REVIVING AMSTERDAM’S CANALS: HOW USING WATERWAYS CONTRIBUTES TO SUSTAINABLE CONSTRUCTION LOGISTICS

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Abstract

This paper examines how modal shift from road to water can contribute to reducing negative externalities such as emissions of CO_2, congestion and air pollution from last-mile construction logistics in urban areas. This concept was tested through the project Amsterdam Vaart!, in which transports of sixteen contruction projects in Amsterdam were monitored during the period 2018 – 2022 by a consortium of TNO, Municipality of Amsterdam and Port of Amsterdam. This study aims to assess the potential of using water transport as an alternative to road transport to reduce the negative impact of construction logistics, by limiting emissions and kilometres driven on inner city. This was done by comparing the traditional logistics operations (i.e., transport by road) with an ambition scenario, in which construction logistics operations are carried out via water transport. To validate the ambition scenario, monitored data were included in the analysis. Results indicate that a modal shift towards water transport can significantly reduce the number of trips and kilometers traveled by road, resulting in a decrease of CO_2 emissions. Positive results on NO_x and PM emissions can only be achieved in case zero-emission ships are used. Success factors contributing to modal shift are the involvement of all stakeholders at an early stage and benefits at the construction site, such as higher labor productivity, increased tranquility and barges providing storage space. To further increase water transport in urban areas, modal shift should be promoted and relevant infrastructure (such as transhipment locations on the outskirts of the city) should be sufficiently available. Overall, the findings of this study suggest that water transport and the use of logistics hubs can be an effective solution for reducing the negative impact of construction logistics.

1. Introduction

More than a quarter of the CO_2 emissions from freight transport in Dutch cities are related to construction logistics (Den Boer, Kok, Ploos van Amstel, Quak, & Wagter, 2017). It is expected that this percentage will increase in the coming years, due to the considerable construction acitivities that are planned for until 2030 (Ministerie van Binnenlandse Zaken en Koninkrijksrelatie, 2022). Without any intervention, the transport of construction materials will have a considerable negative impact on the liveability of cities and the quality of life for their residents. Moreover, freight transport in inner cities, including construction logistics operations, leads to problems in terms of accessibility (Guerlain, Renault, & Ferrero, 2019).

In Amsterdam, an additional challenge is that many bridges and quay walls in the historic inner city are in poor condition. In order to limit further damage, the use of heavy vehicles in the city centre was regulated by the introduction a 7.5-tonne zone in October 2021 (Gemeente Amsterdam, 2022). Several innovative solutions are currently being developed to cope with these rules, to improve accessibility and reduce emissions and nuisance caused by freight transport. One of these innovations concerns the use of water transport. Since 2018, the Port of Amsterdam, the Municipality of Amsterdam and TNO, supported by the Ministry of Infrastructure and Water Management, have been working together in the project *Amsterdam Vaart!* to promote water transport in construction logistics (Van Rijn, Harmsen, Rondaij, & Eckartz, 2020). To this end, the consortium supports and monitors a number of construction projects in the city that use water transport. In addition to water transport in construction logistics, the project extended its focus also on water transport of other city logistics flows such as waste.

From 2018 to 2022, sixteen projects were monitored, of which fourteen pertained construction projects, and two related to the transport of urban waste. This paper shows the results of the use cases of the *Amsterdam Vaart!* project, answering the following research question:

"How can a modal shift from road to water transport contribute to reducing the negative impact of construction logistics in urban areas?"

By monitoring the transport of building materials, construction equipment and waste to and from suppliers (or waste processing companies), it is possible to map the impact of various construction logistics measures, including transport by water. The same methodology was used for each use case to monitor the transports and calculate the key performance indicators (KPIs) and intended savings. In this way, results of the various use cases are readily comparable.

The outline of this paper is as follows. Section 2 contains a background analysis on construction logistics, underlying the problems observed in the current logistics strategies and the possible solution of modal shift from road to water. Section 3 explains the methodology followed to acquire use cases, to gather results and to analyse and compare KPIs. Section 4 provides a description of the type of use cases including examples. Section 5 elaborates on the generalised results of the project, with a comparison between a reference scenario in which transport is done via road. Section 6 and Section 7 conclude the paper, with the conclusion, discussion and recommendations for further work on the subject.

