A THREE-STAGE MODELING APPROACH FOR THE DESIGN AND ORGANIZATION OF INTERMODAL TRANSPORTATION SERVICES

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ABSTRACT

During the past decade containerized intermodal transport has gained in importance as a competitive alternative for the growing road transportation reducing (road) congestion and environmental pollution. The Ministers of Transport, as the Members of the European State Union, try to coordinate at macro level the development of intermodal transportation networks in their plan 'Trans European Networks'. In contrast to this plan the practice of terminal development and intermodal transportation initiatives seem to develop more whimsically. Due to the small profit margins in transportation the perspective of transportation entrepreneur is strongly focused on the profitability of new intermodal transportation services. We have developed a modeling approach which is stronger connected to the various perspectives of the transportation entrepreneurs and the shippers. The first stage in the approach supports the location choices of potential intermodal terminals. The formalization is based on a linear programming model minimizing the integral transportation costs.

1. Railway or water infrastructure permitting, the model decides on the basis of regional transportation demands whether it is more efficient to service by intermodal transportation or by road transportation.

2. When the rough locations of terminals are identified in a region, a second model is applied to search for the exact location in the region. The preference locations are determined on the basis of their infrastructural unlocking possibilities. A detailed cost model is developed to support this exact location decision.

3. The last part of this approach is focused on the possible customers in the neighborhood of the terminals. Analysis of suitability, timeliness, and deliverance reliability of goods are factors of logistic importance. These aspects of integration both for the terminal and its customers are specified by a simulation model.

The approach contains feedback-loops to learn from more detailed insights and has been successfully applied for two new terminal locations.

1. INTRODUCTION

Although 'Transport is in motion' seems to be a superfluous statement, the last decade transport policy is a number one on the political agenda. After the appearance of the Dutch national program for traffic and transport[1] themes like accessibility and livability have become main issues in the development of sustainable society. One of the important policy strategies in order to meet elements of sustainable society is the modal shift of road transport to more environment-friendly modes like railroad, coast and barge transport. To compete with the road transport these transport modes are multimodal setup as intermodal transportation services with pick-up and delivery service by truck. According to a U.S. General Accounting Office report ‘...the trucking industry also provided flexible, reliable, and economical service, but the growth of trucking has contributed to concerns about safety, congestion, pollution, and highway deterioration’[2]. Due to these facts, also actual in Europe, the attention of the Ministers of Transport for intermodal transportation is increasing and several policy documents have been published about this subject[3][4][5].

At different levels of policy making, i.e. the European level, the national level, and the regional level, we notice an ambiguity of plans for stimulating intermodal transport. At each level policy makers base their own plans for intermodal transport focusing on different goals. The integration of these plans, as well as the attention for the stakeholders, seems to be forgotten. Therefore, the practice of intermodal transportation seems to develop more whimsically, and not as aspected in the policy plans.

This paper deals with a methodology which is closer related to the perspectives of shippers, terminal operators, agents, consignees and carriers. After the description the intermodal transport concept in paragraph 2, a new approach for transportation modeling and logistics modeling is discussed. Paragraph 3 forms the application of this new approach and the related actor-perspectives in this paragraph. Based on these insights we describe the developed models. The last paragraph contains conclusions and our ideas about future research on the methodology.

2. A NEW MODELING APPROACH FOR INTERMODAL TRANSPORTATION

Intermodal Transportation

For the description of intermodal transportation we refer to the description of the European Conference of the Ministers of Transport: 'the movement of goods in one and the same loading unit or vehicle, which uses successively several modes of transport without handling the goods themselves in changing modes'[6]. The general logistical practice for intermodal transport handles as follows:
are mainly based on operational research techniques. The traditional policy making for transportation and logistics seems to have still a favorite position. Modes is still focused on price. As we can see in table 1 road infrastructure or equipment involved with the freight movement, but the process, which becomes a major component of the systems approach to business[7]. For destination overseas one of the terminals is located at a port. The break-even distances for intermodal transport in relation to road transport are as follows

<table>
<thead>
<tr>
<th></th>
<th>Barge</th>
<th>Rail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continental Containers</td>
<td>250</td>
<td>400</td>
</tr>
<tr>
<td>Overseas Containers</td>
<td>100</td>
<td>200</td>
</tr>
</tbody>
</table>

Table 1: Break-even distances (in kilometers)[8]

Although transport has grown in importance due to the rise of more just-in-time-oriented logistics, i.e. the value-adding functions time and place, the competition between transport modes is still focused on price. As we can see in table 1 road transport seems to have still a favorite position.

