WORLDWIDE CONTAINER MODEL

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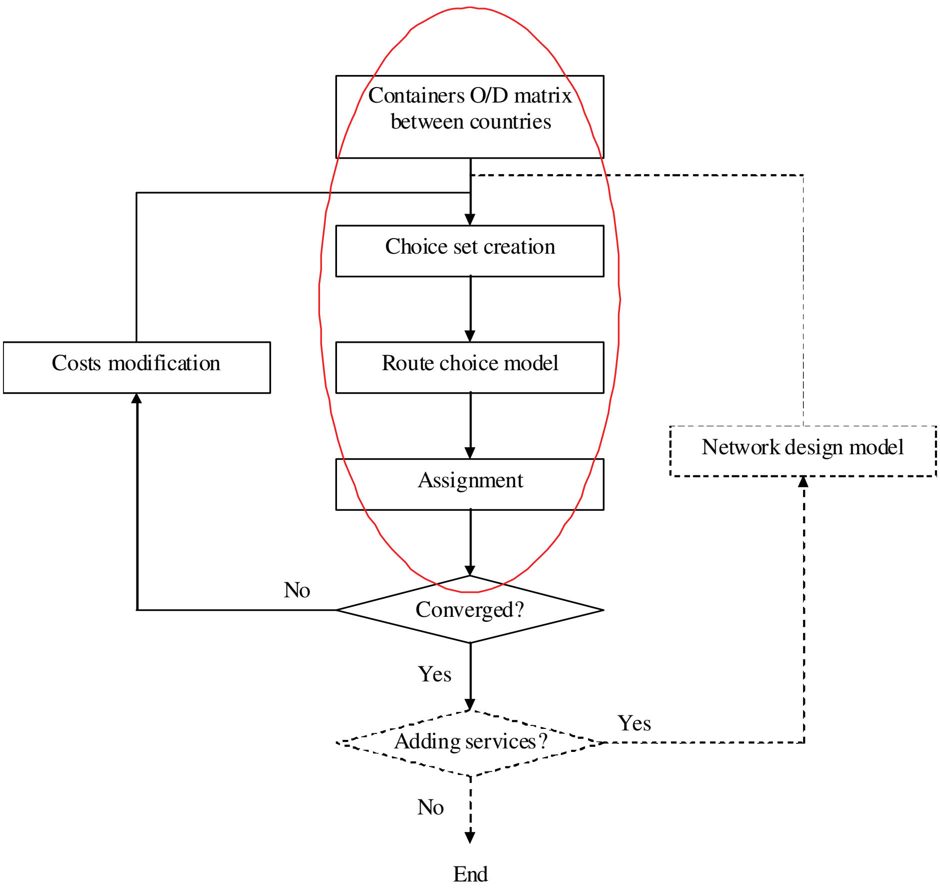
Model description

Overview

We aimed at developing a macroscopic model. One of the reasons is that there is no access to confidential information from individual shipping companies needed to create a microscopic model. Our idea is to model the port choice indirectly by picking a route from a choice set. We have based the choice set on the present service patterns in the maritime world. We have included the services provided by the maritime companies into the network, which we would like to call the super-network concept. Our objective is to develop a model in which the assignment techniques are applied to this network.

The model has a matrix of O/D flows of containers between countries as input. For each of this O/D pair a choice set is created. That means that a sample of routes between origin and destination is generated based on the available ports for the considered countries and a (k-)shortest path algorithm. When the different possible routes are created (a route is a succession of different service-links objects with transhipments available in ports), a route choice model is applied. This model is now a logit model, chosen for its simplicity. Later a path-size multinomial logit will be used in order to take into account overlapping. When the route choice is done for all the O/D pairs, the flow will be aggregated for each service. In the present prototype costs are fixed values instead of functions and the loop backs are not included. This allows an easier calibration of the model, as the costs do not depend of a former assignment.