2. Background

Building and construction-related transports result in a significant contribution to CO_2 emissions, air pollution, traffic unsafety, noise, congestion and wear and tear on roads and bridges. To help reduce these negative externalities, there are several measures that could contribute to more efficient and sustainable construction logistics. Examples of these are employing construction logistics hubs, shifing to other vehicle types or modalities and consolidation upstream in the supply chain ((Quak, et al., 2011); (TNO, 2018); (Janné, 2018)). Several case studies have shown that considerable improvements in construction logistics can be achieved by applying these measures ((Van Merriënboer, 2013); (Quak, et al., 2011); (TNO, 2018)).

In the city of Amsterdam, taking measures to reduce transport by heavy-duty vehicles is a dire necessity due to the poor condition of bridges and quay walls. In the *Amsterdam Vaart!* project, construction projects are therefore supported to shift transport of construction materials from road to transport by water. The use of waterways to transport goods to urban areas has shown to be beneficial before in theoretical research as well as in practice ((Van Duin, Kortmann, & Van den Boogaard, 2014); (Mommens & Macharis, 2014); (Janjevic & Ndiaye, 2014)). Examples of operational use cases are the Beer Boat in the city of Utrecht to deliver drinks and food to local shops, hotels and restaurants and the implementation of a water-bound construction consolidation center for the delivery of building materials into the Brussels-Captial Region ((Maes, Sys, & Vanelslander, 2012); (Brusselaers & Mommens, 2022)). The integration of a logistics hubs in the operation usually supports the organization of water transport by serving as a location for transhipment from road to water (or water to water). Additionally, it facilitates for storage and consolidation of goods.

However, despite the promising results of above-mentioned examples of smart logistics solutions, they are not commonly implemented in practice yet due to lack of logistics knowledge among municipalities and remaining lack of focus on and understanding of logistics in the construction industry (Frederiksson & Huge-Brodin, 2022).

This paper summarizes the findings from the monitoring of construction projects in Amsterdam that employ measures to reduce transportations by road. Besides the impact on relevant KPIs such as emissions, trips and number of road kilometers, also success and improvement factors will be drawn up to serve as guidance for implementation of transport by water for municipalities, the construction industry and other logistics parties.

3. Methodology

The aim of the project "Amsterdam Vaart!" was to understand the impact of a modal shift from road to water transport on the construction logistics operations and how this should be best organised. By monitoring the innovation in practice through use cases, it is possible to formulate empirical results. In these use cases, a situation in which operations are carried out over water is compared to a reference scenario in which the construction material is transported by road. The reference scenario relates to the traditional logistics strategies of the construction companies involved, and can be seen as a baseline measure for comparison. Furthermore, both an ex-ante calculation of the expected results of the modal shift (ambition scenario) as well as an ex-post calculation of the actual monitored results were carried out.

Step 1 – Definition of use cases. The first step is to acquire the right use cases. A collaboration is established with the Municipality of Amsterdam and the Port of Amsterdam to obtain a list of construction projects that were taking place during the execution of *Amsterdam Vaart!*. Based on the interest of constructors and whether they were willing and/or able to provide data, a list of relevant projects was made.

Step 2 – Data gathering. After starting the collaboration with constructors, data were gathered through a template. The collected data describe current and future operations through the following information:

- Type of material (to be) transported
- Amount of material transported (expressed in ton or volume)
- Type and number of vehicles used (modality, energy carrier, emission class)
- Distance covered
- Logistics strategy (e.g., whether the material is transported directly from supplier to construction site or there is a transshipment through a logistics hub)

Step 3 – Create scenarios. Based on the information received from the construction companies, two scenarios are created: a reference scenario and an ambition scenario. The reference scenario describes the situation without adjustments from the traditional logistics process. In this situation no (or less) use is made of transport by water. The ambition scenario elaborates on the new situation in which transport is carried out (partially or totally) by water and in which a logistics hub is introduced. The reference and ambition scenarios are drawn up in before the start of the construction project in an ex-ante tool that was developed by TNO and which provides insights into the desired or expected logistics implementation by mapping out the potential savings.

Step 4 – Monitor operations. Monitored data were also considered, in which actual transport (journeys and sailings) were tracked. By comparing the ambition scenarios with the monitored data it is possible to understand whether the envisioned savings were realistic, and whether the expected benefit of a modal shift towards water transport can be actually met. For some use cases, the construction project has not been completed yet, and therefore it was not possible to complete the monitoring of the actual operations. In that case, only the potential savings are shown, derived from the analysis of the ambition scenario.

Step 5 – Analyse scenarios and operations. The input from the reference and ambition scenarios and monitoring data were analysed with a tool developed by TNO. Combining the modality, vehicle type and energy carrier with the an emission factor per kilometer, and considering the distance travelled and the total amount of material to be transported, the model estimates the number of trips that are needed to carry out the operations and the emissions produced.