The traditional policy making for transportation and logistics are mainly based on operational research techniques. Mulvey[9] indicates that these techniques are poorly understood by the general public. A translation of the technical issues like assumptions into 'plain English' is usually necessary. 'Great strides have been made in the use of optimization. Models with thousands of variables and constraints are being solved regularly and the results are being applied routinely. Still we need to do a better job in making optimization easier to use and in making solutions meaningful to all types of stakeholders'[10].

A New Modeling Approach
As Vidal and Goetschalckx[7] mentioned in their critical review on models, some research opportunities for developing more comprehensive modeling should focus on:
- general simulation of qualitative factors;
- environmental conditions, such as availability of infrastructure, determination of adequate local excess capacities;
- modeling of alliances and multi-company network configurations; and
- development of specialized solution methods.

Of course, it is almost impossible to develop a general single model that integrates all these aspects. The conclusion leads to the development of an overall methodological transportation framework, supported by multiple interrelated models capable of representing qualitative factors and uncertainties. The development of an approach to build these interrelation models must fill the gap between logistic decision processes on the one hand, and the specification of the design contents on the other hand. The new models must be easy to use and understand, with user-friendly capabilities, such as graphical representations of the systems under analysis. Sijbrands[8] clarifies that the task to support strategic logistic issues seems to be simple; however, the way to process and support is the main research objective to be tackled in future.

Dynamic Actor Network Analysis(DANA)
The approach starts with the description of the multi-actor situation. For that purpose, we developed an actor modeling language, which supports the representation of different actor-perspectives[11]. In general, there is no lack of theoretical notions of networks and actors within the policy science. However, there is a lack of practical aid for empirical research on basis of the actor-model and its network-approach. A simple and accessible (ICT-supported) policy-technology for research into networks and actors is in fact still absent[12]. Every actor perception is modeled in terms of factual, causal and teleological assumptions. The factual assumptions represent how an actor perceives the current state of his environment. The causal assumptions represent which changes will occur in the perception of the actor. A causal scheme is a possible representation, but the language supports these relations using if-then commands. The last type of assumptions are the teleological assumptions, which represents the actor’s view on his desirability. Both the causal assumptions and the teleological assumptions are interpretations, respectively the relations and weights of importance, of the actor on factors. Because of the formal description of these perceptions in a database, several queries can be executed. For instance, a question like which actors have conflicting goals on a specific factor or use different definitions for a factor, could be brought to our special attention in the design of the logistic concept.

Performance indicators
The perception-based factors are the normative values of the performance indicators and form the connection to the design of the logistics concepts. The connection is implicit in the definition of a performance indicator: ‘Performance indicators are quantifiable factors which enables a company to measure performances in relation to a pre-defined norm’[13]. In our approach the pre-defined norm forms the normative element which reflects the perception of an actor on a factor. The value part of a performance indicator can be derived from the process modeling of the logistics and transportation. Finally, the measurement of the value part against the normative part forms the definition of the performance indicator.

Transport modeling
The last part of our approach is directed towards the calculation of the value-parts of the performance indicators. Subject to the appointed factors of importance in the network analysis, interpreted from the analyst’s perspective, special models are being developed to measure the impact of various conceptual variants. The great challenge is to develop a model at such a level which is, on the one hand comprehensive and easy to understand for the actors involved and, on the other hand, sufficiently detailed to validate on practice.
With the aid of Dynamic Actor Network Analysis, three specific arenas can be identified in which actors play their part in relation to transport. Each arena can be seen as a level of consideration in which actors are relationally joined. Each perspective of an actor on intermodal transportation is given in terms of goals and instruments. Due to this insight of these perspectives in the specific arenas we have developed three different models. Each model is developed in such a way that it seeks for solutions, taking into account the main performance indicators of the arena.

