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Socioeconomics- and Actor Analyses of Navigational Shore Assistance in Sweden: A Gothenburg Case Study

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Summary

Research project "Navigationsstöd från land – fas 2" is a continuation project that tests the feasibility of providing and using a remote pilotage service in Sweden. Remote pilotage, or Navigational Shore Assistance (NSA), refers to having a trained pilot provide assistance from shore to eligible incoming or outgoing vessels, contrary to the traditional pilotage model where the pilot would physically meet and board the vessel, and provide assistance to the vessel's bridge team on navigating and manoeuvring it to or from berth.

This report serves as the deliverable for Work Package 3 in research project "Navigationsstöd från land – fas 2", referring to the economics- and actor analyses of combining traditional pilotage in Sweden with one of two alternatives: 1) a semi-remote option where each incoming or outgoing vessel eligible for NSA uses an NSA for the outermost part of the pilotage route/stretch, and a traditional/physical pilot for the innermost part of the route/stretch to or from berth; or 2) a fully remote option where each incoming or outgoing vessel eligible for NSA uses an NSA for the full pilotage route/stretch to or from berth.

In this report, Gothenburg is investigated as a case study, and assistance of solely one vessel per NSA pilot at a time is considered in this report. In future analyses, however, the provision of assistance to two or more vessels simultaneously by a single NSA pilot may be considered.

The socioeconomics analyses focus on Sjöfartsverket as the service provider, however costs and benefits are also investigated from the viewpoint of the shipping companies as customers of the service, and from the broader viewpoint of society.

To perform this Work Package, a quantitative analysis of resources and associated costs and savings was performed, as well as a more qualitative analysis based on interviews with shipping companies and port agents.

The results suggest that a combination of traditional pilotage and NSA can help Sjöfartsverket to obtain some cost savings compared to the baseline traditional pilotage model, especially when it comes to the reduced use of the pilot boats that transport pilots to and from vessels (this includes savings on fuel and pilot boat crew) and reduced commutes for the pilots to and from pilot stations and berths. Shipping companies, in turn, may experience a reduction in waiting times and delays, and improved pilot availability.

Acknowledgements

The pilotage simulation tool was developed by company SWECO as a sub-contractor to the project in close collaboration with RISE, Sönke von Wieding (previously employed at RISE), and Sjöfartsverket. The cost evaluation tool was developed at RISE by Sönke von Wieding.

Table of Contents

List of figures

List of tables

1. Introduction

This report is part of the national research project "Navigationsstöd från land – fas 2", funded by Trafikverket and coordinated by Sjöfartsverket.

"Navigationsstöd från land" is translated in this project as "Navigational Shore Assistance (NSA)". NSA refers to a remote version of the Swedish pilot services provided to incoming and outgoing vessels in Swedish ports. The remote version of this service requires the pilot to assist the vessel(s) from a shore-based location near the port in question (at least during a specified portion of the pilotage route) rather than physically boarding the vessel as is typically done in traditional pilotage. NSA is a novel concept in Sweden and this project investigates its feasibility from the viewpoint of operational safety and risks, technology and procedures, and economics, and via the development and use of a testbed in Gothenburg.

This report specifically documents the work performed within the project's Work Package 3 dedicated to "Economics- and Actors Analyses". As part of this Work Package, the following activities/milestones were planned and listed in the project description:

- Description and economics analysis of today's traditional pilot services, including components, costs, fees;
- Similar description and analysis for a scenario where NSA is adopted;
- Similar description and analysis for a scenario where NSA and traditional pilot services are combined;
- Analysis of the conditions, benefits, costs and consequences of NSA implementation economically and societally;
- Inclusion of phasing-in scenarios of the NSA service in different geographical regions in Sweden (including Gothenburg which is the testbed used in this project);
- Identification of the effects of NSA scenarios on different actors (e.g., Sjöfartsverket, pilots, shipping companies and operators, ports) and ship segments via actor interviews, workshops and/or a Multi-Actor Multi-Criteria Analysis (MAMCA);
- Increased knowledge of business and value models for NSA design and implementation plan;
- Identification of future research needs.

The outcomes of this work provide Sjöfartsverket and their pilot service department with insights regarding potential resources, costs, savings, benefits, and other socio-economics aspects of the implementation of NSA in specified Swedish ports. It also provides insights into the impacts of this service on shipping companies/operators traveling to and from Swedish ports. These outcomes are part of the overall feasibility study of the NSA service in this project, and can support the involved organizations in decision making.

1.1 Pilotage alternatives

In this work, three pilotage alternatives are considered and compared in socioeconomic terms:

- *Baseline/business-as-usual*: The traditional pilotage service, where a pilot (or two pilots) boards the incoming or outgoing vessel in order to assist its navigation and manoeuvring from boarding point to quay or from quay to offboarding point, respectively;
- *Semi-NSA*: Each pilotage mission is divided into two sections; one where assistance is provided remotely by an NSA between the original boarding point and an inner boarding

point (closer to quay than the original boarding point), and one where assistance is still provided physically onboard of the vessel between the inner boarding point and the quay;

- *Full-NSA*: The entire pilotage mission from outer boarding point to quay or vice-versa is performed remotely by an NSA.

In this report, assistance of solely one vessel per NSA pilot at a time is considered. In future analyses, however, the provision of assistance to two or more vessels simultaneously by a single NSA pilot may be added to the report.

1.2 Geographical areas

This report includes Gothenburg Port as a case study, hence Gothenburg data and traffic patterns are considered.

2. Methods

To achieve the activities/milestones listed in the Introduction section, a series of methods were employed. Subsections below describe said methods.

2.1 Actor interviews

Interviews with shipping companies and port agents were performed as part of the Actor Analyses in this project. Five interviews in total (eight respondents) were performed. The interviewed companies operate chemical tankers, product tankers, dry bulk vessels, container vessels and gas carriers. All interviewees are active along the Swedish coast, with special focus on Gothenburg, although the trade extends to the Baltic Sea, North Sea, European continent and Mediterranean Sea. The roles of the interviewees include chartering manager, operations manager, ship agent, chief operating officer, and operations director.

During the interviews, the shipping companies' attitude towards shore-based navigational assistance was explored. Questions about how things work today, whether they are satisfied with the level of service or experience delays, and the consequences of these delays, were followed up by questions about pilot exemptions and their general attitude towards pilot assistance. The respondents were interviewed early in the project when the new risk-based pilotage regulations had not yet come into effect, and many parts of the project were still in their early stages.

2.2 Pilotage simulation

2.2.1 Pilotage simulation tool

A simulation tool was developed within the project to be able to emulate the scheduling of traditional pilotage and of a combination of traditional pilotage and NSA. This simulation tool was developed by company SWECO as a sub-contractor to the project in close collaboration with the Work Package 3 team at RISE and Sjöfartsverket. The simulation tool uses Microsoft Excel as the user interface for the simulations.[1]

2.2.1.1 Input traffic data for pilotage simulation

To carry out the simulations for a specified port, the simulation tool requires an input traffic dataset with the following 10 parameters for each observation (i.e., each vessel pilotage):

- *Ship arrival/departure number*: running number for each vessel arriving/departing (from 1 to xxx number of vessels)
- *Pilot station*: number of the pilot station responsible for the vessel
- *Port number*: arrival or departure port of the vessel
- *Boarding point*: number of boarding point where the pilot is boarding/offboarding the vessel
- *Guide Time*: travel time of the vessel between port and boarding point
- *Ship arr/dep time* [min]: time of arrival at or departure from port. The time is given in number of minutes only, i.e., days and hours need to be converted to minutes. Example: A vessel arriving on day 2 (since the beginning of a year) at 12:45 has the following

[1] *The detailed description of the development of the simulation tool and its usage instructions are found in separate internal documents.*

arrival time in the demand file: (24+12) hours x 60 minutes/hour + 45 minutes = 2 205 minutes.

- *Start at Boarding point*: indicating the direction of the pilotage, i.e., if the vessel is arriving or leaving. Boolean format, i.e., either 1 or 0 (1 (true) means that the pilotage starts at boarding point, hence it indicates an arriving vessel; 0 (false) indicates that the pilotage does not start at the boarding point, hence it starts at port, accordingly it indicates a vessel leaving the port).
- *Combo ship & fairway qual*: this defines the required pilot qualification for the given vessel. There are 4 levels of qualification, 1 indicating the lowest and 4 the highest qualification.
- *Ship prepared for NSA*: This indicates whether the vessel can theoretically use an NSA or not. There are three possible values:
  - *0*: no NSA allowed
  - *1*: 'semi-remote'. NSA in the fairway only, i.e., only to and from inner boarding point. Pilotage to and from quay is done with a regular pilot.
  - *2*: "fully remote'. NSA for both fairway and in port all the way to and from quay.
- *Double pilots onboard required*: This indicates whether the vessel required 2 pilots onboard of the vessel. Boolean format, i.e., either 1 or 0 (1 (true) means that the vessel required 2 pilots; 0 (false) indicates that the vessel only requires 1 pilot).

2.2.1.2 Simulation output

The output of the simulations is a set of parameters of summarized land and water pilot transportation distances, and the total number of hours of all the vessels under pilotage (in the term of "bonus hours"), in parallel with the total number of pilots and boatmen, as shown in Table 1. Note that, as a key performance indictor, the corresponding service level of pilotage (over e.g., one year) is also included in the simulation output, which is calculated based on the delays incurred by the vessels as a result of the simulated pilot scheduling.

Table 1 Output parameters of the pilotage simulations.

Output parameter	Units	Description
Total pilots – regular	number	Total number of traditional pilots
Car – work duty	km	Total land travel distance of pilots between pilot station and quays
Total pilots – NSA	number	Total number of NSA pilots
Pilot jobs – regular	number	Total number of traditional onboard pilotage jobs
Pilot jobs – NSA	number	Total number of NSA pilotage jobs
Bonus hours – day	hours	Total hours of the vessels under pilotage, daytime (half-hour time resolution)
Bonus hours – night	hours	Total hours of the vessels under pilotage, night-time (half-hour time resolution)
Car – commuting	km	Total land travel distance of pilots commuting to work from home
Boat transport km	km	Total water transportation distance of pilot boats
Boats	number	Total number of pilot boats
Boatmen	number	Total number of (pilot boat) boatmen
Delays, total all vessels	minutes	Total incurred delays of the vessels
Service level	%	Calculated service level based on total delays

The set of aggregated output parameter values of simulations for different pilotage scenarios forms the basis to further cost evaluations for different actors or stakeholder, as described in the next section.

2.3 Cost modelling for business- and socioeconomics analyses

A cost evaluation model was developed at RISE using Microsoft Access Database as the interactive tool. The core part of this Access tool is the cost modelling of a total of 23 cost items under different cost categories for different actors, as illustrated in Figure 1. The hierarchical relationships between actors, cost categories and cost items are shown in Table 2. Details of each cost item description and their value modelling are given in Table 3.

