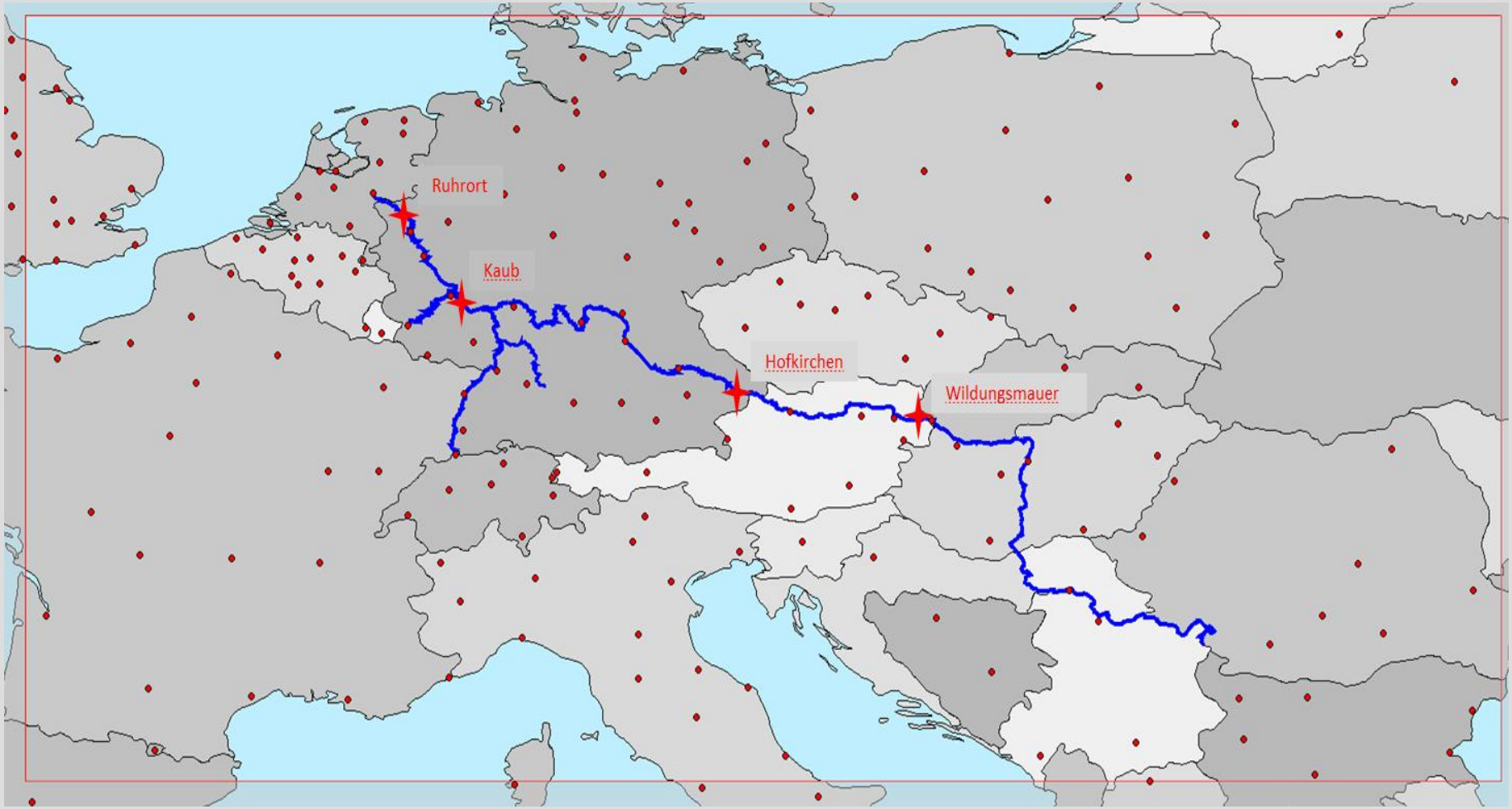
- … provided by different partners :
  - 2005 and 2050 estimated demand matrices: NEA
  - Cost functions: VU, NEA and DST
  - Climatic scenarios: BFG
  - IWW, Rail and Road European networks in 2005 and 2050 with EC TEN-T projects: UCL Mons
  - Network model (Nodus) : UCL Mons