The model is based on a set of assumptions, common to all use cases:

a. Emissions factors for road vehicles are taken from the VERSIT+ model (TNO, 2007), with 2020 as reference year. VERSIT+ is a statistical model which predicts real-world emissions of road vehicles for different vehicle classes and traffic situations by considering real-world driving conditions (TNO, 2007). The model was used to extract emission factors for different vehicle types and three road types RT1 (urban), RT2 (rural) and RT3 (highway). For inner city roads, RT1 values are used. For outer city roads, a weighted average of 20% RT2 and 80% RT3 values are taken.
b. Two general ships types are considered in the use cases: inland vessels and tugs and push boats (for water activities inner city). Emissions factors for tugs and push boats are based on real life measurements conducted by TNO in 2020 on multiple tugs and push boats. The emission factors for larger inland vessels come from the POTAMIS model (Hulskotte, 2014). They are distinguished based on ship type and are the result of averaging the emissions of empty ships and full-load ships.
c. To calculate the number of road vehicles needed (in case the value is not provided by the contact person of the use case), typical load factors and load capacities of vehicles are used. The load factors vary based on the scenario and the trip leg that is considered and are summarised in Table

1. The ambition scenario assumes higher load factors due to the use of logistics hub that contributes to better consolidation options, just-in-time deliveries and formation of building sets.

Table 1 – Load factors for vehicle number estimation, based on type of scenario and trip leg

	Trip legs		
	Supplier – Hub	Supplier – Construction site	Hub – Construction site
Reference scenario	-	50%	-
Ambition scenario	90%	50%	75%

d. When the road distances between construction sites, hubs and suppliers are not known, they are derived from Google Maps, based on the locations of such structures. Similarly, distances sailed on inland waterways are derived from a marine plannner (Marine Plan, 2022).
e. For emissions, only Tank-to-Wheel/-Wake (TTW) have been considered. In some use cases, ships use HVO (biodiesel) using a feedstock that is considered advanced according to Annex IXa of the Renewable Energy Directive of the European Commission. The emissions factors for these ships are set to be 0 g/km for CO_2. According to IPCC agreements, zero emissions can be assumed when using biofuels if you assume Tank-to-Wheel emissions, due to the short-cycle nature of these emissions. For NO_x and PM_{10}, emissions are assumed to be the same as the diesel counterpart.

Step 6 – Evaluation of KPIs. Comparing the results of the reference scenario and the results of the ambition scenario shows the effects of a modal shift from traditional road transport to transport by water. In case that monitored data are available, comparing them with the results of the ambition scenario shows the extent to which the expected results have been achieved.

For the comparison, a set of key performance indicators (KPIs) were considered, based on the main objective of the project: reduce the emissions and nuisance of logistics by shifting transport from road to water. The performance indicators are as follows:

› Number of transport movements by road and water;
› Kilometres driven / sailed by road and water;
› Emissions of CO_2, NO_x and PM_{10}.

Step 7 – Validation with stakeholders.

A significant number of conversations were held with parties that were involved in the *Amsterdam Vaart!* project, such as contractors, nautical service providers, the municipality and Port of Amsterdam, to collect insights regarding the potential of transport by water, its barriers and lessons learned from the practical implementation.

4. Use cases

Between 2018 and 2022, a total of sixteen use cases were analysed in three subsequent *Amsterdam Vaart!* projects. In the first years, the project focused on construction logistics over water in the centre of Amsterdam. From 2022, the scope was broadened to transport by water directly from the supplier and to other city logistics segments such as waste collection and catering. The sixteen use cases are clustered into four groups:

1. Construction projects in the city center;
2. Transport of bulk materials in port-related construction works;
3. Transport by water directly from the supplier for large scale construction projects;
4. Other city logistics flow.

The choice for these four groups is based on type of goods / materials that are transported and the trajectory on which the modal shift is focused (e.g. on the trajectory from supplier to the hub or from the hub to the construction site). The following sections contain a general description of the type of construction projects in each of the four groups. From each group, one use case will be highlighted and described in detail.

4.1 Construction projects inside the city center

This group contains construction projects that are located in the city center of Amsterdam. The type of construction works consist of the replacement of historic quay walls and of residential and commercial construction (new build and renovation projects). In total seven construction projects are included in this group of which two renovation projects, three projects on quay walls, the construction of an underground parking and a large scale new build project. The locations of these projects characterise the cluster. They all lie within the city center and therefore face specific challenges, such as water depth, height of bridges and limited space for storage at the construction site.