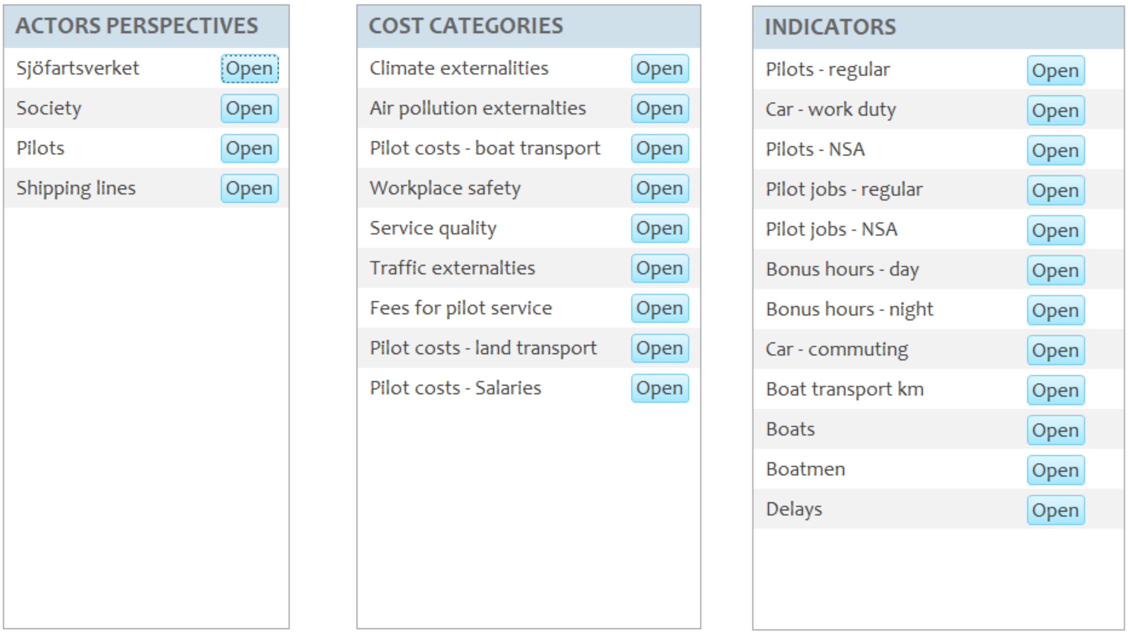

Figure 1 Cost modelling of harbour navigation service.

Table 2 Hierarchical relationships between stakeholders/actors, cost category and cost items.

	Cost type	Indicator name
Pilots	Workplace safety	Pilot jobs – regular
Shipping lines	Fees for pilot service	Pilot jobs – NSA
	Fees for pilot service	Pilot jobs – regular
	Service quality	Delays
Sjöfartsverket	Boat transport	Boat transport km
	Boat transport	Boatmen
	Boat transport	Boats
	Land transport	Car – commuting
	Land transport	Car – work duty
	Pilot costs – Salaries	Bonus hours – day
	Pilot costs – Salaries	Bonus hours – night
	Pilot costs – Salaries	Pilot jobs – NSA
	Pilot costs – Salaries	Pilot jobs – regular
	Pilot costs – Salaries	Pilots – NSA
	Pilot costs – Salaries	Pilots – regular
Society	Air pollution externalities	Boat transport km
	Air pollution externalities	Car – commuting
	Air pollution externalities	Car – work duty
	Climate externalities	Boat transport km
	Climate externalities	Car – commuting
	Climate externalities	Car – work duty
	Traffic externalities	Car – commuting
	Traffic externalities	Car – work duty

Table 3 Description of cost items and their value modelling.

Indicator name	Cost type	Indicator description
Pilot jobs – regular	Workplace safety	Cost for work accidents, mainly during boarding. Should be calculated by the total costs of accidents per year divided by total number of jobs. (Dummy data)
Pilot jobs – NSA	Fees for pilot service	Fee for NSA service to be paid by shipping lines
Pilot jobs – regular	Fees for pilot service	Fee for pilot service paid by shipping lines. (Assumption)
Delays	Service quality	Cost of delays for shipping lines.[2]
Boat transport km	Boat transport	Average operation cost per km. See calculation of costs in Excel document with case data
Boatmen	Boat transport	Annual salary cost per boatmen. Source: Sjöfartsverket
Boats	Boat transport	Annual cost per boat for depreciation and maintenance. See Excel file 'case data'
Car – commuting	Land transport	Taxi costs
Car – work duty	Land transport	Both company cars and taxis are used
Bonus hours – day	Pilot costs – Salaries	Source: Sjöfartsverket
Bonus hours – night	Pilot costs – Salaries	Source: Sjöfartsverket
Pilot jobs – NSA	Pilot costs – Salaries	Bonus for pilot per NSA job. (Assumption)
Pilot jobs – regular	Pilot costs – Salaries	Bonus for pilot per pilot job (Boarding allowance). Source: Sjöfartsverket
Pilots – NSA	Pilot costs – Salaries	Average annual salary for NSA-pilot (all qualifications). Source: Sjöfartsverket
Pilots – regular	Pilot costs – Salaries	Average annual salary for pilot (all qualifications). Source: Sjöfartsverket
Boat transport km	Air pollution externalities	Air pollution impacts generated by pilot boats' emissions of air pollutants, such as particles, Nox, etc. See calculation of costs in Excel document with case data
Car – commuting	Air pollution externalities	0.551 €-cent per person km (pkm) converted to Swedish Crowns per vehicle km (vkm) (30.09.2023) = 0.12 kr. Source: European Commission, Directorate-General for Mobility and Transport, Essen, H., Fiorello, D., El Beyrouty, K. (2020). Handbook on the external costs of transport: version 2019 – 1.1, Publications Office. https://data.europa.eu/doi/10.2832/51388
Car – work duty	Air pollution externalities	See above
Boat transport km	Climate externalities	Average climate costs per km. See calculation of costs in Excel document with case data
Car – commuting	Climate externalities	From EU External cost report, values for Sweden. Climate change costs: 2.188 €-cent per km converted to Swedish Crowns (30.09.2023) = 0.23 kr (Sheet "CC_Output", table for average costs) Source: European Commission, Directorate-General for Mobility and Transport, Essen, H., Fiorello, D., El Beyrouty, K. (2020). Handbook on the external costs of transport: version 2019 – 1.1, Publications Office. https://data.europa.eu/doi/10.2832/51388 Excel file, table for average cost, value for Sweden
Car – work duty	Climate externalities	See above
Car – commuting	Traffic externalities	From EU External cost report, values for Sweden. Includes congestion, accidents, and noise costs.

[2] *The calculation of costs with case data is found in a separate internal document.*

		Congestion cost: 20.58 €-cent per vkm converted to Swedish Crowns (30.09.2023) = 2.43 kr (Sheet "Congestion_Output", table for average costs, delay costs, urban roads) Noise cost: 0.4 €-cent per vkm converted to Swedish Crowns (30.09.2023) = 0.046 kr (Sheet "Noise_Output", table for average costs) Accident cost: 3.9 €-cent per vkm converted to Swedish Crowns (30.09.2023) = 0.45 kr (Sheet "ACC_Output", table for average costs) Source: European Commission, Directorate-General for Mobility and Transport, Essen, H., Fiorello, D., El Beyrouty, K. (2020). Handbook on the external costs of transport: version 2019 – 1.1, Publications Office. https://data.europa.eu/doi/10.2832/51388 Excel file, sheet AP_output, table for average cost, value for Sweden
Car – work duty	Traffic externalities	See above

3. Traditional pilotage in Sweden

3.1 Pilot schedules

A pilot schedule in Sweden is based on the working time agreement between Sjöfartsverket and the Swedish Maritime Pilot Federation. Pilotage services in Sweden are by law only supplied by the state and all pilots in Sweden are civil servants.

The agreement is based on the principle of availability. When one is employed as a maritime pilot, they agree to be available for service 182 days per limitation period. The limitation period consists of 52 weeks (24/7), normally equivalent to a calendar year. Holiday entitlement is for a maximum of 27 days for the same period, i.e., holiday entitlement is to be deducted from the 182 days.

The 182 days differ in flexibility. A minimum of 154 days should be scheduled 2 months prior to the start of the limitation period, at the latest. These 154 days should also include possible vacation. The remaining 18 days are unplanned, with the intention to be used when pilot service is needed on short notice, and there are rules on how this can apply (below).

The 154 days are spread out through the limitation period in accordance with the terms negotiated in the working time agreement. A sequence of days is called a serving period. The terms say that a serving period should consist of a maximum of 6 service days and a minimum of 3 service days. Exceptions with a maximum of 7 days and less than 3 days are accepted under certain conditions. In practice, 7 service days followed by 7 days off have been the standard. The schedule is then determined by the traffic pattern in combination with the individual pilots' preferences. In case of need for service on short notice, Sjöfartsverket can use the unplanned days. In such cases, 1 or 2 unplanned days can be added to the serving period with a minimum of a 24-hour notice, and it cannot surpass the 7-day mark. Only pilots on a serving period can be called in on short notice.

A single service day (24h) is divided into: a 9-hour resting period (can be parted into 5 and 4 hours), a 2-hour travel period to and from missions, and finally a 10- to 13-hour period for pilotage (core mission which includes travel in between different missions). Pilots are normally planned for 10 hours of service but, if congestion occurs, they can be planned for up to 13 hours. Typically, a pilot, depending on the area, can fulfil 2 to 4 missions within a work shift, including travel in between missions. However, it must be emphasized that each 24-hour period shall always contain 9 hours of rest regardless of when the service time starts to be counted. After resting, the pilot is expected to be ready for service within 1h30min. Likewise, after the last mission and at the pilot station, the pilot is expected to start to rest no later than 30 minutes after arrival to the station (resting normally occurs at the pilot's home). See below Figure 2 for an illustration of a pilot schedule and Figure 3 for an example from an actual pilot schedule from the first quarter of 2020 in Gothenburg's pilot station.

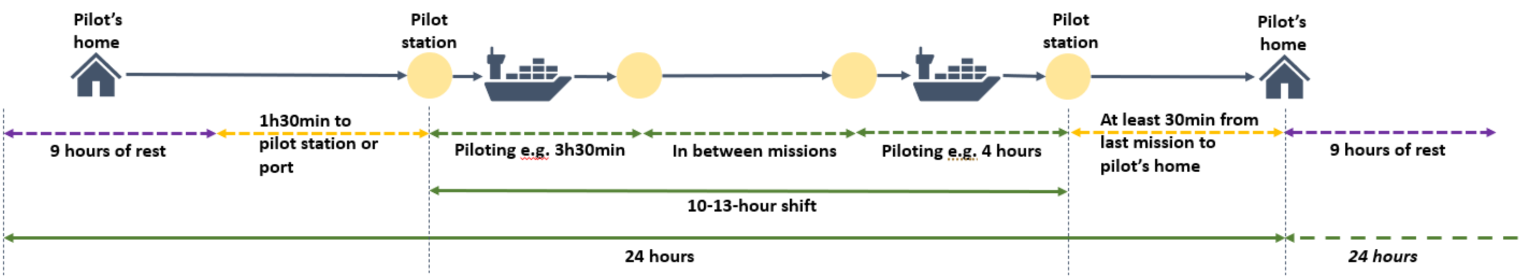

Figure 2 Illustration of a pilot schedule.