Setting the Demand matrixes

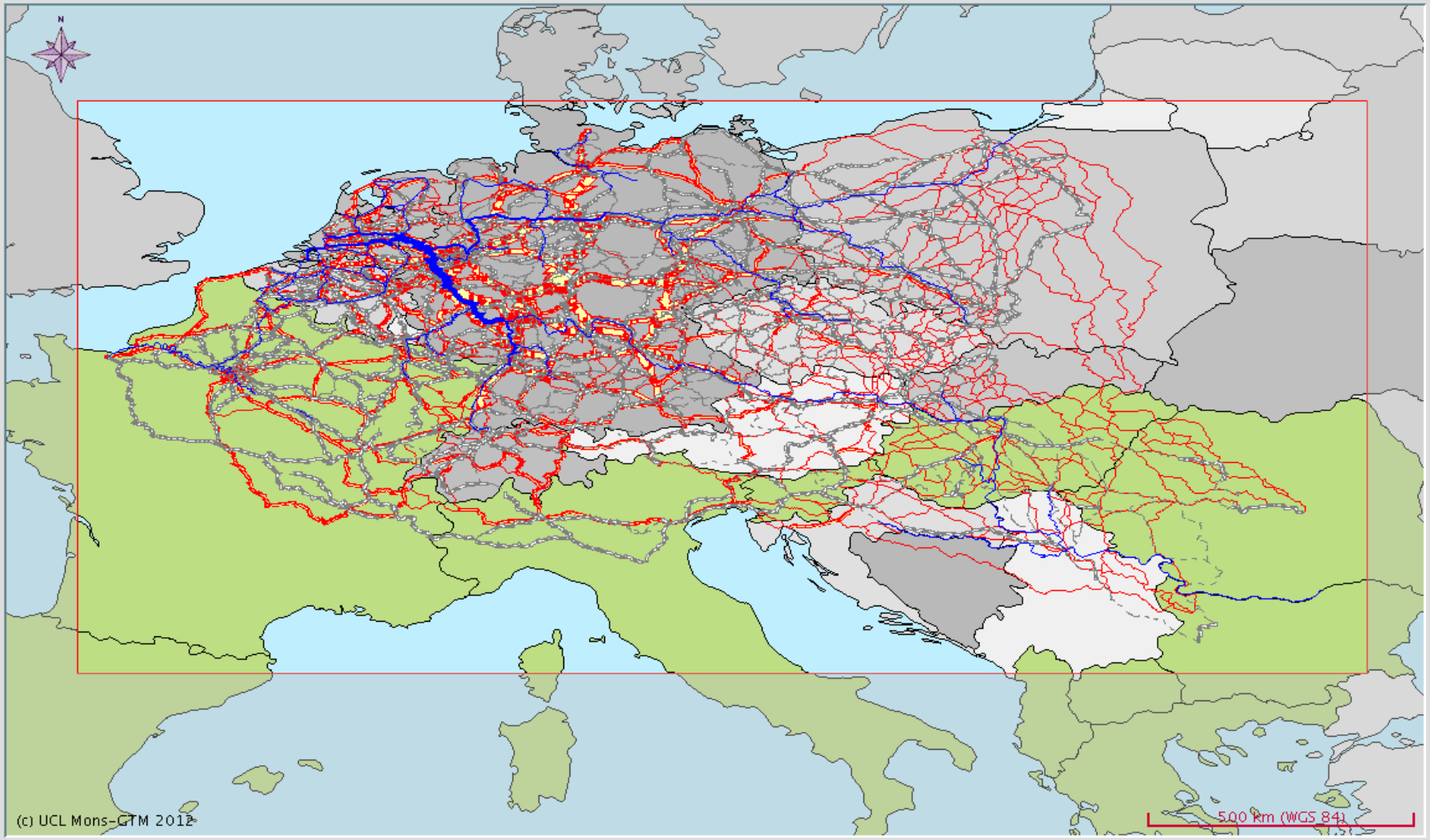


Geographical ECCONET scope

Restriction to ODs that could use the Rhine or the Danube rivers



Flows on the multimodal network



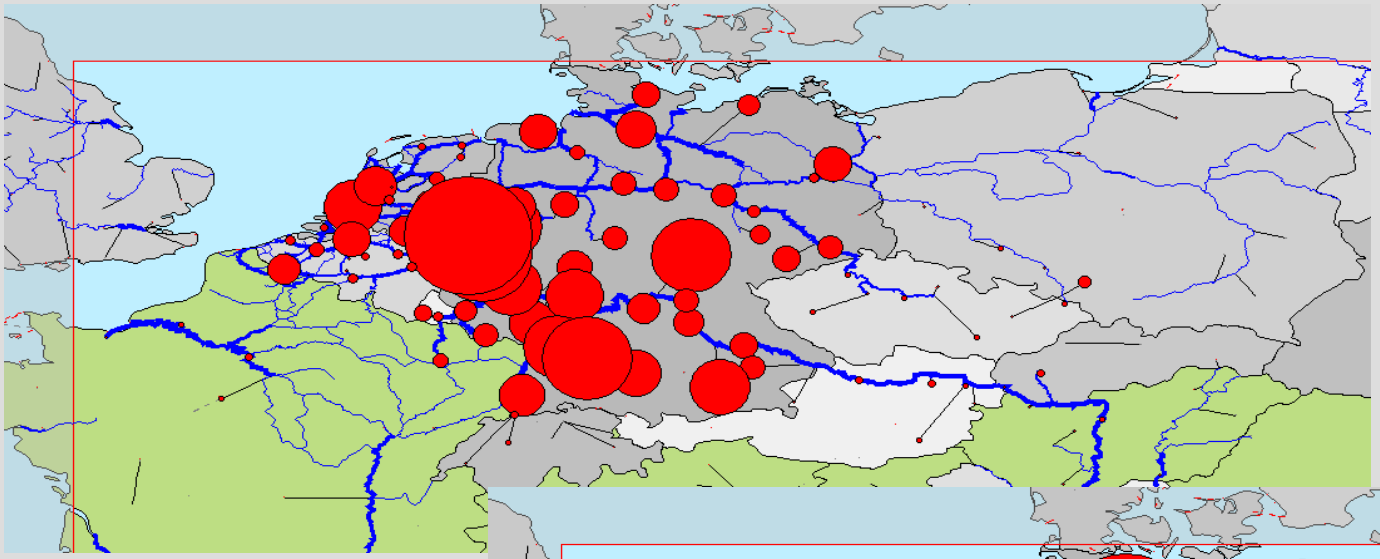
Rhine and Danube matrixes (2005)

Mode	Rhine (Million Tons)	Danube (Million Tons)	Shared traffics Included In Rhine (Million Tons)	% In Rhine's modes
IWT	140.26	**19.13**	**20.99**	14.97%
Rail	196.50	9.99	99.29	50.53%
Road	1,147.52	169.15	451.78	39.37%
Total	**1,484.28**	**198.27**	572.06	38.44%