Use case: Binnengasthuisterrein

The Binnengasthuisterrein use case pertains the new development of the Binnengasthuisterrein and its surroundings. Several construction materials are transported from different suppliers to the construction location for an expected volume of around 48,000 m^3. In the reference scenario, transport operations are carried out by road with several vehicle types (tractor-trailer combination, heavy-duty trucks and cement trucks), directly from the suppliers to the construction site. In the ambition scenario, the transport is decoupled via a logistics hub: first, construction materials are transported by road from the various suppliers to the hub location at Vlothavenweg. From the hub location, the material is bundled and transported by water to the construction site via the Oudezijds Voorburgwal. Waste disposal is taken on the return trip and unloaded at the location of a waste processing company in Vlothaven. The monitoring of transport activities started in August 2021 and will be concluded in February 2023.

4.2 Transport of bulk materials in port-related construction works

This group consists of ground-, road- and waterway construction projects for port-related works such as preparing port grounds for the construction of a new neighborhood or to build docks. In total four construction projects were monitored in this group, each of them located in the area of Port of

Amsterdam. In each project, excavation of materials such as sand, soil, gravel or clay is key. In some projects, the excavated materials were disposed close to the construction site. Disposal of these type of materials (bulk) are much suitable for transport by water due to their high volumes.

Use case: Houthavens Eiland 6

Houthaven will be a new neighbourhood in Amsterdam, consisting of seven artificial islands. On the sixth island, 116 new homes with a parking garage are being built. For the construction of the parking garage, sand must be excavated and transported to two locations where the sand is reused. This involves a total of 25,000 m^3 of soil. In the reference scenario, operations are carried out by road with a diesel semi-trailer. For the ambition scenario, operations are carried out over water, making use of the IJ canal in Amsterdam. The excavation activities took place over a period of two months, between January and February 2021 for which monitored data were gathered.

4.3 Transport by water directly from the supplier for large scale construction projects

For some of the monitored construction projects, construction materials were directly transported from the suppliers to the construction sites without interference of a hub. In general, this concerns the transport of large structural components such as beams and sheet piles that are transported over a longer distance (over 150 kilometers). In total three construction projects were monitored within this group. This includes the construction of quay walls and an underground bicycle parking, the construction of a new bridge and the construction of a multistorey hub for city logistics.

Use case: Amstelstroombrug

To build the new Amstelstroombrug in Amsterdam, 34 beams with an average weight of 100 ton each are transported from Friesland to the construction location of the bridge. In the reference scenario, the transport operations are conducted with a special road vehicle that can accommodate the large and heavy beams. Moreover, a signalling diesel van is also included in the transport operations. In the ambition scenario, the beams are transported by water (two return trips carrying seventeen beams each) from Friesland to the logistics hub in Westelijk Havengebied in Amsterdam, and from there transported in batches of two, again by water, to the construction site. Operations run during the month of August 2021, for a total of 3,722 tons transported.

4.4 Other city logistics flows

As opposed to the other groups, the use cases in this group monitor projects that transport other logistics flows than construction-related materials. Specifically, two use case were monitored where transport of waste was carried out by water. One use case focuses on the waste collection of households in the city center. The other use case concerns the transport of construction and demolition waste.

Use case: Pilot Waste collection Red Light District

In this pilot, the waste collection operations in the Red Light District area are considered. In the reference scenario, collection rounds are carried out with two diesel garbage trucks that operate two times per week. Waste is collected from the district area and is transported to the location of the waste processing company at the port of Amsterdam. In the ambition scenario, the collection rounds are split among different vehicle types (diesel mini trucks, electric bikes and electric vans) that collect the waste from door to door twice a week and bring it to two collection hubs, in Kloveniersburgwal and Oosterdok. From the collection hubs, waste is transported by the canals with two electric ships. Once the ships reach the IJ, waste material is transferred to a bigger diesel vessel, which operates from the IJ to the waste processing company. Operations were monitored from February 2021 to December 2022.

5. Results

5.1 Use cases results

The comparison between the reference scenario and the ambition scenario (or, if applicable, the results from monitored data), was done based on the KPIs defined in Section 3. To understand the impact that the modal shift had on the logistics operation, results can be approached under two points of view:

1. Effects on the number of vehicles and the distance travelled on inner city roads, and
2. Effects on emissions, looking at the CO_2 (and NO_x and PM_{10}) emissions.