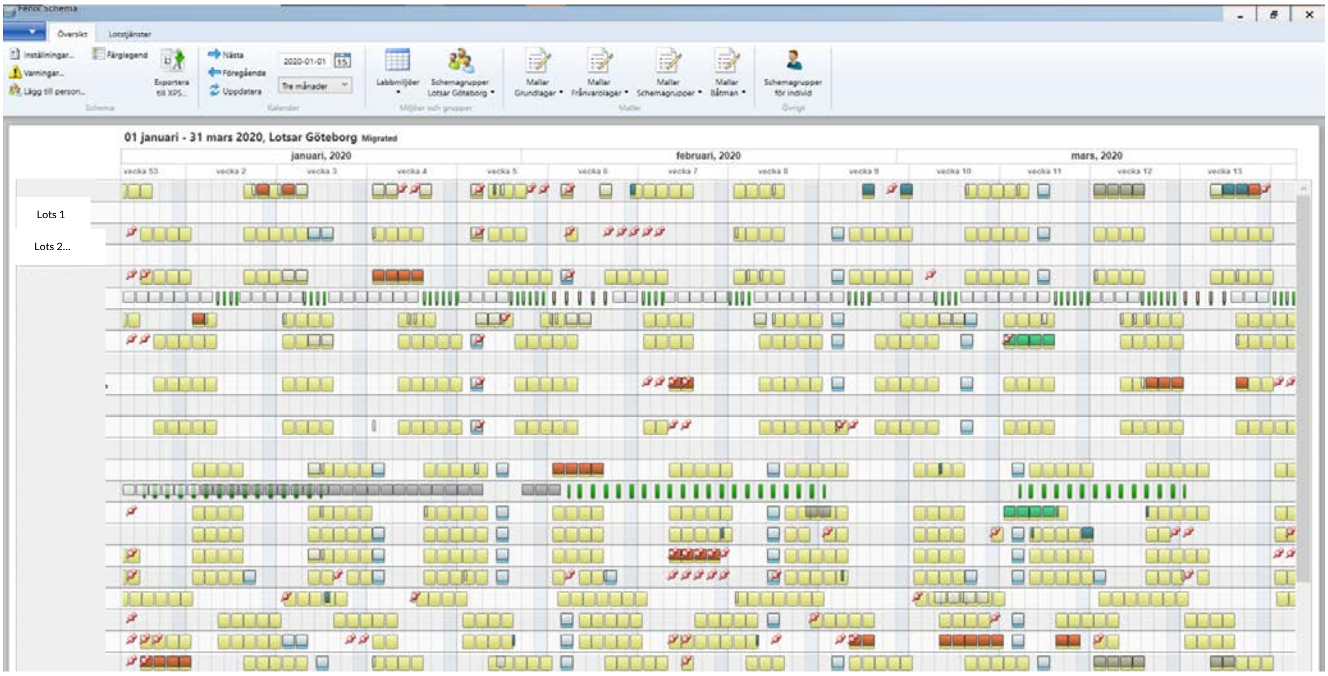

Figure 3 Pilot schedule example from first quarter of 2020 in Gothenburg's pilot station.

Note that, for the purpose of the pilotage simulations described in Section 4 of this report, a simplified representation of pilot schedules was modelled for the Gothenburg case (see description under Section 4.1.8).

3.2 Booking a pilot

Booking a pilot for an incoming or outgoing vessel is a relatively straightforward process. The vessel procures pilotage services through its appointed port agent, who serves as the shipping company's representative and intermediary in port affairs. The port agent arranges for the pilotage service via telephone with the pilot order centre or, most often, via the Swedish Maritime Single Window portal, known as MSW Reportal, a centralized portal for the submission of governmental data pertinent to vessel arrival in port. At the pilot order centre, a suitable pilot and a pilot boat are scheduled for when to perform the pilotage mission. Figure 4 illustrates the pilot booking process and communication pathways.

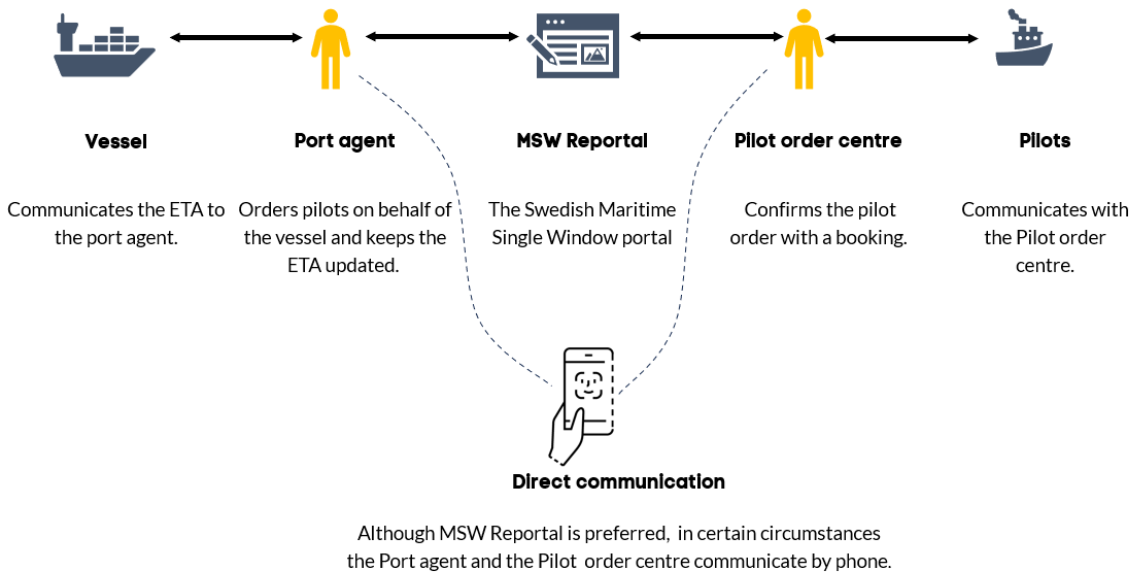

Figure 4 Overview of the pilot booking communication pathways.

3.2.1 Vessel communicating with the port agent

Ships destined for a Swedish port or anchorage within Swedish territorial waters are required to submit specified arrival information to Sjöfartsverket. This ship notification must occur at least 24 hours prior to arrival at the Swedish port or anchorage point, or immediately after departing from the previous port if the voyage is expected to last less than 24 hours, or as soon as information becomes available if the destination port is not known or changes mid-voyage.

Shipping companies employ various strategies for pilot booking. Some prefer to book a pilot as early as possible, while others wait until there is more certainty about their arrival time to minimize changes to the requested boarding time. The approach may also differ based on whether the vessel needs a pilot for arriving or departing. Common practice involves making at least a preliminary booking for a pilot in conjunction with the mandatory ship notification (i.e., at least 24 hours prior to arrival).

The process for ordering pilotage begins with an estimated time of arrival (ETA) at the designated pilot boarding point for vessels arriving to a port. For vessels departing from a port, it begins with an estimated time of departure (ETD) from the quay. The vessel then instructs its port agent to order the pilot on its behalf, specifying whether the pilot order should be considered preliminary or confirmed. Unlike confirmed orders, which may incur penalties if changed, preliminary orders can be adjusted multiple times without incurring any fees.

3.2.2 Role of the port agent

The port agent's role is to act as the shipping company's extended arm during the port stay. Consequently, the agent's task is to facilitate as smooth a port stay as possible, from arrival to departure.

The charter party governs the allocation of risks and the division of time between the parties. Generally, risks and costs at sea are borne by one party, while risks and costs during the port stay are shared between the parties. To distribute the risk of time, the vessel must have arrived according to the specific charter party, for example, at the quay or anchorage. Therefore, the shipping company generally wants the vessel to arrive as quickly as possible, and it is the agent's duty to work towards this.

The same applies to departure; the goal is to arrange for the ship's departure as soon as it has completed cargo handling and all other activities in the port (e.g., paperwork, bunkering etc.). The shipping company wants the vessel to leave the quay as quickly as possible.

3.2.3 The port agent enters data into MSW Reportal

The port agent inputs the vessel's details and the estimated time for the pilot order into the MSW Reportal. This information is then utilized by the pilot planner at the pilot order centre to arrange an appropriate pilot for the vessel.

The pilot order must be confirmed by the port agent no later than 5 hours before the desired boarding time. Usually, the port agent checks with the vessel for any updates to ETA/ETD before changing the order's status from preliminary to confirmed. One modification to a confirmed order is permitted without extra charges, as long as it's done more than 3 hours before the planned time. Any changes after this will result in additional fees. Vessels typically refrain from making alterations to the order unless faced with significant changes.

3.2.4 The pilot order centre schedules the pilot

Upon receipt of the confirmed order via the MSW Reportal, the pilot planner at the pilot order centre undertakes the planning process. Equipped with digital tool Fenix, the pilot planner manages pilot availability status, geographical location in relation to the pilot station, and the estimated completion time of prior pilotage operations. Pertinent considerations include pilots' resting and working hours, time for the pilot to be transported to the pilot boat and onwards to the vessel (see Figure 5 for a depiction of the pilot's commute and route from home, or from previous mission to pilot station and pilot boat, to boarding the vessel, to quay, or vice-versa). Upon completion of the planning phase, the pilot planner validates the booking in the MSW Reportal, by changing the status from *confirmed order* to *confirmed booking* (see Figure 6 with booking process).

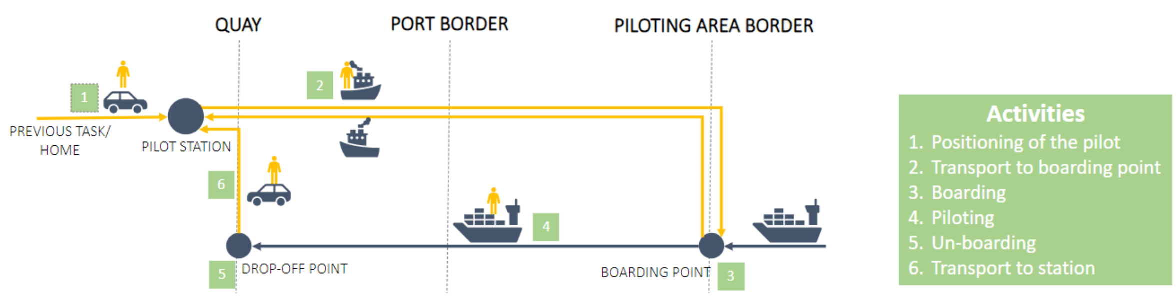

Figure 5 The pilot planner must consider numerous logistical factors to assign a pilot to the vessel.

If the pilot planner cannot schedule a pilot for the requested boarding time, an alternative boarding time is proposed based on the availability of the next available suitable pilot. This can be arranged through the MSW Reportal or via telephone by the port agent, who communicates the proposal to the vessel. Typically, the vessel must accept this alternative, which then becomes the confirmed booking. At present, any discrepancy between the vessel's initially requested time (confirmed pilot order from vessel) and the time at which the first available suitable pilot is actually offered (availability from pilot order centre) and agreed is not logged in the system.

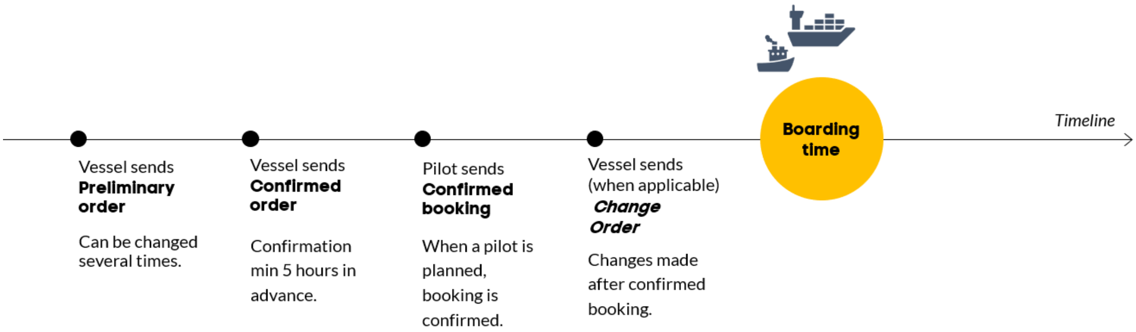

Figure 6 Schematic timeline of the pilot booking process.

3.2.5 Pilotage service level *(performance indicator)*

The current method utilized by Sjöfartsverket measures service level based on the difference between the time of Sjöfartsverket's *confirmed booking* and the time the pilot actually boards the vessel. This existing measurement method focuses on the accuracy of the pilot's boarding time relative to the planned time. Sjöfartsverket defines that service level is at 100% efficiency if the pilot boards the vessel within a half hour before or after the *confirmed booking time* (e.g., if pilot pick-up is booked for 14:00 and the pilot boards the vessel at 14:31, this is considered a low service level by Sjöfartsverket; but if the pilot boards the vessel at 14:29, this is considered a high service level by Sjöfartsverket). Yet, from the shipping company' perspective, the vessel still waited 29 minutes from the *confirmed booking time*, and this may represent additional costs for the vessel.