Figure : Ultimate model structure and present model (circle)



O/D, Network and route choice model specification

The route choice model used is a logit model for the k-th shortest paths in a choice set given by

$$P_r = \frac{e^{-\mu C_r}}{\sum_{h \in CS} e^{-\mu C_h}} \quad \text{with } U_r = -C_r + \varepsilon$$

where

Pr is the choice probability of route r

CS is the choice set

μ is the scale parameter

U_r is the measurable (or systematic) part of the utility function of route r based on the following global cost of the routes:

$$C_r = \sum_{p \in r} A_p + \sum_{l \in r} c_l + \alpha \cdot \left(\sum_{p \in r} T_p + \sum_{l \in r} t_l \right)$$

where

r is the considered route

p are the different ports used by the route

l are the links used by the route

A_p is the out of pocket cost of port calls

c_l is the cost of link l

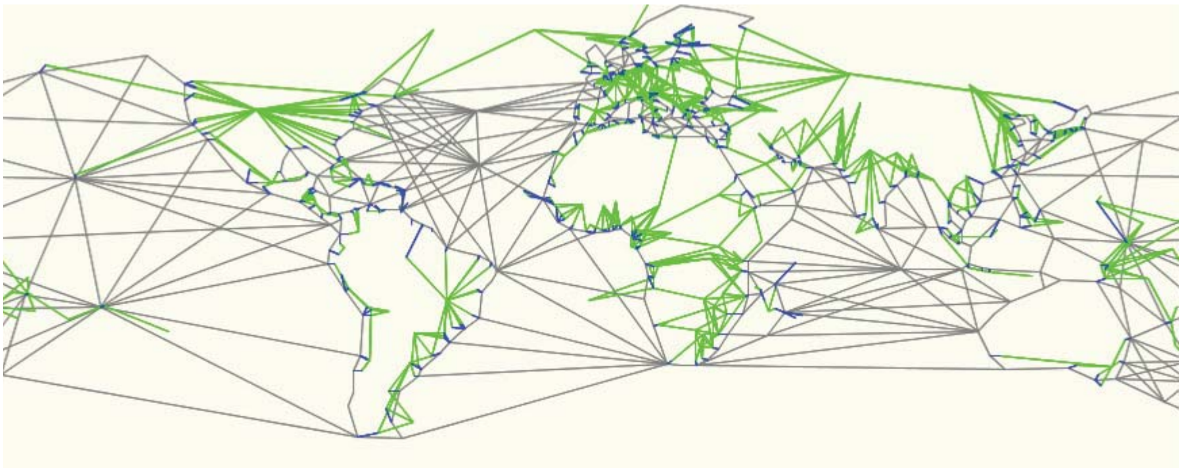
T_p is the time spent at port p

t_l is the time spent during link l

α is the value of the time

The network is composed of the worldwide maritime network and main inland transport links.

Maritime network and its access



We have used three different databases in order to create the input O/D flows. We first have used a United Nation database of exchanges between countries in $ and ton. We have used this database for its scope: it's a worldwide base. However, we need to convert metric tonnes in TEU (Twenty foot Equivalent Unit). That is the reason of the second database, a Eurostat one. The area covered is a bit narrower, but information on the exchanges in ton, unitised ton and TEU are available. This database allows us to calculate a ratio of unitisation: number of ton potentially unitised divided by the total number of ton and another ratio of "density": unitised ton divided by TEU. These two ratios were calculated per type of goods and OD pair. We applied them to the UN database. When some ratios were lacking, we used averages ratio per OD and/or type of goods. We now have obtained all the flows from country to country, but only for the containers with goods in it. It lacks the empty ones. The last database of Eurostat concerns maritime transport[2]; this shows for each OD pair the number of TEU empty and full. This also allows us to calculate a percentage of return of empty containers. As before, we have applied them per OD and type of goods.