The European Level

The first arena is oriented at the actors playing a part in the European hinterland. The main borders of this area stretch out from the sea-ports: Le Havre, Zeebrugge, Antwerp, Rotterdam, Bremen, and Hamburg to several European hinterland terminals, such as Milan, Metz, Munich etc. The main actors involved are shippers, European Ministers of Transport, road carriers, intermodal agents and their carriers. Many shippers have changed their distribution structures as a result of the removal of trade barriers. Due to the costs reducing opportunities many stock-holding units have, in their distribution structure, been eliminated or outsourced. To maintain the same reliability just-in-time deliveries have become more important. Therefore a growth in transport, mainly conceived by road carriers, has been inevitable and has caused, in interaction with motor traffic, congestion on important highways. The congestion negatively influences the total transport time for delivery, the reliability of the delivery, and, eventually, the costs. For this reason the shippers are not unwilling towards new intermodal transport initiatives. Besides this reason, some shippers strive for a ‘green’ company image by choosing environment-friendly transport like intermodal transport. There are still some obstacles in the eyes of the shippers which have to be solved. Their main concern is the current price of intermodal transport.

Another point for improvement is the number of intermodal destinations in the European hinterland. The total number of terminals connected by water and/or rail infrastructure is still too limited regarding the enormous supply and flexibility of road transport. The European Ministers of Transport try to draw up plans for the development of Transport European Networks (TENs)[12]. These plans are focused on integration of the transport modes and define the transport networks in hubs and spokes. At hubs fast transshipment should be facilitated and subsequently transported by the spokes. The integral management of the transport at a hub consists of physical transport infrastructure, traffic controlling systems, positioning systems and navigation systems. The European Ministers of Transport try to coordinate and stimulate the infrastructural developments of each country in the direction of the plans for TENs. They do not have an explicit disposal for steering instruments on national governments, but they can stimulate some developments by providing subsidies. The intermodal agents and carriers have already established intermodal transport services for long distance haulage. Thick maritime container flows are transported by these agents from harbors to far locations in the hinterland (for example from Rotterdam to Milan). Facing the break-even distances it is possible for the carriers to exploit profitable transport services. So far it seems impossible to collect thick container flows for short distances. Because of their strong competitiveness, price and flexibility, the road carriers still have the greatest market share as to transport in Europe. The internal competition between road carriers is strong and therefore many carriers operate break-even or less than break-even. As in other lines of business merges, takeovers and creating alliances are daily news and should be interpreted as a matter of strategic management to survive in the long run. Some road carriers experience hindrance caused by some measures of national policies which aim at reducing the truck traffic. For instance, in Switzerland and Austria truck traffic is forbidden and all trucks are placed on trains.

The National Level (Dutch)

The national government is represented by respectively the Ministry of Transport, Economic Affairs and Environmental Affairs. All the ministries show a strong compassion for the development of intermodal transport. The Ministry of Transport tries to stimulate intermodal transport initiatives to maintain accessibility of important economic centers. The rail and water infrastructure still has enough capacity to adapt more traffic on these modes. The environment-friendliness of these modes appeals to the ministry of environmental affairs. The Ministry of Economics Affairs attaches importance to the economic generating value of the hub-terminals. At these terminals a lot of transshipment is carried out and these terminals attract companies having a good accessibility by all kinds of transport modes. While the Ministry of Economic Affairs is strongly focused on the economic generating value, a governmental policy can be observed being extremely focused on terminal development within the frontiers of the Netherlands[5]. Combined with the knowledge of the break-even distances of intermodal transport the national policy is completely ‘frontier-oriented’ by trying to develop economic activities in the Netherlands.

Two branch organizations also playing an important part at national level are the interest groups EVO and TLN. The EVO serves the interests of the shippers in the Netherlands. Facing these interests, the EVO is quite similar to the attitude of the shippers at European level. The freedom of transport choice seems to be a more important issue. TLN represents the carriers, the members of which consist 90% of traditional road carriers and of 10% of intermodal carriers. This important union strives after a fair competition on the transport market without governmental interference regarding any of the transport modes. TLN wants to maintain its current position as...
well as its total number of members. At the moment the transport sector has a keen internal competition and many carriers even accept losses. The inland intermodal agents are to a limited extent represented in the TLN. These agents develop long-distance services in the Netherlands. Because the Netherlands is a small country, the number of these services is restricted.