Moreover, this approach does not account for potential lost time for a vessel due to the unavailability of pilots. The vessel may have originally requested pilot pick-up at 12:00 instead of 14:00 but not been given that slot from the pilot ordering centre due to pilot unavailability. If a pilot is not available at the vessel's requested time, the pilot ordering centre offers the vessel an alternative time based on the next available pilot. Often, vessels have no choice but to accept this later time, which then becomes the new *confirmed booking* time (see Figure 7 for the pilot booking process from the shipping companies' viewpoint).

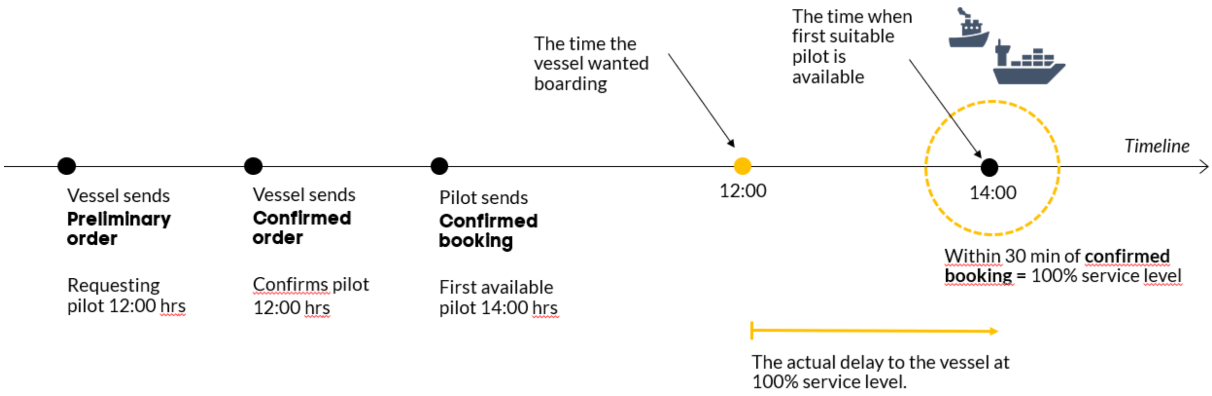

Figure 7 The service level in the eyes of shipping companies.

The interviewed shipping companies argue that this method leads to an overstatement of reported service levels by Sjöfartsverket. It fails to capture the true extent of challenges and delays caused by the lack of pilot availability, thereby not accurately reflecting the real impact on vessel operations.

The interviewed shipping companies advocate for a re-evaluation of how Sjöfartsverket measures its service level. They propose assessing the service level as the gap between the time a pilot was requested (*confirmed order*) and the actual arrival of the pilot onboard.

3.3 Maritime operators' perspectives on pilotage and NSA

3.3.1 Maritime operator's perspective on booking of pilots

The interviewed shipping companies find that in ports where there is constant communication between the pilot, terminal operator, and vessel, the accuracy of pilot orders is better. They experience that in some areas there is more proactivity and communication, while in others, not as much.

3.3.2 Maritime operator´s perspective on pilot availability in different areas

The interviewed shipping companies find the varying overtime rules for pilots across different geographical pilot areas as problematic. Where overtime is voluntary, companies find it particularly troublesome.

In the worst case, the combination of pilots' rest periods, daylight restrictions and weekends can result in days of delay. The situation worsens during the summer due to holidays. During the cruise season, it is even worse as cruise ships often require double pilots, increasing the demand for pilots.

The interviewed shipping companies do not perceive Gothenburg as problematic from a pilot availability point of view. It was stated that there was an ample supply of pilots and good communication. In Gothenburg, it was seen as rare for a pilot service to be more than half an hour different to the wanted time (confirmed pilot order). However, even if there is no significant delay for a single port call, one shipping company that frequently visits Gothenburg points out that, cumulatively, these delays amount to a considerable amount of time.

Some areas were identified as more problematic concerning pilot availability. According to the interviewees, Lake Vänern experiences problems every week, where the need for pilots is greatest due to narrow passages and many hours in difficult-to-navigate fairways.

Lake Mälaren also has long pilotage routes, and even with a pilot exemption, it is not possible to navigate the entire stretch without a pilot. Here, the situation becomes particularly challenging during the cruise and summer seasons. Frequent late changes due to pilot shortages also occur.

The east coast of Sweden recurrently suffers from a shortage of pilots, but the coast of Norrland is considered the worst case.

However, according to the pilots, the issues in Vänern are not due to pilot availability but to fairway narrowness and the amount of traffic.

3.3.3 Consequences of unavailability of pilots

Delays and consequential costs attributable to unavailability of pilots generally fall on the shipowner with no means to recover elsewhere. Thus, these costs are rarely systematically recorded, making it difficult to in retrospect get a clear overview. Even so, it is clear that costs due to delays are substantial, both in terms of hours lost, additional cost and lost opportunities. The consequences of delays that incur costs include but are not limited to:

- Extra hours in ports, including cranes and stevedores;
- No-show costs for trucks and trains scheduled for the cargo;
- Risk of being cancelled, not meeting the laycan (also on subsequent voyages);
- The risk of needing to omit subsequent port calls;
- Adding extra time due to daylight restrictions;
- Additional need for pilot to an anchorage position.

There are different ways of evaluating the actual cost of delays. A period of delay can be compared with the equivalent of the daily cost of running the vessel and additional cost of running late (overtime charges etc.) can be summarized. It is more difficult to evaluate lost opportunities of potential subsequent charters.

The interviewed shipping companies particularly stress the extra costs of the port call. Direct costs increase due to extra hours for cranes and stevedores. One example mentioned is that additional time for a crane can be 10 000 SEK per hour. Stevedoring costs may double after 16:00, due to overtime. Overtime may be voluntary in the ports, adding a factor of uncertainty. Therefore, costs also depend on when in time the delay occurs.

For example, the unavailability of a pilot at a desired time may lead to further delays due to daylight restrictions of entering a port. Another cost, depending on the cargo type, may be that trucks or rail wagons are waiting for the cargo onboard. This leads to missing trucks and rail times. Furthermore, delays can mean additional costs and lost opportunities.

For liner services running on a tight schedule, there is little leeway, and they may need to omit a subsequent port for schedule recovery. This in turn means that cargo waiting in that port cannot depart with the intended vessel, thus affecting Swedish exporting companies.

There is also a risk of missing the laycan, the specific period during which a vessel must arrive at the first port of loading. Missing laycan can lead to cancellation of the charter without any compensation to the vessel. Finally, a direct cost resulting from pilot shortages occurs when ships that have loaded in Gothenburg and are destined for Lake Vänern cannot obtain a pilot for the canal's pilot area. While waiting for the canal pilot, the ship must vacate the berth and wait out at sea in the anchorage area, needing an additional pilot from berth to the anchorage area and then from anchorage to canal pilot boarding point again.

One significant issue is the inability to guarantee availability of pilots, causing a cascade of consequences for the vessel, such as delays forcing the only available pilot to end their shift due to rest requirements and daylight restrictions. With such short notice, the vessel does not have much distance left to the pilot boarding area, leaving little room to adjust for a just-in-time arrival. However, if the reliability of pilot availability could be established earlier on, it would enable the vessel to slow steam, adjusting its speed well in advance to meet the timing accurately, minimizing disruptions and ensuring smoother operations.

3.3.4 Maritime operator´s perspective on challenges related to pilot exemptions

On paper, the process to obtain a pilot exemption appears straightforward. However, in practice, it involves two informational voyages no older than six months. Challenges like crew changes and the necessity for “trial pilots” – who require doubles and special competency – further complicate matters. Additionally, exemptions risk being forfeited if not utilized within 12 months. Notably, even sister ships equipped identically are not considered interchangeable for the purpose of counting the number of voyages. Both shipping companies and Sjöfartsverket find these requirements challenging to meet, often because ship´s trading patterns do not align well with the criteria for obtaining or maintaining a pilot exemption.

The interviewed shipping companies would want a qualification process that is not unnecessarily complicated and that having modern equipment onboard that is above the minimum required standards would become beneficial for them in terms of more easily obtaining eligibility for using NSA. At the time of the interviews, shipping companies were looking forward to the new risk-based pilot duty rules, but unsure about what they would mean in practical terms. Generally, among the interviewed companies, there were greater expectations related to the risk-based pilotage duty regulations than in shore-based navigational assistance as a remedy for pilot unavailability.

3.3.5 Maritime operator´s perspective on the use of pilot services

The ultimately responsible for the ship is the master, regardless of whether there is a pilot onboard or not. In good weather and conditions, the pilot is seen as redundant but an important support in bad conditions. It is important they are available if the captain so wishes.

In situations where there is a pilot shortage, regulations mandating the presence of a pilot on all vessels exacerbate the situation. This is because ships, which might not otherwise need a pilot if given the option, also occupy the limited pool of available pilots.

The interviewed shipping companies recognized that there might be different cultures and attitudes related to a pilot taking over the wheel. The respondents generally preferred to do the berthing themselves and pointed out that there is an advantage when pilots, tugs, boatmen etc. speak the same language and communicate easily.

When the interviews were conducted, many details of how the NSA would work in practice were still unclear and the new risk-based pilot dispensation rules were not in force.

Overall, shipping companies were cautiously positive to NSA; all initiatives that can contribute to a better availability of pilots are long awaited. There was a common impression that if the utilization of NSA contributes positively to the overall efficiency, it would benefit not only those who actively use NSA. Beyond the possible reduction of waiting times or delays and associated costs, the main benefit expected of NSA compared to traditional pilotage is increased flexibility, resulting in fewer disruptions related to the sea leg in the supply chain.

At the same time, shipping companies expressed a concern that costs might increase to allow for NSA without significantly increasing availability. Swedish port calls are already relatively expensive, the most expensive in the Nordics, which has a negative impact on the competitiveness for Sweden.

From a safety point of view, the interviewees expressed that if NSA reduces the number of boardings, it could increase safety in that critical moment. On the other hand, when a critical navigational situation appears, it is preferred to have the pilot onboard on the bridge.

4. Navigational Shore Assistance – Gothenburg case study

In this Gothenburg case study, the simulation tool developed by SWECO is used to simulate pilot scheduling involving both traditional and NSA pilotage for one traffic year based on the 2022 real traffic dataset provided by Sjöfartsverket.

4.1 Assumptions made for the Gothenburg case study

4.1.1 Infrastructure for NSA

Infrastructure elements for NSA include fairway sensors and other potential additional facilities required to provide NSA services.

Assumptions for the Gothenburg model calculations are:

- No need for new facilities for NSA. Pilot station and/or VTS would serve as NSA station;
- No need for fairway sensor infrastructure. This is already in place in Gothenburg.

4.1.2 Distances between geographical points

Distances between pilot facilities and other geographical points are relevant since they determine travel time and costs for transferring pilots by car and by pilot boat. The following distances are relevant:

- *Water travel distances* between pilot station and boarding points (BPs) for the transfer of the pilots to or from the vessel by pilot boat;
- *Road distances* between pilot station and quays for the transfer of the pilots to or from the arrival or departure quay by car. Since there is only one pilot station in Gothenburg, distance between pilot stations is not relevant.