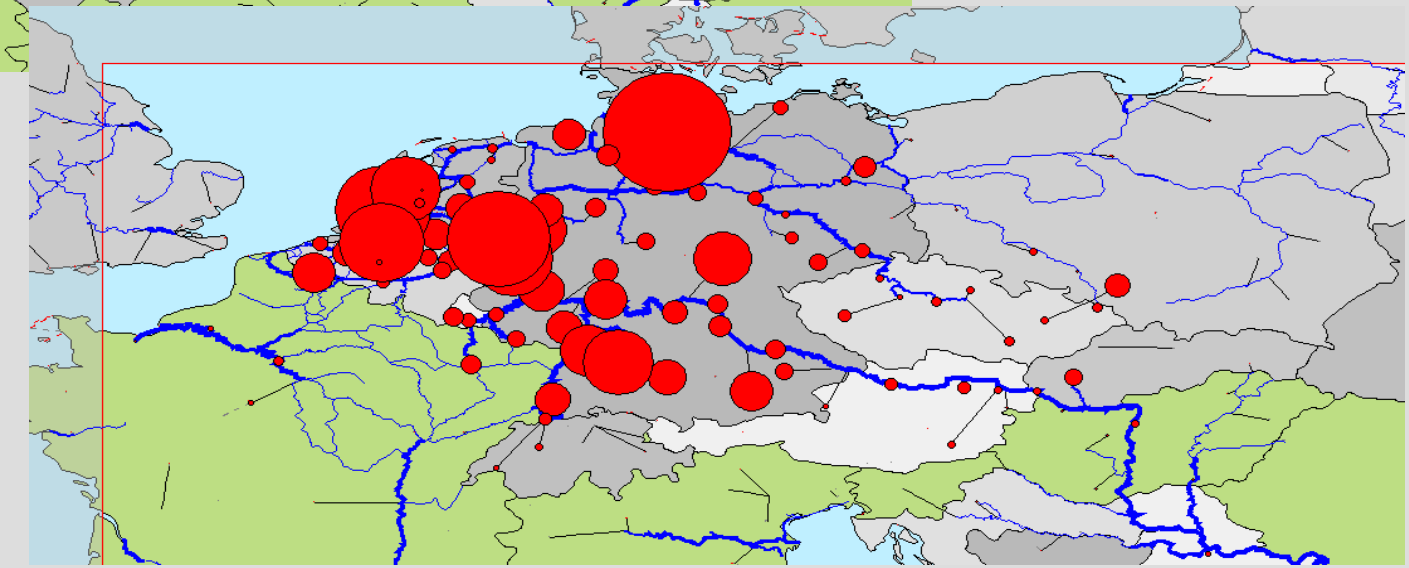
Trips on both the Rhine and Danube = Shared traffics are assigned to the Rhine market