**The Regional Level**

At regional level the local authorities would like to develop their cities in terms of economic growth by providing accessible company fields. The attraction of an intermodal terminal could be a serious alternative for the improvement of the accessibility. By providing subsidies or/and raising low ground taxes they try to attract companies to their areas. For this reason some shippers are reconsidering locations, but the main motive for changing locations is the accessibility and their location towards their customer’s positions. Shippers try to organize their transport with high frequencies (allowing inventory reductions) against low wages and demand a high flexibility towards the ordering times. Therefore, terminal agents have to attract large freight volumes and transport them with high frequencies on a regular basis.

**The Operational Level**

At operational level the carriers do their utmost to follow the fixed transport schedule. The terminal operator wants to use its transshipment equipment and its floor space as well as its total number of members. At the moment the transport sector has a keen internal competition and many carriers even accept losses. The inland intermodal agents are to a limited extent represented in the TLN. These agents develop long-distance services in the Netherlands. Because the Netherlands is a small country, the number of these services is restricted.

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**The Linear Programming model**

Because price seems to be the most important performance indicator at both European and National level, we developed a linear programming model which provides us with some insights into price variation. The continental container transport demands[13] between several European regions, with origin or destination Netherlands, are optimally assigned to the transport network. The transport network contains direct road transport connections and intermodal transport connections between terminals. The optimization is restricted to one year.

The objective is defined as follows:

$$\sum_{o,d} \sum_{u,t} c_{o,t,u} x_{o,t,u} + \sum_{o,d} \sum_{u,t} c_{o,t,u} x_{o,t,u} + \sum_{o,d} \sum_{u,t} c_{o,t,u} x_{o,t,u} + \sum_{o,d} \sum_{u,t} c_{o,t,u} x_{o,t,u} + \sum_{o,d} \sum_{u,t} c_{o,t,u} x_{o,t,u} + \sum_{o,d} \sum_{u,t} c_{o,t,u} x_{o,t,u} + \sum_{o,d} \sum_{u,t} c_{o,t,u} x_{o,t,u} + \sum_{o,d} \sum_{u,t} c_{o,t,u} x_{o,t,u}$$

The objective contains the next cost elements:

- **Costs per TEU for direct road transport between regions (1.3).**

  The linear search algorithm minimizes the objective subject to the next restrictions:

  $$x_{o,t,u} \geq \sum_{u,d} x_{o,t,u} \geq \sum_{u,d} x_{o,t,u} \geq \sum_{u,d} x_{o,t,u} \geq \sum_{u,d} x_{o,t,u} \geq \sum_{u,d} x_{o,t,u} \geq \sum_{u,d} x_{o,t,u} \geq \sum_{u,d} x_{o,t,u} \geq \sum_{u,d} x_{o,t,u}$$

  The capacity of an intermodal shuttle-service connection is determined by the volume of the biggest transport flow in forward or backward direction. This restriction is necessary to model the empty container returns (2.1,2.2)

  $$x_{o,t,u} \geq x_{o,t,u} \geq x_{o,t,u} \geq x_{o,t,u} \geq x_{o,t,u} \geq x_{o,t,u} \geq x_{o,t,u} \geq x_{o,t,u} \geq x_{o,t,u}$$

Applying this model formulation to the TEMII-data provides us with a large solution space. The model contains 129 regions with a transport demand, 21 choices for intermodal rail terminal locations, and 13 choices for intermodal barge terminal locations enabling more than 9 million alternative transport connections. To reduce the solution space some restrictions have been added to the formulation. This LP-formulation allows us to make a network optimization based on costs. The results of this model indicate which terminal locations could have competitiveness towards road transport. Furthermore, based on the incoming and outgoing transport volumes, an evaluation of the geographical position of a terminal could be given.

**Results linear programming model**

The results of the model indicate a restricted attraction for the terminals mentioned in Dutch policy plans. Apart from the barge terminal at Nijmegen, the other terminals located nearby the frontiers seems to be less important. The Dutch policy plan for terminal development has forgotten to take into account the international competition of terminals situated nearby the Dutch frontiers, such as Duisburg and Liège. Not mentioned in the Dutch policy plans are terminals for short distances. The model results show opportunities for inland terminal development, i.e. Utrecht and Leiden/Alphen.