Description of the database used

Database	1	2	3
Source	UNCTAD	Eurostat	Eurostat
Area	World	Europe-World	Europe-World
Type	Trade	Trade	Maritime
Units	ton, $	ton, U ton, TEU	TEU
Categories	Yes	Yes	No
Empties	No	No	Yes

Calibration

In order to calibrate the model, we have considered the out of pocket costs of a port call as an unknown parameter. We have made the modification of these costs by using the Newton algorithm. The considered function used for the algorithm is the difference between observed and calculated flows for each port:

$$\sum_{r \in Port\_set} P_{r_{ODpair}} \, . \, F_{ODpair} - F_{observed}$$

where

Port_set	the set of routes (r) using the considered port
$P_{r_{ODpair}}$	the probability of using route r in its OD pair set of routes
F_{ODpair}	the flow in TEU of the OD pair
$F_{observed}$	the real flow

The only difference with a classical regression is that we regenerate the routes choice set after each calibration. As the routes are created with an economical shortest path algorithm based on generalized costs (in order to take transhipment and value of time into account), we have to regenerate them when the costs are modified.

The European sea port association gives some figures of the number of TEU handled in 2005. We have compared them with our results:

Comparison of ESPO and our model flows (without distinction of the types of goods)

Source	Total port handling	Port to port - Full	Port to port - Empty	Transhipment
ESPO	399	231	59	108
Observed flows[3]	407			
Input data[4]		360	66	
Output data	400		74[5]	145[5]

What can be seen from this table is that the TEU observed (and used for the calibration) is in line with the ESPO data. The input flows of the model are higher than the ESPO data (empty and full), but they also include flows that will use inland path. For the output, the total number of TEU handled is correct. After the calibration of the spread factor μ and the cost parameters, the difference between observed and calculated flows at port level is relatively small. The sum of the absolute differences for all the ports divided by the total flow is under 10 %. Also the model shows a coefficient of variation (R^2) which is very satisfactory: it explains more than 98% of the variation in the ports' throughputs.

Case studies

Landbridges between Asia and Europe

We have introduced another service which represents the Trans-Siberian inland bridge. This service goes form Shanghai to Hamburg and comes back in 34 days. We have use this transit time in order to match the test performed by ERS (European Rail Shuttle) or the Deutsch Bahn. As the distance from Hamburg to Shanghai is about 8 500 km, the average speed of the service is near 500 km / day. We have created one weekly service like the maritime ones. Containers can also tranship at Hamburg or Shanghai and then use the Tran Siberian link.

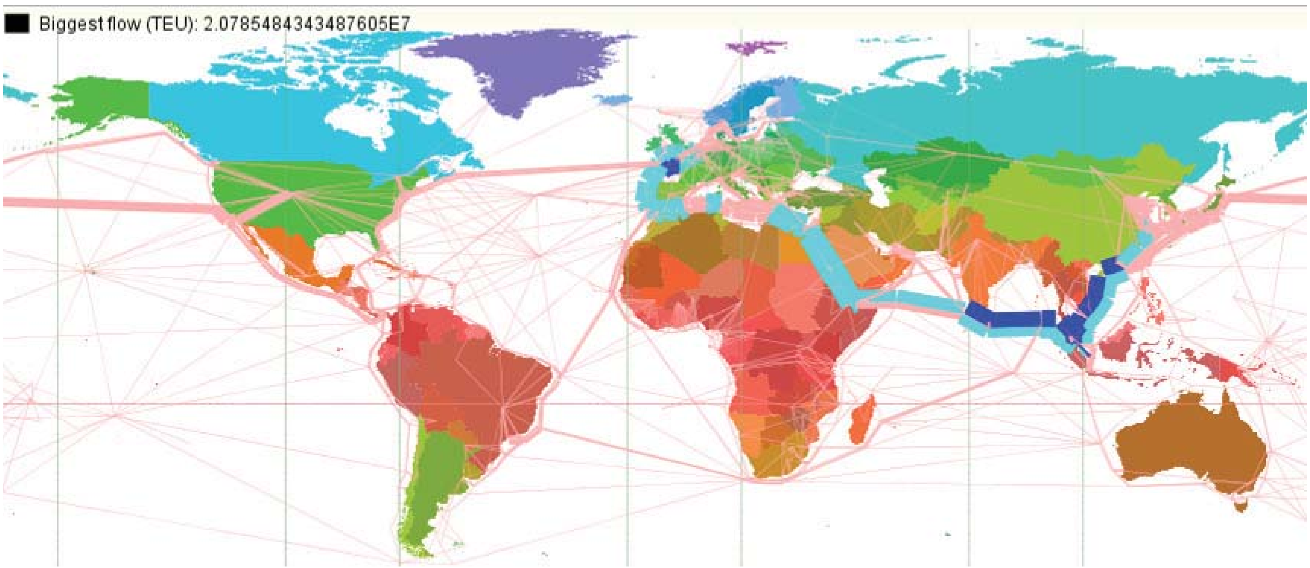
We have tried to charge different cost per km per TEU varying from 3 x 0,81 / 1,42 (equivalent to the inland cost applied in Asia) to 0,5 x 0,81 / 1,42 (half the cost applied in Europe):

