The Impact of Increased Lock Capacity on Inland Waterway Freight Transport

K.J. Terlouw

Abstract

The Netherlands as the 'Gateway to Europe' is highly profitable for the Dutch Ministry of Infrastructure and the Environment (Ministry of I&E). To maintain this position, infrastructure investments are required to remove (potential) bottlenecks and to stimulate intermodal transport. This thesis focuses on two (potential) bottlenecks in the inland waterway network, namely the sea lock IJmuiden and inland waterway lock Beatrix. Sea lock IJmuiden connects the Port of Amsterdam with the North Sea and the new IJmuiden lock will replace the current northern lock. The Beatrix lock is an inland waterway lock and is one of the three main hinterland connections of the Port of Amsterdam.
The need for additional locks at IJmuiden and Beatrix has been modelled in macro and micro simulation models, although the actual impact of both locks in the waterway network is unknown. Therefore, the research question is as follows:

What is the impact of constructing additional locks at IJmuiden and Princess Beatrix for freight transportation to and from the hinterland via inland waterways in the Netherlands?

The impact of additional locks is measured in ship arrivals and deadweight capacity of passing ships at both IJmuiden and Beatrix. To measure the impact, a studied waterway network was developed, which consists of nodes (terminals), links (waterways) and infrastructure components (locks). The studied waterway network includes (inter)national, regional and local details of nodes, links and components. As additional locks will be constructed, the current and future studied waterway network will differ. Differences in ship arrivals and deadweight capacity (i) without and (ii) with additional capacity are measured by making use of a simulation model.

To choose an appropriate model, existing macro-, meso and micro- waterway simulation models are evaluated to identify (potential) bottlenecks. The Dutch macro simulation model, BIVAS, determines (potential) bottlenecks by making use of ship register data over a year. The output data of BIVAS highlights a black spot at IJmuiden due to the fact that IJmuiden is managed by the Habour Master of the Port of Amsterdam and not by Rijkswaterstaat. As a result, ship register data is managed differently and difficult to include in the macro simulation model. This is why a black spot occurs and because of that, IJmuiden is not connected with its hinterland in any simulation model. Apart from that, critical nodes are made for the use of ship register data, as this data appears to be inaccurate. The inaccurate ship register data is used to identify (potential) bottlenecks and is therefore an indication for (future) infrastructure investments. The (potential) bottleneck is verified, by making use of micro simulation models. In addition, micro simulation models are used to determine (new) lock variables, (new) lock parameters and (new) lockage details. Apart from macro and micro simulation models, limited meso simulation models are available, which simulate multiple locks in one simulation model. Since the studied waterway network consists of multiple locks, this type of model becomes appropriate to illustrate the impact of additional locks in the studied waterway network.

Next to existing waterway simulation models, other research fields related to freight transport are also evaluated as limited waterway simulation models are available and lag behind. First, port simulation models simulate every terminal area separately next to a simulation model of all terminal areas. Therefore, the sum of all terminal areas becomes more important than evaluating them independently. As shippers travel through the waterway network focused only on themselves, the system as a whole is rejected. Second, road simulation models are able to simulate traffic management and policy changes and their effects on traffic flows. This is not possible for waterway simulation models, as only annual averages are taken into account. Furthermore, road simulation models via information systems are able to calculate the shortest routes even if traffic jams occur in the infrastructure. Third, rail simulation models are able to model fixed and variable freight trains throughout the rail infrastructure, which could be useful for waterway simulation models.

Next to this, as existing waterway simulation models run short and lag behind, a new simulation model has been developed to determine the impact of increased lock capacity in the studied waterway network. Discrete event simulation in Simio Simulation is used to examine the impact. The new simulation model includes three impact variables for the future added locks: Nmax (average number of ships per lockage); weights of links (rerouting of ships as ships are able to load deeper); and decreased enter/departure time of ships (larger dimensions of locks). All impact variables are determined out of the analysis of existing simulation models. In addition, as with both current and future cases, a fourth additional impact variable is evaluated, namely an alternative ship departure pattern at nodes. This is due to the fact that ship data registration appears to be inaccurate.

The new simulation model illustrates significant differences in ship arrival patterns for the current case (without additional locks) and the future case (with additional locks). It appears to be difficult to prospect future ship arrival patterns and peak arrivals, as separate impact variables result in completely different ship arrival patterns and peak arrivals. In addition, none of the impact variables are dominant when observing the impact of a combination of them all.

Despite the unpredictable future ship arrival patterns, three scenarios have been developed for current and future ship arrival patterns. The first scenario assumes valid ship data registration for both current and future cases. The second scenario assumes valid ship data registration for the current case and an alternative ship data registration for the future case and the third scenario assumes alternative ship data registration for both cases. The output of the scenarios appear to be positive in terms of equally distributed ship arrival patterns and peak arrivals, while scenario 2 and 3 appear to be neither positive or negative. Thus, every ship arrival pattern for each hour can be measured to be positive or negative in terms of equally distributed ship arrival patterns and peak arrivals. It is important to acknowledge that peaks remain in ship arrival patterns, despite of the fact that additional locks will be constructed in the studied waterway network.

The impact of additional capacity in the studied waterway is thus difficult to prospect. Future ship arrival patterns at IJmuiden might be managed by traffic management and therefore will decrease future peak arrivals. For Beatrix this is not the case, since ship arrival patterns and peak arrivals will remain or even increase in the future. Thus, even with additional capacity, the Beatrix lock might remain a (potential) bottleneck. The effect of constructing additional locks at Beatrix could be increased by managing ship arrival patterns. Even with traffic management, the construction of Beatrix might be postponed if fleet sizes do not increase. Therefore, the impact of constructing additional locks at IJmuiden and Beatrix is larger for IJmuiden as they schedule ship arrivals with traffic management. By doing so, the system is optimized as a whole, which means that shippers do not have the opportunity to optimise their own route through the waterway network.

Future research is required to evaluate the implementation of traffic management at Beatrix. Implementing traffic management will have sufficient benefits, but also disadvantages. Especially for shippers (dis)advantages might occur, as they have to travel through the waterway network also at off-peak hours. The reason why many shippers travel through the network at peak hours is explained by fuel savings, due to upstream/downstream benefits. The exact disadvantages, in terms of costs, for shippers travelling through the waterway network at off-peak hours, however, are unknown. Moreover, traffic management could lead to benefits for fixed shuttle services, but for variable (on-demand) services, this might be more complicated. Besides that, the many surrounding terminals at the Beatrix lock make arrival time difficult to prospect. Despite the unknown consequences of implementing traffic management, the Schuttevaer (Dutch organization of inland waterway operators) acknowledges the potential of traffic management and is willing to cooperate.

Future research is also required to increase the reliability of ship data registration. Many dynamic information systems are available for inland waterway transport. Apart from the availability, none of these information systems is used as input data for any simulation model. Moreover, by improving input data, the simulation models can be improved in terms of accurateness and future freight flows. It is recommended that Rijkswaterstaat and the Ministry of I&E cooperate to improve the data input and further development of existing waterway simulation models.

Increased lock capacity in inland waterway freight transport is only positive for the short-term ship arrival patterns and peak arrivals. In the long-term, structural traffic management changes are also required to improve inland waterway freight transport. Waterway freight transport has substantial potential to stimulate intermodal transport and to strengthen the Netherlands' position as the 'Gateway to Europe'. If the sector, Rijkswaterstaat and the Ministry of I&E can work closely together, the potential can be realized. Otherwise, inland waterway freight transport and its infrastructure investments will be placed at risk.