**Detailed Cost Model**

For this last possible terminal initiative a detailed cost model is developed[14]. In order to determine the cost for transshipment, the cargo-handling equipment, acreage and personnel requirements of a terminal is relevant.

1 TEU = Twenty foot Equivalent Unit
<table>
<thead>
<tr>
<th>Throughput (containers)</th>
<th>&lt;5000</th>
<th>5000-15000</th>
<th>&gt;15000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- gantry crane</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>- mobile crane</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- forklift truck</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Personnel:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- crane operator</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>/forklift driver</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>- gatehouse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acreage (hectares)</td>
<td>&lt;0.33</td>
<td>0.33-1.0</td>
<td>&gt;1.0</td>
</tr>
</tbody>
</table>

Table 2: Typical requirements for inland (barge) terminals[15]

On this basis, the cost of transshipment can be calculated. In the feasibility study, due to economies of scale, the costs per container will decrease, but interestingly, stabilize when throughput exceeds approx. 10 thousand containers annually.

Results Cost model Alphen a/d Rijn

At the moment, a new inland terminal in Alphen aan den Rijn is under consideration. In this region several large shippers are to be found, amongst others, the Heineken Brewery and the Swedish Electrolux company. This initiative received a warm welcome. Given the amount of cargo, forecasts indicate a throughput of at least 20,000 containers annually, or 80 containers every day. To get an impression of the terminal operations: the rail mounted gantry crane needs approximately 5 hours to (un)load the barge. In the vessel, two out of every three slots are in use. The terminal is to be built south of Alphen aan den Rijn, which allows daily sailing’s to the Port of Rotterdam with just one barge. Special attention should be paid to minimize the number of callings at the deep-sea terminals in the port area. Moreover, handling barges at the sea quay incurs extra costs. These extra terminal handling charges (THC) were added as a surplus of Fl 20 on the transshipment costs. The final cost comparison between road transport and intermodal transport showed four favorable locations in the vicinity of Heineken. The calculated tariffs demonstrated opportunities of cost reductions up to twenty percent of the road tariff.

Simulation Model for operations

If shippers have decided to service their transport demands by intermodal transport, the management of the operations becomes an important issue. The transport schedules have to be determined in such a way that from the shippers’ perspectives the time conditions for delivery have to be met, from the carriers’ perspectives the vessel/train loads have to be filled up as much as possible, and from the terminal agents perspective the productivity’s of the crane are to be guaranteed. To visualize these individual important factors of the actors the logistic processes are modeled in a simulation model.

Drayage

Local pickup and delivery of containers are usually carried out by truck. The fee charged for the movement of a container between the terminal and the point of origin/destination differs from the tariffs in long distance road haulage (9). On short distances, costs are determined more by time (Fl 66.10 per hour) than by distance (Fl 0.71 per kilometer). For long distance road transport an average tariff of Fl 1.85 per kilometer was applicable.

4. CONCLUSIONS

Based on our experiences with this approach we are able to indicate locations for new terminals. Two identified terminal locations have lead to serious terminal initiatives in practice. The gap between the policy plans of the governments and the level of operational processes has grown too far apart. The dynamic behavior of the actors involved can not be static stated
in policy plans, but as Muller[7] mentioned: intermodal transportation is not just the hardware or equipment involved with the freight movement, but the process, which becomes a major component of the systems approach to business[7]. Due to the dynamic actor network analysis we have been able to identify critical (success and fail) factors which are felt to be important by the actors at every level. Thanks to the recognition of actors in specific arenas we can build specific decision support models for adapting specific factors of concern. Traditional sensitivity analysis can be applied on the critical parameters.

Our future research will focus on the extension of the dynamic actor network analysis within the modeling of transportation and logistic processes. This integral modeling should finally be embedded in a decision support environment. We will seek for new representation forms of actor perspectives which are common in the field of policy management. Furthermore, our emphasis is also focused on the underlying database structure. The decision support environment should be setup relatively ‘open’ while various modeling techniques will use different data from the database. At the moment we are study over our approach on the evaluation of city logistics.

5. REFERENCES

[16] Publicatieblad van de Europese Gemeenschappen, Beschikking nr 1692/96/EG van het Europese Parlement en de Raad van 23 juli 1996 betreffende communautaire richtsnoeren voor de ontwikkeling van een transeuropese vervoersnet, September 1996