Figure 8 illustrates the geographical modelling of Gothenburg harbour as the following:

- One pilot station – Tångudden
- Three boarding points (BP). Distances between boarding points and pilot station:
  - BP1 – pilot station: 21 km (water route)
  - BP2 – pilot station: 20 km (water route)
  - BP3 Rivöfjorden – pilot station: 6 km (water route)
- BP1 and BP2 are regarded as the so-called outer BP while BP3 is regarded as the so-called inner BP
- Five quays. Distances between quays and pilot station:
  - Quay 1 – pilot station: 14 km (land route)
  - Quay 2 – pilot station: 10 km (land route)
  - Quay 3 – pilot station: 6 km (land route)
  - Quay 4 – pilot station: 11 km (land route)
  - Quay 5 – pilot station: 6 km (land route)

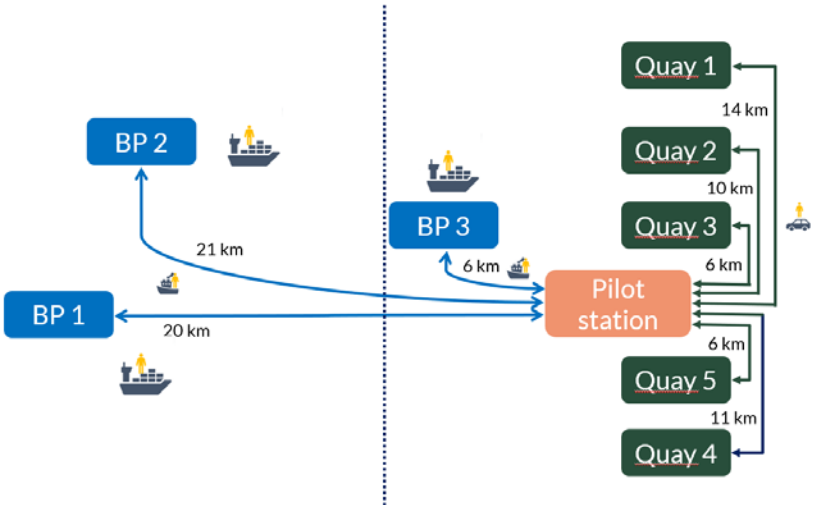

Figure 8 Geographic modelling of Gothenburg harbour. Dashed line illustrates the differentiation between the inner and outer boarding points.

Note that the differentiation between outer boarding points (BP1 & BP2) and inner boarding point (BP3) pertains to the simulation case of semi-NSA pilotage. In this semi-NSA case, the NSA-capable vessels will be under NSA pilotage between the outer BPs and the inner BP, while traditional onboard pilotage will be carried out between the inner BP and the five quays.

4.1.3 Travel between boarding points and quays

Travel between boarding points and quays is relevant as emissions and time may differ between conventional pilotage and NSA. Nevertheless, in Figure 8, distances between the boarding points and quays are not outlined, since the vessels under pilotage are expected to navigate in the same way under NSA pilotage as under conventional pilotage. Even so, in the simulation study, the pilotage times of the vessels are needed for the pilot scheduling. For the Gothenburg case study, the pilotage times are either directly extracted from the historical traffic data or re-constructed for NSA-capable vessels based on respective pilotage times between outer boarding points (BP1&BP2) and inner boarding point (BP3), and between inner boarding point (BP3) and the five quays, depending on the vessel length and direction (inbound/outbound), as described below.

Assumptions for the Gothenburg model calculations:

- For the 304 vessels (see section 4.2) arriving (inbound) or leaving (outbound) from inner BP3 to (or from) the 5 quays, *the original "actual" guide times are used*, since they will not use any NSA pilotage in the semi-NSA case;
- For the 1946 vessels arriving (inbound) or leaving (outbound) from the two outer boarding-points (BP1&BP2) requiring pilot qualification levels above level 1, the original "actual" guide times are used, as for these vessels the pilotage will only be carried out by traditional onboard pilotage;
- For the 2087 vessels arriving (inbound) or leaving (outbound) from the two outer boarding points (BP1&BP2) requiring level-1 pilot qualification, for the semi-NSA case the pilotage will be the combination of NSA from/to outer BP1&BP2 to/from inner BP3 and traditional onboard pilotage from/to inner BP3 to (or from) the 5 quays, if the vessels are capable of using NSA (e.g., by randomly assigning 50% of these (2087)

vessels that can use NSA in the simulations). Accordingly, the guide times are re-constructed as the following (according to Sjöfartsverket's input information):

1. For "Open sea" (i.e., between outer BP1&BP2 and inner BP3) guide times:
   a. For inbound vessels from outer BP1&BP2 to inner BP3 the guide times are adjusted as:
      - 53 minutes for smaller vessels (45-60 minutes in reality);
      - larger vessels up to maximum allowed for NSA adding 15 minutes.
   b. For outbound vessels from inner BP3 to outer BP1&BP2 the guide times are adjusted as:
      - 45 minutes for smaller vessels;
      - larger vessels up to maximum allowed for NSA adding 8 minutes (5-10 minutes in reality).
   c. Criteria for "larger vessels" is 120m vessel length.
2. The guide times between inner BP3 and quays are set according to the inbound/outbound tables as shown in Table 4 based on Sjöfartsverket's input information.

Table 4 Guide times between inner BP3 and quays.

BP3 – quay	Inbound (min)	quay/port – BP3	Outbound (min)
1	33	1	26
2	45	2	35
3	45	3	35
4	33	4	26
5	40	5	31

4.1.4 Pilots, qualifications, and vessel sizes

The number of pilots working each shift at a pilot station is relevant for costs and availability. Note that it is not the total number of pilots employed but the pilots available for work at a specific point in time. The pilots have different qualification levels determining which vessels they can be assigned to pilot. The pilot qualification levels depend on the pilot area and station in Sweden.

Specifically in Gothenburg, there are four levels of pilot qualification, being that level-4 pilots can assist any vessel type and size in the area, whereas lower-level pilots cannot assist vessels above a certain size (see Table 5 for pilot qualification levels and vessel size limits).

Table 5 Pilot qualifications and vessel size limits per qualification level in the Gothenburg area.

Pilot qualification level	Vessel depth limit (m)	Vessel length limit (m)	Vessel beam/width limit (m)
1	8,5	155	30
2	10	200	33
3	15	260	40
4	(no limits)	(no limits)	(no limits)

Assumptions for the Gothenburg model calculations:

- 8 pilots per shift[3]

[3] Information in this report referring to the pilot qualifications in Gothenburg is protected.

[redacted]

- This means that 7 out of 8 pilots can undertake NSA service (seeing that pilot level-1 cannot perform NSA jobs).
- The pilot shifts in Gothenburg are of 1 week (over a 3-week rotation period).
- Vessels requiring two pilots onboard or requiring tugboats, or vessels above 155m length and above 30m beam (width)) are not eligible for the NSA service in this project. Hence, only pilot-level-1 vessels can use NSA.

In addition, pilots who do NSA also need to do normal pilotage the next month to maintain level of expertise.

4.1.5 Pilot exemption certificates

In order to be able to use NSA services, the vessel will require a simplified Pilot Exemption Certificate (PEC) that proves the ability of the captain onboard to navigate in port areas. The specifics of the training and certification for this special PEC have not been decided upon in this project, but they would also represent an added cost for the shipping companies.

4.1.6 Pilot boats

The number of pilot boats available at each pilot station is relevant as there are costs and emissions related to pilot boat travels, and the number of pilot boats may influence the availability of pilots for specific time slots. The pilot boats travel between pilot station and pilot boarding points in order to deliver or pick up the pilot to/from the vessel. For emission calculations, the speed of the pilot boats is relevant. The pilot boat crew (here called boatmen) also represent costs.

Assumptions for the Gothenburg model calculations:

- 2 pilot boats available each shift
- 5 pilot boat crew each shift. (2 crew members per pilot boat + one extra on call)
- The pilot boat speed is set at 33.3 km/h (18 knots)

4.1.7 Service level

Earlier report has highlighted that NSA, for shipping companies, might lead to increased accessibility of pilotage and increased flexibility regarding vessels arriving and departing from ports. The service level is influenced by the number of available pilots and pilot boats. In this project, it has been stated that the service level should not decrease compared to the current situation.

Assumptions for the Gothenburg model calculations:

- Service level today is approximately of 98% (baseline). The calculations in this project were, however, compared against the service level calculated from the input data that was provided, and is slightly lower than 98% (i.e., 97.1%, see section 4.4).
- High service level according to Sjöfartsverket is when pilot arrives within a half-hour (before or after) of the provided pilot booking. Therefore, a pilot delay of 29 minutes after pilot booking time equals a high service level, but a 31-minute delay after pilot booking time equals a low service level.
- Service level calculation formula in this project is "*verklig lotsstart*" minus "*senaste önskad lotsstart*" from the input data files.

4.1.8 Pilot schedules

For the purpose of the pilotage simulations described later in this report, and based on the requirement of a 9-hour resting period, it was assumed that all pilots are available for duty 15 hours per day, including the time spent on commuting to and from the pilot station (1 hour). This way, the number of pilots necessary to fill in 8 pilot positions in Gothenburg is modelled to a total of 27 pilots[4], which matches the current number of pilots in Gothenburg in reality.

The NSA service is offered to shipping companies 24/7 (on call) as long as the NSA pilot on duty is not occupied with assisting another vessel at that time. This does not necessarily signify that the NSA pilot chair at the pilot station/shore centre must be physically manned 24/7; instead, the NSA pilot may stay at home when starting a new shift until he/she is called in to the pilot station/shore centre to perform the first job of the shift. Afterwards, the NSA pilot should remain at the pilot station/shore centre for the rest of the shift to avoid multiple travels and associated costs. In other words, the NSA jobs are coordinated together with the regular pilotage jobs in order to maximize the service level, and the (on-call) NSA service 24/7 could, in theory, be achieved by using a different NSA pilot working shift over a longer period of time, e.g., on a monthly basis rather than a weekly basis, if we want to have dedicated NSA pilots. However, in practice, NSA pilotage could be on the same schedule as regular pilotage, and pilots (of 2-4 qualification levels) may rotate to fill in the NSA position. This means that an NSA pilot on duty would have a maximum of 13 hours of work before being required to enter a resting period of 9 hours. In the meantime, another pilot could take over the NSA position, and the previous NSA pilot could have the next shift as a regular pilot, and so on and so forth. In this way, the NSA service and regular pilotage are both maintained 24/7 for shipping companies.

4.2 Gothenburg dataset

The input traffic data for the simulations for the Gothenburg case study are based on the real inbound and outbound traffic data for year 2022 provided by Sjöfartsverket. The original data contain a total of 4487 vessels' records, of which 4337 vessels are used for the simulations in this project that fit the modelling of the quays, boarding points, and pilot stations.

Table 6 summarizes the total number of vessels in the input traffic data requiring different pilot qualification levels together with those vessels requiring double pilots. There is a total of 356 vessels requiring higher level 3 and 4 pilot qualifications and also requiring double pilots, which means that the total number of pilot jobs amounts to a total of 4639, i.e., 356 more than the total number of vessels due to double pilotage.

Table 6 Overview Gothenburg 2022.

Pilot level requirement	Number of vessels	Number of vessels requiring double pilots
Level 1	2379	
Level 2	981	
Level 3	567	10
Level 4	410	346
Total number of vessels	4337	356
Total pilot jobs	4337 + 356 = 4693	

[4] The total number of pilots for 8 pilot positions is calculated as: (8*365*24)/(182*(15-1))=27, assuming each pilot works 182 days per year with 15 hours of on-call duty each day (including 1 hour of commuting).

4.3 NSA pilotage simulation scenarios

Based on the total number of vessels deemed eligible for NSA, five simulation scenarios were defined to quantitatively categorize the penetration degree of NSA pilotage, as the following:

- Scenario 1 – 5% randomly selected level 1 vessels capable of using NSA
- Scenario 2 – 10% randomly selected level 1 vessels capable of using NSA
- Scenario 3 – 25% randomly selected level 1 vessels capable of using NSA
- Scenario 4 – 50% randomly selected level 1 vessels capable of using NSA
- Scenario 5 – 100% level 1 vessels capable of using NSA

Table 7 shows the respective total number of NSA capable vessels of different NSA simulation scenarios for the case of Gothenburg, based on the year 2022 traffic data.

Table 7 Total number of NSA-capable vessels in each scenario for the Gothenburg case study, based on the 2022 traffic dataset.