Demand 2005 vs 2050 – Rhine market

2005



2050



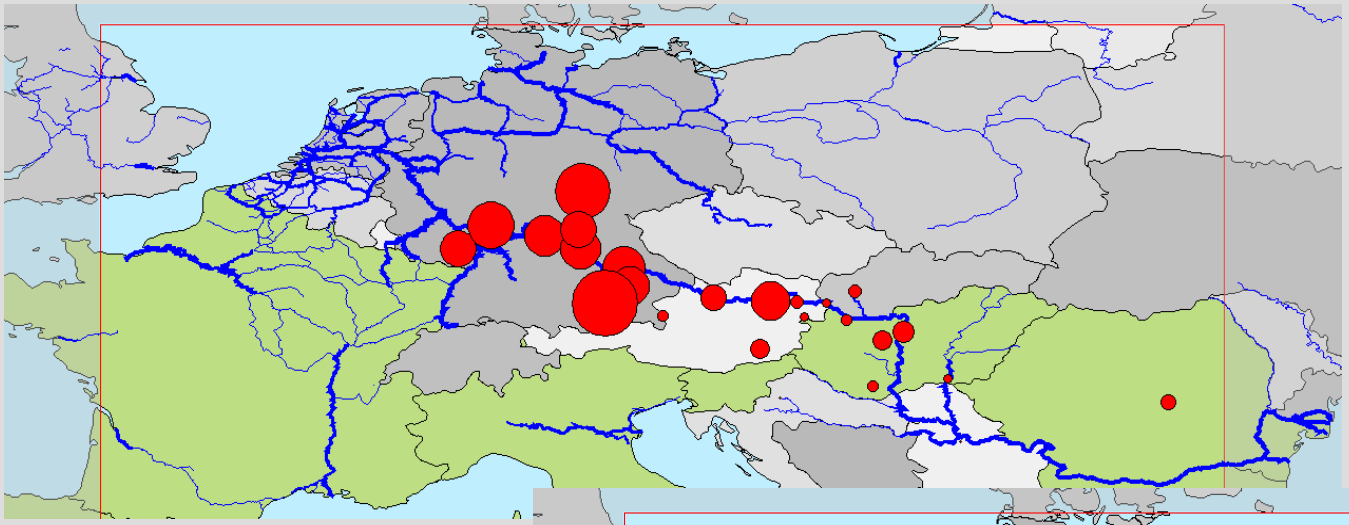
IWW share ↘

Rail share ↘

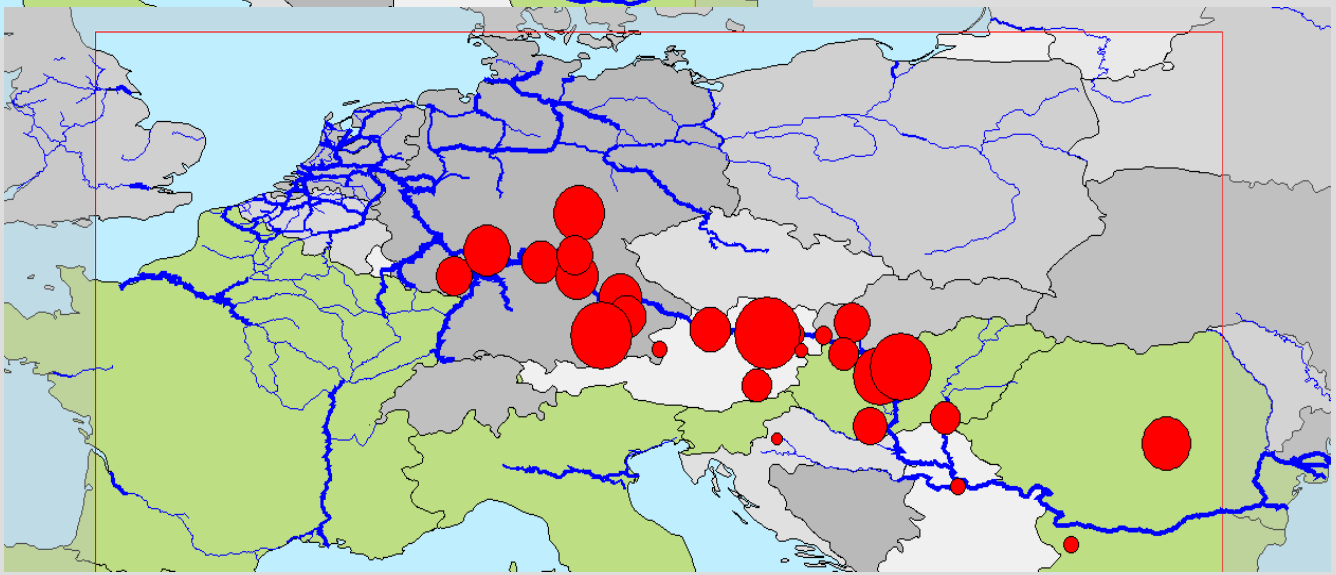
Road share ↗

Demand 2005 vs 2050 - Danube market

2005



2050



IWW share ↗

Rail share ↘

Road share ↘

TEN-T projects included for 2050

- **IWW 18**: Juliana canal upgrade to Vb + larger locks on Canal Albert and on Meuse (VIb);
- **IWW 30**: Compiègne-Creil + several projects on Oise and Leie (Vb), on Escaut and Condé-Charleroi(Va);
- **Railway 5**: freight Betuwe line (Rotterdam-Emmerich);
- **Railway 22**: upgrade Athina-Sofia-Budapest-Wien-Praha-Nürnberg/Dresden;
- **Road 7**: motorway Budapest-Constanza;
- Deepening projects of fairways between Straubing and Vilshofen, and East of Wien in Austria