Table 2 – Summary of results of Amsterdam Vaart! projects

	Absolute reduction		**Average overall reduction (in %)**
KPI	**2018 – 2019 9 use cases**	**2020 – 2022 7 use cases***	**2018 - 2022 16 use cases**
Trips (inner city)	1,600	7,300	71%
Trips (outer city)	19,700	7,500	80%
Road kilometers (inner city)	23,000	113,000	62%
Road kilometers (outer city)	1,078,000	1,589,000	96%
CO_2 emissions (tons)	521	763	44%

* The monitoring and analysis for two use cases are still ongoing and not included in these results.

The results in Table 2 show that the modal shift to water transport is beneficial, both in terms of kilometres driven inner city and in terms of emissions. On average, 71% of trips inside the city and 44% of the CO_2 emissions were reduced. In some use cases inside the city, small electric (or hybrid) boats are used, which results into a relatively higher CO_2 reduction. Other emissions (i.e., PM_{10} and NO_x) are also reduced, although with a lower percentage, due to a share of the trips being carried out with biodiesel on vessels with relative older engines (and thus a higher emission of nitrogen).

For large scale construction projects in which transport by water takes place directly from the supplier, the results show that modal shift is not in all conditions beneficial in terms of NO_x and PM emissions reduction. Although a reduction in number of road trips is observed, this is not directly translated into a reduction of emissions. For these use cases, trips over water usually cover a long distance and are carried out with large diesel inland shipping vessels for which NO_x and PM emissions per kilometer are usually higher compared to transport by road (due to the old age of the engine compared to trucks). Similar results were recently found when comparing NO_x emissions of road and barge transport for containers (Harmsen, Fransen, Ligterink, & Verbeek, 2021).

5.2 Success factors and development points for modal shift

In this paragraph, the success factors and development points for modal shift from road to water for construction logistics and inner city transport are described, which are based on the results of the use cases and conversations with stakeholders in the *Amsterdam Vaart!* project.

Success factors

Results show that transport by water has a positive impact on the reduction of inner-city road trips and thus contributes to the accessibility of the city, improved traffic safety and the reduction of wear and tear on quays and bridges. Also, modal shift leads to a significant CO_2 reduction.

In terms of organization of transport by water, the main driver that contributes to successful execution of modal shift inside cities include involving all stakeholders at an early stage. By doing this, the facilities and requirements that are needed for transport by water (such as transshipment locations, hubs and vessels, design of the construction site (such as where to place cranes)) can be arranged for and agreements can be made on how costs and gains are allocated between parties. Furthermore all subcontractors should be included in the consideration to shift transport from road to water to increase the opportunities for modal shift, hence increasing impact. Including modal shift as award criteria in the procurement policy can help to encourage transport by water in inner cities.

Companies that use transport via barge found that it contributes positively to time savings since materials are transported in higher volumes and arrive at the construction sites with less delays. Moreover, by using barges, construction personnel spend less time on handling transports and vertical transport (use of cranes) can be better planned. Apart from time savings, this better planningalso leads to more tranquility on the construction site. Another benefit that is mentioned by construction parties is that barges can function as an additional storage location, which is especially convenient in case storage space at the construction site is limited (in dense areas for example). For long distances, transport by water can be more cost-effective (on the condition that sufficiently enough volumes are transported).

Development points

The results show that NO_x and PM emissions of a construction project might increase in case (bio)diesel ships are used, especially for longer distances. To prevent negative impact on air quality, use of vessels with a modern Stage V[1] engine (or at longer term even zero-emission shipping) should therefore be encouraged. This also shows the importance of ex-ante assessments that map the impact of modal shift (and the use of vessels) not merely on CO_2 emissions or number of transports, but also on a broader selection of KPIs such as NO_x and PM, to prevent rebound effects.

The cost price of transport by water in combination with a hub for inner city transport often is higher than direct delivery due to the extra transshipment. In addition, savings due to more efficient transports cannot be charged to the supplier since traditional transport is still included in the cost price of the products. Based on conversations with contractors that were involved in the use cases, the higher transport costs might be compensated though due to higher labor productivity (less time is needed to unload trucks) and improved logistics planning (less delays and failure costs). However, cost savings at the construction site have not been looked into in this project.

Many parties are still unfamiliar with the concept and how to arrange and organize modal shift. Transport by water should therefore be further promoted and encouraged, for example by policy measures and by running pilots. To facilitatie upscaling of transport by water, sufficient availability of locations for transshipment inside the city is of importance and should be point of attention to municipalities in case they want to promote transportation of goods by water inside the city. In terms of policy, the permit process for transport by water should be easy and clear to all parties.

6. Conclusions

In the *Amsterdam Vaart!* project, the impact and feasibility of a modal shift from road to water transport for construction logistics were researched. To facilitate the transition, the modal shift was combined with the introduction of logistics hubs to allow for the transshipment of material. The main aim was to reduce the number of road trips and kilometres driven in the city centre to avoid further damage of the already heavily utilized bridges and quays and reduce emissions. With this project, the following research question was answered: "*How can a modal shift from road to water transport contribute to reducing the negative impact of construction logistics?*"

Together with the Municipality of Amsterdam and the Port of Amsterdam, sixteen use cases were considered, for which a reference scenario (i.e., current logistics operations) and ambition scenario (i.e., with modal shift and logistics hubs) were analysed, to compare their performances and derive some expected benefits in terms of number of trips, kilometres and emissions. Whenever possible, operations were monitored to validate these expected benefits. Moreover, conversations with the stakeholders

[1] Stage V refers to the European emission limits for inland waterway vessels.

(e.g., use cases construction contractors, Municipality and Port operators) led to an evaluation leading to general success factors and development points of modal shift.

Results of the analysis of the use cases show that many trips and kilometres can be avoided, especially for the transport of bulk materials, waste collection and transport of materials for inner city construction projects. The benefit in emissions, on the other hand, is only achievable in the case of short distance water transport or in case zero-emission ships are used. For inland shipping with heavy diesel ships, in fact, emissions are worse off, especially for NO_x and PM_{10}. The use of biodiesel proved to be beneficial in terms of CO_2 reduction, but not sufficient for NO_x and PM_{10} reduction.

Conversations with stakeholders helped to validate the analysis and the monitoring of operations. According to the construction companies, large benefits are found in the time savings, due to the higher volume that can be transported in one trip and less delays of water operations. The decoupling of operations via a hub, on the other hand, might increase the overall costs due to transshipment operations. The reduction of inner city journeys benefits the accessibility and traffic safety, while also reducing the wear and tear at bridges and quays.

In terms of emissions, the overall reduction of CO_2 but increment of NO_x and PM_{10} (depending on the particular transporting conditions) shows the importance of the developed ex-ante tool to map the impact of modal shift and to make strategic decisions on the type of fleet (e.g., promote low or zero-emission shipping).

Overall, stakeholders agree that transport over water is a valid alternative to the conventional road transport for construction logistics. However, it seems that the concept should be further promoted as parties are often not aware of the concept and organizational aspects.

7. Discussion

As results have shown, the use of zero-emission shipping is important to achieve beneficial results in emissions, especially for NO_x and PM. These emissions are particularly relevant in the inner city due to their negative impact on public health. During *Amsterdam Vaart!* we have observed an increase of zero-emission ships used by nautical service providers inside the city, which shows that the technology is ready for short distances. For transport by water outer city though, options for cleaner and zero-emission inland shipping are in development.

The use of water transport in other logistics segments were only briefly touched upon in this research. Due to possible different transport conditions in other city logistics segments, such as in the hotel and catering industry, the conclusions of this research cannot be extended directly to these logistics flows. To further improve the upscaling of transport by water in cities, it is therefore recommended to research additional applications of modal shift, for example by looking into the opportunities for other city logistics segments such as the hotel and catering industry. In the final delivery of the *Amsterdam Vaart!* project, a use case will be evaluated in which catering products are supplied to restaurants in the city center by water transport and the use of light electric vehicles for the last-mile.

Though possible impact on costs were mentioned, this project did not research the costs and cost effectiveness of the logistics measures. To better understand the impact of transport by water for construction companies on their business operations, costs that are associated with modal shift should be looked into.

As conversations which different stakeholder throughout the project pointed out, collaboration with different parties is an important factor contributing to the success of shifting transport of construction materials from road to water. A recommendation for further research is to see how such collaboration can be further intensified, ultimately benefiting both the environment as well as the construction industry, for example by researching asset sharing.

Another option for further research is to see how new technologies, such as autonomous vessels and digitalization, can improve the organization of the logistics process and inner city water transport. Research could also be extended to show how construction sites and loading/unloading locations can be used for other purposes as well, such as houseboat moorings, terraces, canal cruises or parking spaces. This is possibly relevant, especially in a context where the competition for public space is fierce.

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