Scenarios	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*
Total NSA capable vessels	119	238	595	1190	2379

4.4 Full-NSA simulation results

Below, the first simulation results of full-NSA pilotage for Gothenburg are reported. The simulation tool version used for full-NSA simulations is the version denoted NSA_SSPA_Multi_S3P5F11_Final_v3 delivered by SWECO. Note also that the simulation results with NSA pilotage are limited to pilot setups/arrangements with only one NSA position per working shift and each NSA pilot can only guide one vessel at a time.

4.4.1 Full-NSA – Scenario 1

Table 8 summarizes the simulation results of full-NSA pilotage for Scenario 1 – 5% randomly selected level 1 vessels capable of using NSA, for different number and qualification level setups of pilots at duty. In the simulations, the starting baseline pilot setup is referred to as "business-as-usual (BAU)", i.e., there is no NSA service. Furthermore, for simulations involving NSA pilotage, the table shows the optimum pilot qualification level setup for the respective total number of pilots at duty in terms of the best achievable service level. Note that columns "6 pilots" and "5 pilots" in Table 8 have regular pilots of qualification level 4 only. These setups present the highest NSA potential. The same can be seen in Table 9-Table 12. However, in a real-life situation, there would always be at least one pilot level 1, one level 2, and one level 3 in every group, because there are always new pilots under training. In future analyses, this setup should be considered for every pilot arrangement.

In the baseline BAU case, the simulation results show a total delay of 10842.5 minutes for all the vessels over a year, or 2.5 minutes per vessels in average, corresponding to a calculated service level of 97.1% (slightly lower than the 98% in reality).

If, instead, a regular traditional pilot is replaced with an NSA pilot, the simulated total delay can be reduced slightly to 10408.8 minutes and the corresponding service level can be enhanced slightly to 97.3% when keeping the same total number of 8 pilots at duty per shift. Note that the NSA pilot does not necessarily have to be at the highest qualification level (4), and indeed the simulation shows that an NSA pilot at level 3 or 2 can achieve the best performance (in terms of total delay and subsequent service level). Note also that, for Scenario 1, there is a total of 119 (randomly assigned) NSA-capable vessels, out of which 117 vessels indeed utilize NSA pilotage, while 2 NSA-capable vessels still use traditional onboard pilotage, in order to achieve the best performance. This may be due to NSA unavailability at the time (e.g., if the NSA pilot is assisting another vessel), since this report only considers a single NSA position out of the 8 pilots (see Section 4.1.8).

Due to the utilization of NSA pilotage, the total land and water transport distances are reduced accordingly, while the bonus hours also decrease slightly since NSA pilotage is not limited by pilot boat availability and therefore it is able to commence in better alignment with the desired start time of the vessels compared to traditional pilotage.

Furthermore, when continuing the simulations with one NSA pilot and reducing the total number of regular pilots at duty by one pilot, results show that the same service level can still be maintained. If the number of regular pilots is further reduced by one more pilot (i.e., equaling to a total of 6 pilots including 1 NSA pilot at duty), the total delay will increase by ~20% while the corresponding service level will be degraded slightly by 0.3%. When going down to 5 pilots on duty (including the NSA pilot), on the other hand, the total delay increases dramatically by over 100% and the corresponding service level is degraded more significantly to just under 95%.

Table 8 Simulation summary, full-NSA, 1 NSA 1 vessel, Scenario 1 – 5% randomly selected level 1 vessels capable of using NSA.

Pilot number at duty		8 pilots		7 pilots	6 pilots	5 pilots
Pilot setup at duty	units	BAU-[redacted]*	NSA N3-L4444421*	NSA N3-L444441	NSA N3-L44444**	NSA N3-L4444**
Total pilots – regular	Number	27	24	20	17	14
Car – work duty	km	39447	38673	38673	38673	38673
Total pilots – NSA	Number	0	3	3	3	3
Pilot jobs – regular	Number	4693	4576	4576	4576	4576
Pilot jobs – NSA	Number	0	117	117	117	117
Bonus hours – day	hours	4013.9	4008.1	4004.1	4007.5	4003.9
Bonus hours – night	hours	3569.1	3566.4	3568.5	3576.5	3605.1
Car – commuting	km	174720	152880	131040	109200	87360
Boat transport km	km	133856	130444	129900	129312	130404
Boats	number	2	2	2	2	2
Boatmen	number	22	22	22	22	22
Delays, total all vessels	minutes	10842.5	10408.8	10842.5	12577.3	22118.7
Service level	%	97.1	97.3	97.2	96.8	94.7

* BAU: business-as-usual L44444321: regular pilot setup with 5 level-4, 1 level-3, 1 level-2 and 1 level-1 pilots.
N3-L4444421: pilot setup with 1 level-3 NSA pilot, and 5 level-4, 1 level-3, 1 level-2 and 1 level-1 regular pilots (and so on for other pilot setups).
** Note that columns "6 pilots" and "5 pilots" have regular pilots of qualification level 4 only. This was done in order to show the maximum potential of a 6- or 5-pilot arrangement. However, in a real-life situation, there would always be at least one pilot level 1, one level 2, and one level 3 in every group, because there are always new pilots under training. Note also that the NSA pilot is always a level 3 pilot in this arrangement. This was selected for this analysis because it rendered the most optimal results. However, pilots of level 2 or 4 can also perform NSA jobs. The same can be seen in Table 9-Table 12. In future analyses, at least one pilot level 1, one level 2, and one level 3 should be included in every pilot arrangement.

4.4.2 Full-NSA – Scenario 2

Table 9 summarizes the simulation results of full-NSA pilotage for Scenario 2 – 10% randomly selected level 1 vessels capable of using NSA, for different number and qualification level setups of pilots at duty. Compared to the baseline BAU case, replacing a regular traditional pilot with an NSA pilot leads to a reduced total delay below 10000 minutes and the corresponding service level can be enhanced to 97.5% when keeping the same total number of 8 pilots at duty per shift. Note that the NSA pilot does not necessarily have to be at the highest qualification level (4). Note also that, for Scenario 2, there is a total of 238 (randomly assigned) NSA-capable vessels, out of which 228 vessels indeed utilize NSA pilotage, leaving 10 NSA-capable vessels to still use traditional onboard pilotage, in order to achieve the best performance. Just as for Scenario 1, the utilization of NSA pilotage in Scenario 2 allows for the total land and water transport distances to be reduced accordingly, while the bonus hours also decrease slightly since NSA pilotage is not limited by pilot boat availability and therefore it is able to commence in better alignment with the desired start time of the vessels compared to traditional pilotage.

Furthermore, when continuing the simulations with one NSA pilot and reducing the total number of regular pilots at duty by one pilot, results show that a service level equal or higher than the BAU case can still be achieved. If the number of regular pilots is further reduced by one more pilot (i.e., equaling to a total of 6 pilots including 1 NSA pilot at duty), the total delay will increase just slightly by ~8% while the corresponding service level will be maintained as BAU. When going down to 5 pilots on duty (including the NSA pilot), on the other hand, the total delay increases dramatically (by nearly 2 times) and the corresponding service level is degraded significantly (to 95%).

Table 9 Simulation summary, full-NSA, 1 NSA 1 vessel, Scenario 2 – 10% randomly selected level 1 vessels capable of using NSA.

Pilot number at duty		8 pilots		7 pilots	6 pilots	5 pilots
Pilot setup at duty	units	BAU-[redacted]	NSA N3-L4444421	NSA N3-L444441	NSA N3-L44444	NSA N3-L4444
Total pilots – regular	Number	27	24	20	17	14
Car – work duty	km	39447	37839	37839	37839	37839
Total pilots – NSA	Number	0	3	3	3	3
Pilot jobs – regular	Number	4693	4465	4465	4465	4465
Pilot jobs – NSA	Number	0	228	228	228	228
Bonus hours – day	hours	4013.9	4002.7	4003.0	4006.4	4002.4
Bonus hours – night	hours	3569.1	3564.3	3566.0	3573.1	3596.6
Car – commuting	km	174720	152880	131040	109200	87360
Boat transport km	km	133856	127916	127442	126812	127694
Boats	number	2	2	2	2	2
Boatmen	number	22	22	22	22	22
Delays, total all vessels	minutes	10842.5	9541.4	9975.1	11709.9	20383.9
Service level	%	97.1	97.5	97.4	97.1	95.0

4.4.3 Full-NSA – Scenario 3

Table 10 summarizes the simulation results of full-NSA pilotage for Scenario 3 – 25% randomly selected level 1 vessels capable of using NSA, for different number and qualification level setups of pilots at duty. Compared to the baseline BAU case, replacing a regular traditional pilot with an NSA pilot leads to a reduced total delay just over 8000 minutes and the corresponding service level can be enhanced to 97.8% when keeping the same total number of 8 pilots at duty per shift. Moreover, for this scenario, there is a total of 595 (randomly assigned) NSA-capable vessels, of which 536 vessels indeed utilize NSA pilotage. Correspondingly, due to the utilization of NSA pilotage, the total land and water transport distances are further reduced, while the bonus hours also decrease slightly since NSA pilotage is not limited by pilot boat availability and therefore it is able to commence in better alignment with the desired start time of the vessels compared to traditional pilotage.

Furthermore, when continuing the simulations with one NSA pilot and reducing the total number of regular pilots at duty by one or even two pilots, results show that a service level equal or higher than the BAU case can still be achieved. When going down to 5 pilots on duty (including NSA pilot), on the other hand, the total delay increases dramatically by nearly 50% and the corresponding service level is degraded by 1.1% compared to BAU. By reducing the manning further by one more regular pilot (i.e., keeping a total of 4 pilots out of which one is an NSA pilot), the total delay becomes almost 4 times that of the BAU case and the corresponding service level is reduced to 90,4% against 97,1% in the BAU case.

Table 10 Simulation summary, full-NSA, 1 NSA 1 vessel, Scenario 3 – 25% randomly selected level 1 vessels capable of using NSA.

Pilot number at duty		8 pilots		6 pilots	5 pilots	4 pilots
Pilot setup at duty	units	BAU-[redacted]	NSA N3-L4444421	NSA N3-L44444	NSA N3-L4444	NSA N3-L444
Total pilots – regular	Number	27	24	17	14	10
Car – work duty	km	39447	35651	35651	35645	35609
Total pilots – NSA	Number	0	3	3	3	3
Pilot jobs – regular	Number	4693	4157	4157	4156	4152
Pilot jobs – NSA	Number	0	536	536	537	541
Bonus hours – day	hours	4013.9	4003.7	4007.1	3998.9	4014.4
Bonus hours – night	hours	3569.1	3554.3	3562.9	3579.6	3646.1
Car – commuting	km	174720	152880	109200	87360	65520
Boat transport km	km	133856	120484	119254	119968	123652
Boats	number	2	2	2	2	2
Boatmen	number	22	22	22	22	22
Delays, total all vessels	minutes	10842.5	8240.3	9541.4	16046.9	42502.6
Service level	%	97.1	97.8	97.6	96.0	90.4

4.4.4 Full-NSA – Scenario 4

Table 11 summarizes the simulation results of full-NSA pilotage for Scenario 4 – 50% randomly selected level 1 vessels capable of using NSA, for different number and qualification level setups of pilots at duty. Compared to the baseline BAU case, replacing a regular traditional pilot with an NSA pilot results in a reduced total delay by nearly 50% and the corresponding service level can be enhanced to 98.5% while still maintaining the same total number of 8 pilots at duty per shift. Moreover, for this scenario, there is a total of 1190 (randomly assigned) NSA-capable vessels, of which 968 vessels indeed utilize NSA pilotage. Correspondingly, due to the utilization of NSA pilotage, the total land and water transport distances are further reduced, while the bonus hours also decrease slightly.