Rhine market analysis

Costs functions :

Reference boats for CEMT classes II to VIb for Rhine navigation

CEMT class	Name	Length	Beam	Average max. draught	Average payload at max.
II	Kampine	55-55	6.6	2.50	600
III	Gustav Koenigs	80	8.2	2.50	1,080
IV	Johann Welker	85	9.5	2.80	1,560
Va	GMS 110	110	11.4	3.50	2,873
Vb	Coupling train GMS 110 + E II	185	11.4	3.50	5,292
VIb	Pushed train 2 x 2 E II	193	22.8	4.00	11,356

Rhine market analysis

Costs functions :

- two road functions with three speeds of 20, 40 and 80 km/h;
- two rail functions with three speeds of 25, 50 and 75 km/h;
- twelve IWW functions for the six classes of vessels.

Category of vessels	II	III	IV	Va	Vb	VIb
Upstream (km/h)	13.931	14.627	15.788	16.625	16.482	12.513
Downstream (km/h)	16.531	16.918	17.207	17.318	17.568	15.113

Rhine market analysis

Calibration of the NODUS model

- Comparison of observed modal shares with assignments for each of the 11 commodities.
- Cost functions are calibrated to take into account missing factors (behaviour of the shippers, etc.)
- Example: 2005 Rhine market with the multi-modal assignment

	Reference						Multi-Flow assignement					
	T			T.km			T			T.km		
	IWW	Rail	Road	IWW	Rail	Road	IWW	Rail	Road	IWW	Rail	Road
Total	9.45%	13.24%	77.31%	12.67%	18.97%	68.35%	9.90%	16.97%	73.12%	12.69%	18.60%	68.71%

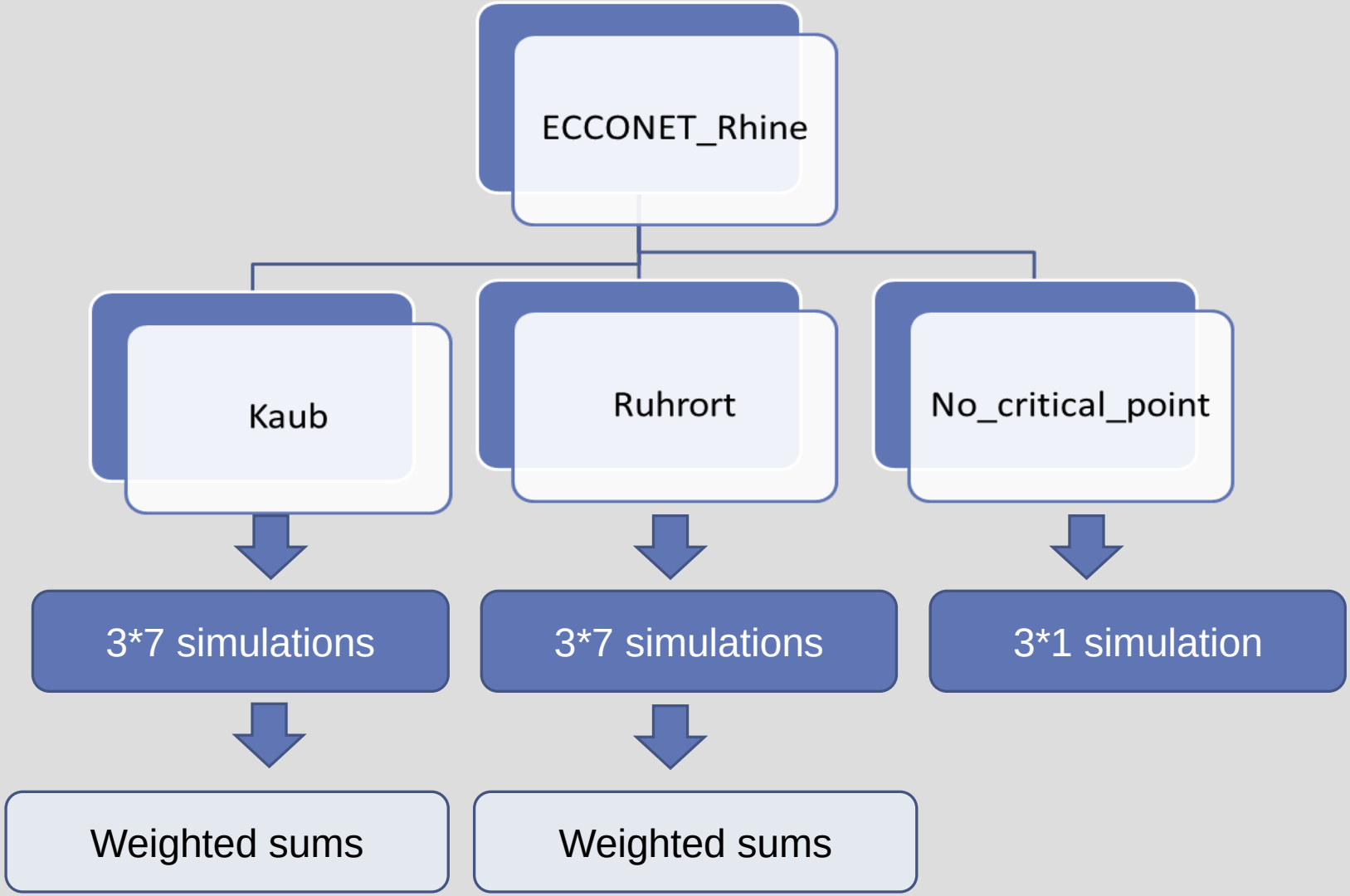
- Performance of the models: most correlation coefficients > 0.99

Climate impacts

- **Climates are defined over a period of 30 years**. The period **1977-2006** is used as reference for the 2005 climate situation, and the **2021-2050** period for 2050 climate situation.
- Two scenarios are considered: one **Dry** and one **Wet**
- BFG provided **average distributions of days at different water levels** at Kaub and Ruhrort, at Hofkirchen and Wildungsmauer, over these reference periods and for the two scenarios.
- DST derived a **relationship between the vessels' allowed draught and their loading**, which permits to compute the possible load and costs per type of ship.

Rhine market analysis

Impact of climate change - Rhine case



Rhine market analysis

Example for Kaub sub-sample (2005)

Water depth	Days frequency								Average cost per ton/km class Va Upstream Dry bulk	% Payload Va
	1993 (D2)		1989 (D5)		1985 (D10)		Average			
	Nbr	%	Nbr	%	Nbr	%	Nbr	%		
> 4.3 m	13	3.56%	10	2.74%	18	4.93%	**55**	**15.07%**	0.0122	100.00%
3.6<x≤4.3	80	21.92%	58	15.89%	94	25.75%	**97**	**26.58%**	0.0122	100.00%
3.1<x≤3.6	181	49.59%	170	46.58%	119	32.60%	**129**	**35.34%**	0.0136	84.00%
2,8<x≤3.1	90	24.66%	73	20.00%	30	8.22%	**55**	**15.07%**	0.0157	68.00%
2.5<x≤2.8	1	0.27%	37	10.14%	65	17.81%	**20**	**5.48%**	0.0180	56.00%
2.2<x≤2.5	0	0.00%	17	4.66%	28	7.67%	**7**	**1.92%**	0.0221	44.00%
1.8<X≤2.2	0	0.00%	0	0.00%	11	3.01%	**2**	**0.55%**	0.0333	28.00%
Total	365	100.00%	365	100.00%	365	100.00%	**365**	**100.00%**		

Rhine market analysis

Climate impact estimation for 2005-2050

Model relevancy evaluation

2050 demand and network impacts

Scenario	Mode	Observations 1977-2006	Climate scenario 1977-2006		Climate scenario 2021-2050		Climate scenario 1977-2006		Climate scenario 2021-2050	
		2005 Data	2005 Data		2005 Data		2050 Data		2050 Data	
			Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Average	IWW	10.82%	10.79%	10.82%	10.78%	10.84%	9.39%	9.42%	9.38%	9.45%
	Rail	16.67%	16.68%	16.67%	16.68%	16.66%	11.52%	11.51%	11.52%	11.50%
	Road	72.51%	72.53%	72.52%	72.54%	72.50%	79.09%	79.07%	79.10%	79.05%

Climate impacts if demand & network remain identical (2005)

Climate impacts if demand & network remain identical (2050)

Rhine market analysis

Climate impact on the use of ships (long term)

2005 Demands, Infrastructures and Costs			
Class of ship	Average **Dry** scenario (Million Tons)	Average **Wet** scenario (Million Tons)	Difference (%)
II	10.51	10.51	**0%**
III	19.03	16.69	**-12.28%**
IV	40.11	39.49	**-1.54%**
Va	34.37	36.51	**6.23%**
Vb	12.47	12.94	**3.70%**
VI	23.76	24.11	**1.48%**

Rhine market analysis

The deepening (20 cm) at the Kaub pass

Kaub sub-sample: Climate impacts simulations in 2005-2050 with average distributions								
Mode		Observed scenario 1977-2006	Climate scenario 2021-2050		Climate scenario 2021-2050		Climate scenario 2021-2050	
		2005 data	**2005 Data**		**2050 Data without deepening**		**2050 Data with deepening**	
			Dry	Wet	Dry	Wet	Dry	Wet
%	**IWW**	7.74%	7.66%	7.78%	6.93%	7.09%	7.05%	7.16%
	Rail	18.54%	18.57%	18.53%	12.91%	12.86%	12.88%	12.85%
	Road	73.72%	73.77%	73.69%	80.15%	80.05%	80.07%	80.00%
Million Tons	**IWW**	56.76	56.18	57.02	72.59	74.17	73.77	74.92
	Rail	135.98	136.20	135.90	135.20	134.66	134.85	134.49
	Road	540.62	540.98	540.44	839.09	838.05	838.26	837.47

Danube market analysis
Climate impact estimation for 2005-2050
Aggregated results

Climate impacts if demand & network remain identical (2005)

Mode		Observed scenario 1977-2006	Average Climate scenario 2021-2050		NEA forcast	Average Climate scenario 2021-2050	
		2005 Data	2005 Data		2050 Demand	2050 Data	
			Dry	Wet		Dry	Wet
%	IWW	9.62%	9.55%	9.57%	15.15%	15.10%	15.12%
	Rail	5.18%	5.21%	5.20%	4.56%	4.61%	4.60%
	Road	85.20%	85.24%	85.22%	80.29%	80.29%	80.28%
Million T	IWW	19.07	18.93	18.98	43.26	43.14	43.19
	Rail	10.28	10.34	10.31	13.03	13.15	13.14
	Road	168.92	169.00	168.97	229.34	229.33	229.30

2050 demand and network impacts

Conclusion

- **Limited climate impacts** : the expected climatic evolution up to 2050 is too weak to induce much change in the modal shares.
- **The changes in modal shares from 1977 to 2050 are mainly due to demand evolution:** the general economic evolution and its spread throughout Continental Europe.
- **Limited impacts of infrastructure projects on the modal shares** when assessed at a macro level all new infrastructures together. To a large extent this follows from the demands characteristics. This does not mean that these investments are not useful.

Thank you for you attention !

Questions?