Utilization of the Trans Siberian link for different prices

Cost / TEU / km	Link cost	Total flow E ☐ W	Total flow W ☐ E
3x0,81/1,42	14 596 $	51 889	73 465
2x0,81/1,42	9 731 $	53 482	74 389
1x0,81/1,42	4 865 $	538 323	231 133
0,8x0,81/1,42	3 892 $	974 069	328 319
0,5x0,81/1,42	2 432 $	2 765 756	1 295 090

We can see that the utilization of the link is relatively well sensitive to its price. We can also notice that the flows are more important from Asia to Europe.

Global flows with Trans-Siberian service with a cost of 0,81 / 1,42 $ / (TEU . km)



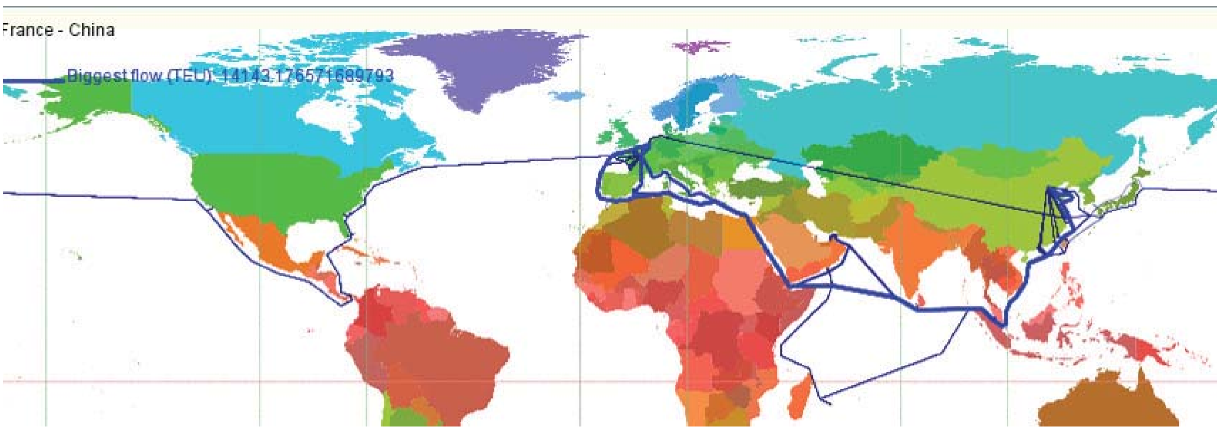
The proportion taken from this route in each OD pair route set differs for each European country depending on its distance to Hamburg. For example, France which has no direct inland link to Hamburg into the model can use a maritime service to reach this port before taking the Tran Siberian link. Sometimes, only having this maritime access is not realistic. The place of the routes using this link for different OD pairs' route sets is shown in the following table:

Comparison of Trans Siberian routes with the others of the same OD, with a cost of 0,81 / 1,42 $ / (TEU . km)

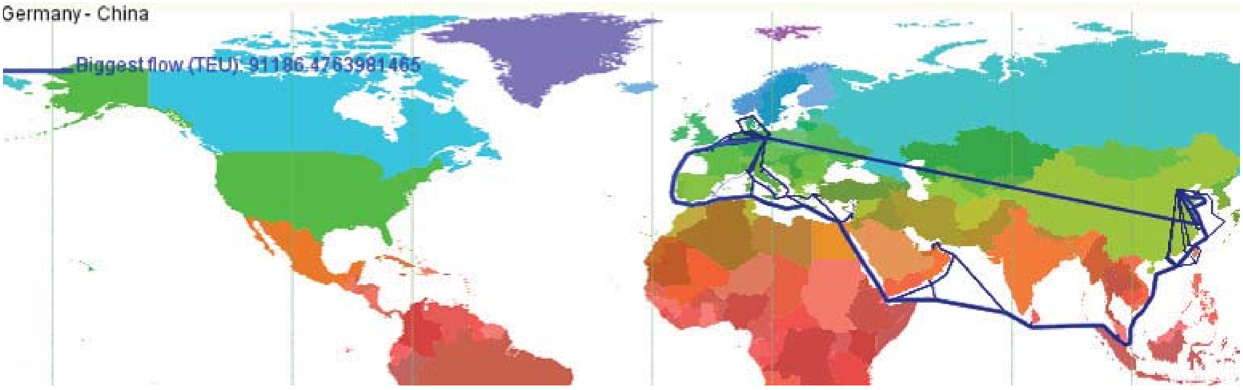
From	To	Number of routes	Global average cost	Tran Siberian cost	Global average time	Tran Siberian time	Tran Siberian flow	% of total flows	Tran Siberian empty flow	% of total empty flows
Germany	China	168	8 177	11 019	29,8	24	75 415	12,33%	1	0,00%
France	China	182	6 008	10 262	35,9	23	80	0,04%	0	0,00%
Belgium	China	112	6 655	9 516	28,9	22	3 253	1,70%	0	0,00%
Netherland	China	56	6 808	10 449	27,9	23	0	0,00%	0	0,00%
Poland	China	84	12 598	13 236	30,3	28	6 875	24,31%	9	0,06%
Luxembourg	China	126	6 522	9 574	29,3	23	115	1,95%	0	0,00%
Austria	China	112	6 216	8 911	31,8	23	4 074	15,29%	0	0,00%

We can see that globally the cost of the routes using the Tran Siberian link is higher than the one of the others routes. On the other hand their transit time is lower. With this price the Trans Siberian routes are taking a non negligible place in three countries of our set for their relation with China: Germany, Poland and Austria. We can also notice that empty flows use less this link than full containers. The explanation remains in their value of time, which is lower.

Route set and flows between China and Germany with inland link



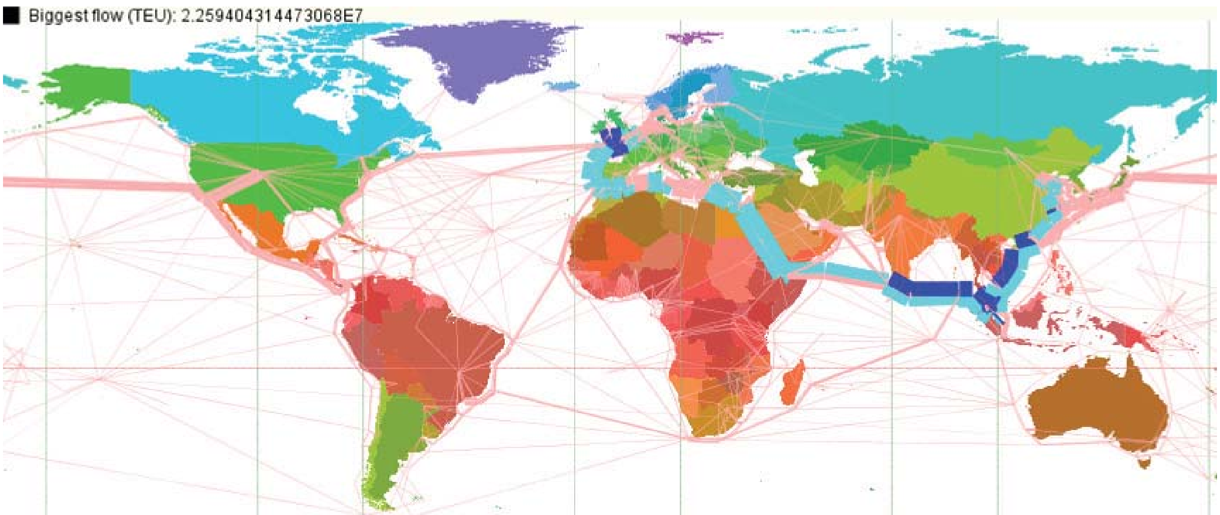
Route set and flows between France and China with inland link



Increase of inland costs

We have doubled all inland costs in order to observe if there are changes in the number of TEU handled by different ports. The total number of TEU handled by the ports is 33 M TEU higher with a total of 435 M TEU. This increase is mainly due to more transhipment and "short sea shipping", with 31 M TEU movements created. The other 2 M TEU are modal report from inland mode to maritime one. The total increase (transhipment and modal report) for empty container is 4 M TEU high and 29 M TEU for full ones. The new map of the flows is the following:

Map of the maritime flows with inland cost doubled



We also would like to find out if there are more maritime flows or not and/or some reports form one port to another. The following table compares the increased inland costs situation with the reference scenarios for a selection of ports:

Port	Difference of transhipped flows (in TEU)	Difference of total flows (in TEU)
Hong-Kong	4 905 411	5 075 003
Singapore	-377 979	-1 126 165
Shanghai	11 760 426	3 914 038
Ningbo	4 791 480	2 031 244
Pusan	740 196	-1 384 241
Tanjung Pelepas	120 356	-398 340
Port Klang	966 298	3 130 245
Rotterdam	658 261	543 520
Antwerp	471 092	449 371
Le Havre	10 494	281 075
Bremen	420 350	463 117
Hamburg	512 062	1 492 104
Gioia Tauro	333 548	111 975
Valencia	220 748	639 296
Felixstowe	0	13 193
New York	137	375 019
Norfolk	16 246	-1 083 777
Charleston	-15 347	-915 055
Savannah	2 390	-875 359
Long Beach	430 491	2 308 065
Oakland	-38 772	-854 631
Baltimore	0	-186 432
Montreal	1	312 508

What can be seen is that for all European ports, the flows are a bit higher, with Hamburg meeting the biggest increase. The increase is due to both transhipment and modal report. In Asia, Singapore encounters a great decrease which is mainly due to the fact that Malaysian flows are using a closer port to the country dot, namely Port Klang. The ports with the highest number of services calling have gained transshipped flows: Hong Kong, Shanghai, Ningbo. Singapore is the only exception. Beside another factor the distance to the country dot interferes. Pusan and Tanjung Pelepas are more distant from their country dot than others ports. They have gained transhipped flows but lost local ones. In America, the difference for the transshipped flows is relatively small (except for Long Beach). The main driver is the distance to the country dot. In that case, a more detailed network for the USA will lead to more accurate results.

Conclusion

We have described a working prototype model for global container network movements. It uses the publicly available databases and a simple route choice model to assign container flows over a network including ports and inland transport links. The model was calibrated and found to provide a satisfactory fit with observed counts of container throughput in ports. The model has allowed us to make some simulations. The results of the different case studies give inside in the effects of a number of major expected changes in transport conditions on port choice and the possible evolutions of the maritime system.

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Notes

[1] By strategic we mean that the networks contain the services and ports of worldwide scale, connecting continents and individual states. Networks at national level and below are not detailed.

[2] The drawback of this database is that the flows considered only take into account the maritime part of the trips. We do not have any information on the exchanges of a country with no maritime boundary and port.

[3] Sum of the number of TEU handled by all the ports of our set in 2005/2006.

[4] Conversion of UN data from tons to Utons and to TEU: also include inland flows.

[5] Also include empty container transhipped.

DISCUSSIEBIJDRAGE

M. Kraan, TRAIMCO

Discussiebijdrage bij: **Worldwide Container Model**, door L.A. Tavasszy, J. van Meijeren, M. Minderhoud, A. Burgess, N. Bowden, J.-F. Perrin.

Inleiding

In dit paper wordt een beschrijving gegeven van de ontwikkeling van een model dat uitspraken doet over de mondiale vervoerstromen van containers. Het model is in ontwikkeling. Een eerste versie, gebaseerd op beschikbare data en zonder allerlei terugkoppelingen is beschikbaar. Uit callibratie blijkt dat de omvang van containerstromen en –overslag redelijk lijkt. Met het model is een aantal cases doorgerekend om gevoel te krijgen voor de huidige werking.

De paper bevat een heldere en duidelijke beschrijving van het model en de bedoelde resultaten. Het is interessant om te zien hoe de verder ontwikkeling vorm gaat krijgen. Deze discussiebijdrage is bedoeld in dat licht: een bijdrage te leveren aan de verdere ontwikkeling.

Hoofdbijdrage

Er is een heel belangrijk punt voor de verdere ontwikkeling van het model, en dat is dan toch de beschikbaarheid van gegevens die het al dan niet mogelijk maken in meer detail het model te ontwikkelen en terugkoppelingen te introduceren. Hier heeft in het verleden wel vaker de crux gelegen van de ontwikkelingen van containermodellen (wel voor meer vervoermodellen, maar containers spannen de kroon).

Hoe denken de opstellers over de beschikbaarheid van gegevens versus het gewenste detailniveau op termijn van dit model? Is er voldoende geld beschikbaar om data te zoeken en verder te verrijken? Wanneer zijn de achterliggende partijen tevreden over het detailniveau van de mogelijke antwoorden van het model?

Ik waardeer enorm de opbouw die nu gekozen wordt, want op deze manier wordt stapsgewijs duidelijk wat het model wel en niet kan. Dat is van enorme waarde. Zorg dient uit te gaan naar het verder managen van de verwachtingen. Ik heb grote zorgen over databeschikbaarheid voor de verdere ontwikkeling.

Detail-bijdragen

Bij het lezen van de paper heb ik nog de volgende opmerkingen/vragen:

- Aan welke terugkoppelingen in het uiteindelijke model wordt gedacht: terminal handling, port availability, berth capacity, ….
- De Value of Time voor varen is gelijk aan die voor wachten. Wat is hiervan de logica?
- De prijsgevoeligheid is nu gigantisch (met een duidelijke sprong wanneer de sealinks de meeste landlinks verslaan, maar ook beneden dat niveau is de gevoeligheid veel groter), welke impact gaan de terugkoppelingen hier op hebben?

Mijn bijdrage moet gezien worden als een bijdrage aan het mogelijk maken van de verdere ontwikkeling van dit model, ik vind het goed om te zien dat er zo open over de beperkingen en mogelijkheden van deze versie wordt gesproken, dat zou de basis moeten zijn van elke modelbespreking!!