Furthermore, when continuing with one NSA pilot and reducing the total number of regular pilots at duty by three regular pilots, the simulation results show that a service level equal or higher than BAU can still be achieved. Note here that, with the decreasing number of pilots, their qualification levels become more and more important, as can be seen when a (highest) level-4 pilot is replaced with a lower level-2 pilot, the total delay will increase dramatically by nearly 50%, even though the total number of pilots at duty remains the same. If yet one more regular pilot is removed, i.e., keeping 4 pilots including 1 NSA pilot at duty, the total delay and the corresponding service level become significantly affected (from a 10842-minute delay in BAU to 40767 minutes, and from a 97.1% service level in BAU to 91.7%), even if all the regular pilots have the highest qualification level.

Table 11 Simulation summary, full-NSA, 1 NSA 1 vessel, Scenario 4 – 50% randomly selected level 1 vessels capable of using NSA.

Pilot number at duty		8 pilots		5 pilots		4 pilots
Pilot setup at duty	units	BAU-[redacted]	NSA N3-L4444421	NSA N3-L4444	NSA N3-L4442	NSA N3-L444
Total pilots – regular	Number	27	24	14	14	10
Car – work duty	km	39447	32611	32593	32581	32497
Total pilots – NSA	Number	0	3	3	3	3
Pilot jobs – regular	Number	4693	3725	3722	3720	3710
Pilot jobs – NSA	Number	0	968	971	973	983
Bonus hours – day	hours	4013.9	4001.8	3999.7	3995.1	4013.3
Bonus hours – night	hours	3569.1	3545.7	3559.3	3566.4	3626.7
Car – commuting	km	174720	152880	87360	87360	65520
Boat transport km	km	133856	109142	108656	109466	111596
Boats	number	2	2	2	2	2
Boatmen	number	22	22	22	22	22
Delays, total all vessels	minutes	10842.5	5638.1	10842.5	15613.2	40767.8
Service level	%	97.1	98.5	97.2	96.2	91.7

4.4.5 Full-NSA – Scenario 5

Table 12 summarizes the simulation results of full-NSA pilotage for Scenario 5 – 100% level 1 vessels capable of using NSA, for different number and qualification level setups of pilots at duty. Compared to the baseline BAU case, replacing a regular traditional pilot with an NSA pilot equals to a reduced total delay of just 1/3 of that of BAU and the corresponding service level can be enhanced to nearly 99% while still keeping the same total number of 8 pilots at duty per shift. Moreover, for this scenario, there is a total of 2379 NSA-capable vessels, of which 1633 vessels indeed utilize NSA pilotage, which suggests that even when having only one NSA pilot who can guide only one vessel at a time, this single NSA pilot still has the capability to take more than 1/3 of all pilotage jobs, demonstrating the potential of full-NSA pilotage. Correspondingly, due to the utilization of NSA pilotage, the total land and water transport distances are further reduced, while the bonus hours also decrease slightly as expected.

Furthermore, when continuing with one NSA pilot and reducing the total number of regular pilots at duty by three regular pilots, the simulation results show that a service level equal or higher than BAU can still be achieved (with a big margin). If reducing the manning by one more regular pilot, i.e., keeping 4 pilots including 1 NSA pilot at duty, the total delay and the corresponding service level will be degraded significantly.

Table 12 Simulation summary, full-NSA, 1 NSA 1 vessel, Scenario 5 – 100% level 1 vessels capable of using NSA.

Pilot number at duty		8 pilots		5 pilots	4 pilots	3 pilots
Pilot setup at duty	units	BAU-[redacted]	NSA N3-L4444421	NSA N3-L4444	NSA N3-L444	NSA N3-L44
Total pilots – regular	Number	27	24	14	10	7
Car – work duty	km	39447	27756	27720	27570	26926
Total pilots – NSA	Number	0	3	3	3	3
Pilot jobs – regular	Number	4693	3060	3054	3033	2941
Pilot jobs – NSA	Number	0	1633	1639	1660	1752
Bonus hours – day	hours	4013.9	4001.8	4001.4	3997.3	3976.2
Bonus hours – night	hours	3569.1	3544.8	3552.1	3595.7	3659.9
Car – commuting	km	174720	152880	87360	65520	43680
Boat transport km	km	133856	92432	91818	92610	92972
Boats	number	2	2	2	2	2
Boatmen	number	22	22	22	22	22
Delays, total all vessels	minutes	10842.5	3903.3	6505.5	19082.8	83270.4
Service level	%	97.1	98.9	98.3	95.2	84.1

4.5 Business- and socioeconomics analyses (cost evaluations)

The simulation results presented in the previous section form the basis to further cost evaluations for different stakeholder or actors (pilots, shipping lines, Sjöfartsverket, and society) in each simulated pilotage scenario.

4.5.1 Cost modelling values

Table 13 shows the 23 cost item values under different cost categories for the 4 actors. Detailed description of each cost item and their value modelling and reference sources are given in section 2.3.

Table 13 Cost item values.

	Cost type	Indicator name	Indicator unit	Cost intensity (kr/unit)
Pilots	Workplace safety	Pilot jobs – regular	regular job	100
Shipping lines	Fees for pilot service	Pilot jobs – NSA	NSA job	500.00
	Fees for pilot service	Pilot jobs – regular	regular job	500.00
	Service quality	Delays	minute	51.00*
Sjöfartsverket	Boat transport	Boat transport km	km	132.80
	Boat transport	Boatmen	Boatman	842 700.00
	Boat transport	Boats	boat	3 000 760.00
	Land transport	Car – commuting	km	15.00
	Land transport	Car – work duty	km	25.10
	Pilot costs – Salaries	Bonus hours – day	hour	130.00
	Pilot costs – Salaries	Bonus hours – night	hour	160.00
	Pilot costs – Salaries	Pilot jobs – NSA	NSA job	200.00
	Pilot costs – Salaries	Pilot jobs – regular	regular job	195.00
	Pilot costs – Salaries	Pilots – NSA	pilot	1 014 000.00
	Pilot costs – Salaries	Pilots – regular	pilot	986 960.00
Society	Air pollution externalities	Boat transport km	km	2.15
	Air pollution externalities	Car – commuting	km	0.12
	Air pollution externalities	Car – work duty	km	0.12
	Climate externalities	Boat transport km	km	8.35
	Climate externalities	Car – commuting	km	0.23
	Climate externalities	Car – work duty	km	0.23
	Traffic externalities	Car – commuting	km	2.89
	Traffic externalities	Car – work duty	km	2.89

* Source: CE Delft 2019, Handbook on the external costs of transport, Version 2019 – 1.1.
The costs of delays for shipping companies may, however, be higher than the value presented here (e.g., a sample average delay cost of 88 kr/min could be derived from Trafikverket's representation report for Samgods (Vierth, Lord, & Daniel, 2009)). On top of this cost, there may be additional costs relating to port delay fees, for example. Those fees are not considered here. The delay costs will be further examined in the following cost analysis.

Note that, as mentioned in section 4.1.1, costs of infrastructure elements including fairway sensors and other possible facilities for NSA should also be included in principle. Nevertheless, for the Gothenburg model calculations, it has been assumed that: 1) there is no need for new facilities for NSA, since the existing pilot station and/or VTS centre would serve as NSA station; 2) there is no need for fairway sensor infrastructure since this is already in place in Gothenburg. Accordingly, the corresponding costs are not considered in the cost evaluations.

4.5.2 Cost evaluation – Business-as-Usual

As an illustration, we first look at the cost evaluations of the business-as-usual baseline case based on the corresponding simulation results. Figure 9 – Figure 10 and Table 14 show the aggregated total and relative costs for each actor.[5]

It can be seen that the cost of Sjöfartsverket dominates the total cost of pilotage service by up to 74.58 mnkr per year (with a total of 27 regular pilots), corresponding to 93.2% of the evaluated total cost. If the yearly cost of Sjöfartsverket is further broken down, as shown in Table 15, it can be seen that the cost of the pilots' salaries contributes to 35.7%, while the two

[5] *The detailed results on each cost item are found in a separate internal document.*

pilot boats including the boatmen's salaries amount up to 32.9% of Sjöfartsverket's total cost. Moreover, the transportation distance of pilot boats also contributes significantly to up to 23.8% of Sjöfartsverket's total cost, making the total cost associated with (maintaining and operating of) the two pilot boats amounting up to 56.7% of Sjöfartsverket's total cost. Apparently, with the introduction of NSA, the significant cost related to pilot boat transportation distance will be reduced directly, as can be seen next.

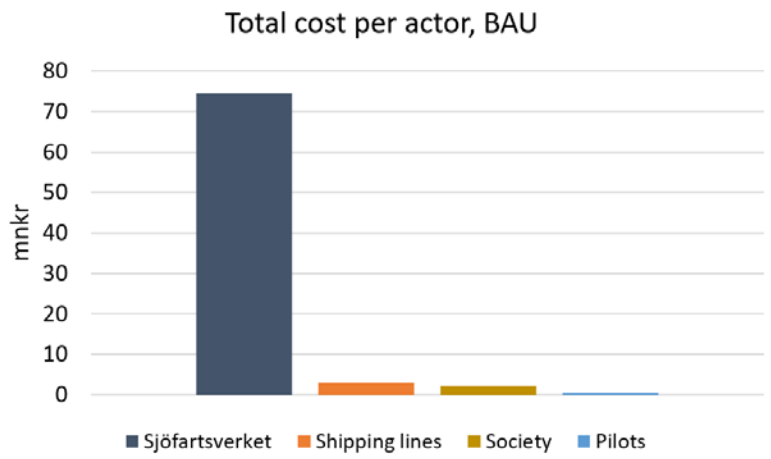

Figure 9 Total yearly cost per actor for business-as-usual pilotage.

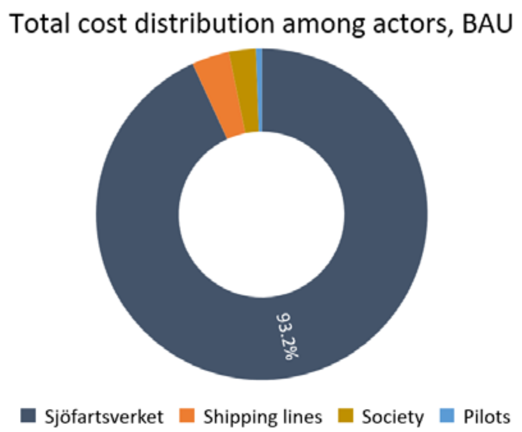

Figure 10 Relative cost per actor for business-as-usual pilotage.

Table 14 Total and relative cost per actor for business-as-usual pilotage.

Business-as-usual	Total	Sjöfartsverket	Shipping lines	Society	Pilots
Total cost (mnkr)	80.05	74.58	2.90	2.10	0.47
Relative to total cost		93.2%	3.6%	2.6%	0.6%

Table 15 Detailed yearly cost of Sjöfartsverket for business-as-usual pilotage.

	Cost type	Cost per year (kr)	Relative to total cost
Sjöfartsverket Business-as-usual	Boat transport km	17 776 077	23.8%
	Boatmen-salaries	18 539 400	24.9%
	Boats	6 001 520	8.0%
	Car – commuting	2 620 800	3.5%
	Car – work duty	990 120	1.3%
	Bonus hours – day	521 807	0.7%
	Bonus hours – night	571 056	0.8%
	Pilot jobs – NSA	0	0.0%
	Pilot jobs – regular	915 135	1.2%
	Pilots – NSA	0	0%
	Pilots-salaries – regular	26 647 920	35.7%
	Total	74 583 835	

4.5.3 Cost evaluation – Full-NSA – 8 pilots at duty

This section describes the total costs and the relative cost reductions as compared to business-as-usual for different full-NSA pilotage scenarios involving 1 NSA pilot (that can guide one vessel at a time) using the corresponding simulation results as described in section 4.4. Firstly, we look at the total costs if we still maintain 8 pilots at duty, as illustrated in Figure 11 – Figure 12 and shown in Table 16 – Table 17. It can be seen that even though the relative cost reductions as compared to business-as-usual for Sjöfartsverket are less than other actors, the total cost reductions of Sjöfartsverket still dominate the total cost reductions by nearly 9% with the increasing number of NSA-capable vessels, mainly due to the reduced pilot boat transportation distances with the increased utilization of NSA pilotage. In parallel, for other actors, the respective yearly costs also decrease significantly with the increasing utilization of NSA pilotage, even though the absolute total cost reductions are considerably smaller than those of Sjöfartsverket.

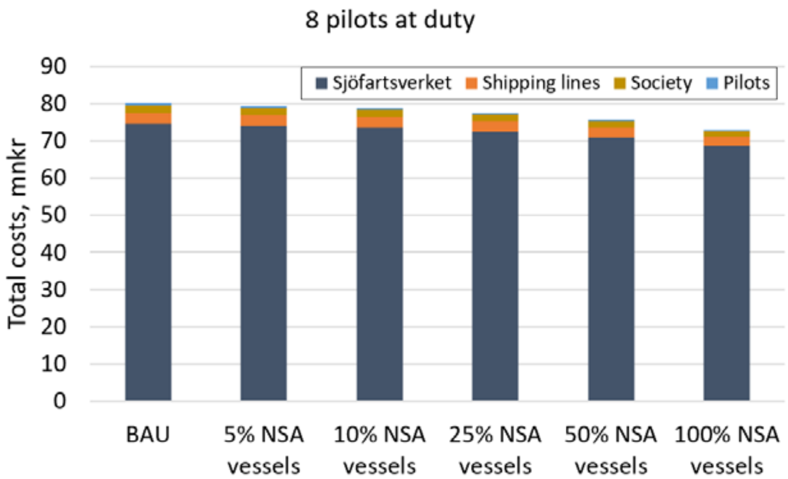

Figure 11 Total costs of full-NSA pilotage scenarios, 8 pilots at duty.

Table 16 Total costs of full-NSA pilotage scenarios, 8 pilots at duty.

Cost (mnkr)	Total	Sjöfartsverket	Shipping lines	Society	Pilots
BAU	80.05	74.58	2.90	2.10	0.47
Sc 1, 5% NSA vessels	79.19	73.86	2.88	1.99	0.46
Sc. 2, 10% NSA vessels	78.75	73.51	2.83	1.96	0.45
Sc. 3, 25% NSA vessels	77.52	72.47	2.77	1.88	0.42
Sc. 4, 50% NSA vessels	75.64	70.88	2.63	1.75	0.37
Sc. 5, 100% NSA vessels	72.95	68.55	2.55	1.56	0.31

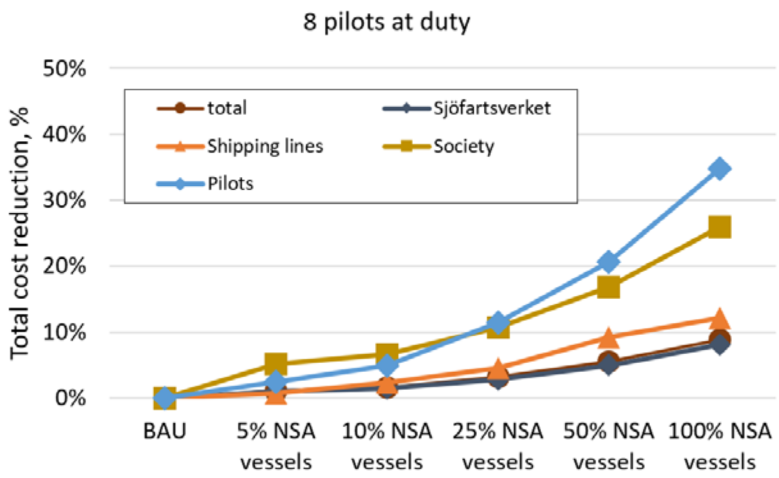

Figure 12 Relative cost reductions compared to BAU for full-NSA pilotage scenarios.

Table 17 Relative cost reductions compared to BAU for full-NSA pilotage scenarios.

Cost reduction to BAU	Total	Sjöfartsverket	Shipping lines	Society	Pilots
BAU	0.0%	0.0%	0.0%	0.0%	0.0%
5% NSA vessels	1.1%	1.0%	0.8%	5.2%	2.5%
10% NSA vessels	1.6%	1.4%	2.3%	6.6%	4.9%
25% NSA vessels	3.2%	2.8%	4.6%	10.6%	11.4%
50% NSA vessels	5.5%	5.0%	9.2%	16.8%	20.6%
100% NSA vessels	8.9%	8.1%	12.2%	25.9%	34.8%

4.5.4 Cost evaluation – Full-NSA – optimal pilot number at duty

We now further look at cost reductions involving full NSA pilotage with reduced number of total pilots at duty (with 1 NSA pilot that can guide one vessel at a time). Figure 13 – Figure 14 illustrates the total costs and relative cost reductions with the optimal, i.e., the minimum required, number of total pilots at duty at service levels not lower than that of business-as-usual, while Table 18 – Table 19 show the corresponding results. It can be seen that, with the guaranteed service level (higher or equal to BAU), and with the increasing number of NSA-capable vessels, the total costs can be reduced to up to nearly 23%, dominated by Sjöfartsverket's cost reductions due to both the reduced pilot boat transportation distance as well as the reduced pilot salaries. Note here that, for Scenario 1 (5% level-1 NSA-capable vessels) and Scenario 4 (50 level-1 NSA-capable vessels), the cost reductions for shipping lines are zero, due to the same service level (or equivalently the total delays) as BAU with the reduced total number of pilots at duty.

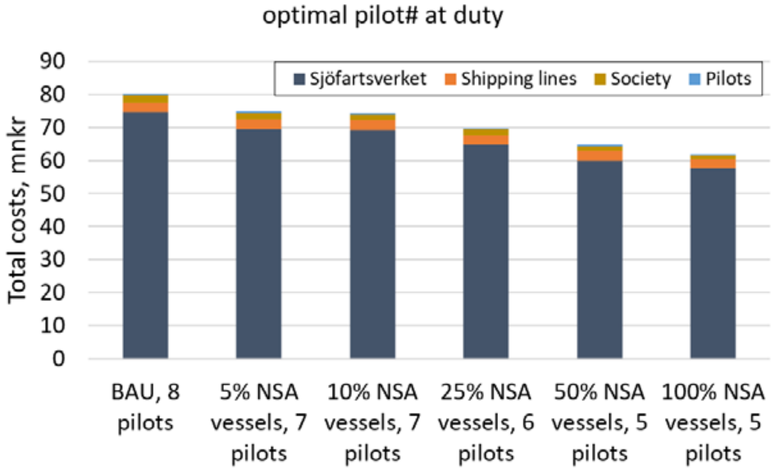

Figure 13 Total costs of full-NSA pilotage scenarios, optimal/minimum required total number of pilots at duty.

Table 18 Total costs of full-NSA pilotage scenarios, optimal/minimum required total number of pilots at duty.

Cost (mnkr)	Total	Sjöfartsverket	Shipping lines	Society	Pilots
BAU, 8 pilots	80.05	74.58	2.90	2.10	0.47
5% NSA vessels, 7 pilots	74.79	69.52	2.90	1.91	0.46
10% NSA vessels, 7 pilots	74.36	69.17	2.86	1.89	0.45
25% NSA vessels, 6 pilots	69.71	64.74	2.83	1.72	0.42
50% NSA vessels, 5 pilots	64.77	59.97	2.90	1.53	0.37
100% NSA vessels, 5 pilots	61.93	57.61	2.68	1.34	0.31

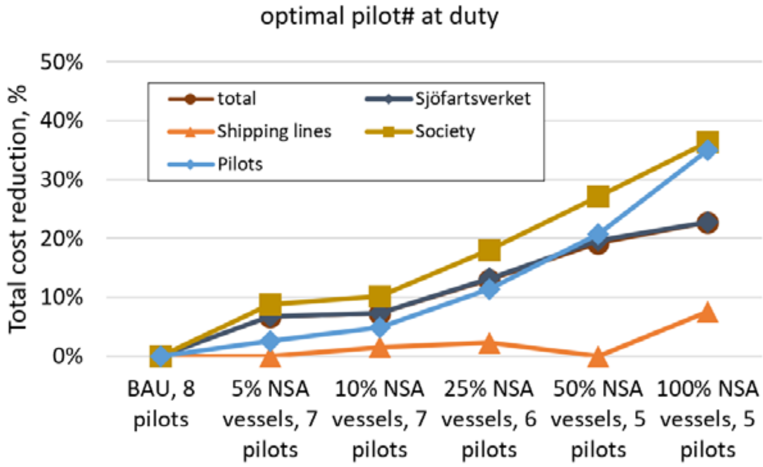

Figure 14 Relative cost reductions of full-NSA pilotage scenarios compared to BAU, optimal/minimum required total number of pilots at duty.

Table 19 Relative cost reductions of full-NSA pilotagescenarios compared to BAU, optimal/minimum required total number of pilots at duty.

Cost reduction to BAU	total	Sjöfartsverket	Shipping lines	Society	Pilots
BAU, 8 pilots	0.0%	0.0%	0.0%	0.0%	0.0%
5% NSA vessels, 7 pilots	6.6%	6.8%	0.0%	8.8%	2.5%
10% NSA vessels, 7 pilots	7.1%	7.3%	1.5%	10.2%	4.9%
25% NSA vessels, 6 pilots	12.9%	13.2%	2.3%	18.0%	11.4%
50% NSA vessels, 5 pilots	19.1%	19.6%	0.0%	27.1%	20.7%
100% NSA vessels, 5 pilots	22.6%	22.8%	7.6%	36.3%	34.9%

5. Discussion and final remarks

Based on the quantitative results obtained, it can be assumed that the implementation of the NSA alternative, in combination with traditional pilotage, could lead to cost savings for Sjöfartsverket, especially when it comes to the use of pilot boats, pilot boat crew and associated fuel consumption, as well as pilot commutes by car between home, pilot station and port.

In terms of performance, it could lead to reduced delays and improved service levels and pilot availability, which is in turn one of the main perceived benefits for the shipping companies, as this could help to reduce the ships' waiting times and associated costs.

It is not hereby proposed that the number of pilots in Gothenburg should be reduced. The simulations are a simplified representation of pilotage and do not account for sick leave or similar events. The simulations show the potential of NSA pilotage with reduced pilot numbers, which may be especially useful for port areas where the recruitment of pilots is more difficult, or the service levels are lower.

It is uncertain how much Sjöfartsverket could charge its customers for the NSA service. From a regulatory standpoint, similar services cannot be charged differentially, or outside of the set pricing scheme (ref: *Förordning (1999:215) om lotsavgifter*), but the fee may depend on how the NSA service is categorized at Sjöfartsverket.

It is expected that the safety of the pilots would increase when providing assistance from shore, as the risk for potential injuries when boarding the ship would be reduced. This is also an important societal benefit, as is the reduction of fuel consumption and subsequent emissions. The safety of ships using NSA is assumed in this report as equal or above the safety of traditional pilotage, and therefore associated costs of potential NSA safety hazards are not considered in the calculations (e.g., if a ship using NSA instead of regular pilot experiences an incident). Safety hazards are, however, under consideration in a separate work package.

Other potential costs may include technical or real-estate investments required to be able to offer the NSA service at Sjöfartsverket (e.g., an NSA shore centre and equipment), as well as technical investments from the ships' perspective (e.g., new communications system onboard the bridge); the need to train pilots on NSA operations; or the need for shipping companies to obtain special pilot exemption certificates in order to be eligible to use NSA.

More specific evaluations are needed in order to get a full picture of the investment costs for Sjöfartsverket, the long-term impacts on pilotage operations, as well as the impact and costs for shipping companies.

6. References

Vierth, I., Lord, N., & Daniel, J. M. (2009). *Representation of the Swedish transport and logistics system (Logistics Model Version 2.00)*. Retrieved from https://bransch.trafikverket.se/asek: