YRKESHÖGSKOLAN NOVIA

SHIPPING WATER FROM FINNISH PORTS FOR CRISIS AID

Evaluation on Ability of Finnish Ports to Supply Potable Water for Business or Crisis Aid Purposes

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Abstract

Subject of the thesis is to evaluate how viable it is to ship water from Finland and Finnish ports to drought-stricken or other crisis locations and to figure out if Finnish ports have the capacity to ship it quickly at the time of the need. The aim is to assess if such a capacity is available on quick notice and what would be the optimal way to perform such an operation. Main sources for the information were different ports, operators and terminals, and the municipal water suppliers providing them with water.

It was found that due to the vastly cheaper energy and economic costs of producing potable water through desalination, shipping water from Finland during regular times has no viability as business model.

An imaginary crisis scenario was used to framework what kind of solutions could be viable and what kind of solutions different ports and operators could offer. As superior options were found the options with weaker performance were eliminated.

Different ship types and methods of carrying cargo were evaluated, as well as different port types and their capabilities at sourcing the water to the ships along with the municipal water facilities supplying the ports with the water.

It was found that most of the ports in Finland are only equipped to deal with the water needs of merchant vessels and that their capacity to provide large quantities of water were low. With some modifications to the infrastructure the capacity could be increased in some locations quickly at a cost.

A suitable location with readiness to provide large quantities of water with little warning and little issues for the municipal water provider was found. With these capabilities it was found that certain Finnish ports could easily fulfil the criteria set for the aid project in the crisis scenario at reasonable cost.

Language: English
Key words: shipping potable drinking water Finland Finnish ports crisis aid viability

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1 Introduction

Among Finns our supplies of fresh drinking water are generally revered as one of our greatest assets. Yet there seems to be very little being done to utilize these assets. Other sources closer to the destination as well as costs of desalination create an upper threshold for the price of water as resource. While bottled spring water from Finland is gaining some interest around the world as luxury product, there hasn't been any notable attempts to sell it commercially in bulk.

With climate change disturbing weather patterns around the world, it's entering a time of uncertainty where changes in rainfall and worsening heat waves can create dire need of water in some geographic regions such as Southern Europe. So far in these kinds of situations the locals have been able to supply water from nearby areas or regions. As the amount of people affected by the drought increases, the available resources also tend to be reduced while the demand rises. This could lead to a situation where sources that could usually help can't provide the aid anymore. In this kind of situation having the infrastructure and ability to quickly ship water from Finnish ports could be both economically and humanitarianly viable option. Having the knowledge of if, how, how quickly and how much and at what cost Finland would be able to supply water would be advantageous if the situation ever arises.

In this thesis the capabilities of Finnish ports and the water suppliers to quickly provide water for shipping is studied. The key points of interests are the ports capacities to load the water, the type of vessels to carry the water with, the capabilities of water supplier to provide water, the price of the water, and what methods of transportation would be most efficient and economical.

Based on these findings it can be discovered if such economic business or humanitarian aid could be conducted. The thesis aims to act as a basic roadmap if the need for such a project ever arises.

1.1 The Objective, research question and methodology

At the beginning of this study the goal was to analyze and assess the viability of shipping water from Finnish ports and what kind of capabilities the ports have for supplying the water. Quite soon the research showed that desalinating water was superior option for water supply at coastal areas, and shipping couldn’t contend with it economically during regular times.

The aim was then shifted towards figuring out if Finnish ports could be used for supplying water in a time of crisis. This set the aims towards figuring out if Finnish ports have readily and quickly available capacity to transport bulk amounts of potable water from them. A scenario was built for a situation where such capacity was required.

The main method of figuring these capacities was contacting the different port, terminal, and municipal water suppliers. Many phone interviews were conducted, emails sent, and some facilities were visited. From the information gathered a good solution was found that eliminated the other options and answered the research question.

1.2 The scope of the thesis

The process of supplying water from other parts of the world to another is a complicated one involving many different fields, topics, and parties. Multiple thesis worth of material could easily be written over different parts of the scenario that was designed for the thesis. To keep the thesis from bloating into deep dive into every topic, the decision was made to write the thesis so that it could provide necessary basic information of the important steps to a reader who doesn’t have prior knowledge on the topics.

2 Background

The age-old story in Finland has been that our freshwater resources are our greatest asset and that it could even be a reason for foreign power to invade us. As climate change alters the weather patterns the availability of water becomes harder to predict. In Southern Europe areas are already struggling with their water supply, and restrictions must be put on the water use (Karismo, 2023). Could shipping water from Finland be the solution?

2.1 Prior examples of shipping water with ships

When looking at the prior cases of water being supplied through the sea with ships, some examples were found. In Barcelona during 2008 water was transported with chemical tankers to alleviate the water crisis. (Keeley, 2008) In Tripoli, Libya during the Arab Spring the water deliveries from the pipelines to the capital were disrupted and trucks and a ship loaded with water were used to alleviate the looming water crisis. (UPI, 2011) Such prior examples prove that there can be situations where shipping water in time of need is an viable alternative. No scientific papers on the topic were discovered.

2.2 Why water transportation isn't viable business during regular times

When one starts to look at the costs of water desalination it quickly becomes obvious that transporting the water to any meaningful distance during regular times is not economically viable (advisian, n.d). The technological advances in water desalination have made both the economical and energy costs of water desalination far cheaper options than carrying the water over the sea in ships.

At the given examples of the production costs for m^3 of water being around 1$ or less, an handysize chemical tanker with carrying capacity 20 000m^3 would end up having a cargo that's total value would be less than 20 000€ when compared to desalination (advisian, n.d). With the rough fuel consumption estimates for this sized and the current MGO price closing in on 600$/tonne the value of fuel burned would exceed the value of the ships cargo in just couple of days vessel (Shafran, How Much Fuel Does a Cargo Ship Use? Ship Fuel Consumption Explained with Examples, n.d) (Reuters, nd).

In Spain the daily production of desalinated water is already over 5 000 000m^3 per day and the energy requirements per m^3 have gone down from 20kWh/m^3 down to 2.5-3kWh/m^3 (Zarza, Spanish desalination know-how, a worldwide benchmark, 2022). If a ship with 8000 kW engines would steam at full power for a week, roughly the duration it would take to travel from Finland to Spain, it would produce enough power to produce ~500 000m^3 of water just with the fuel used to power the ship. If the ship had a carrying capacity of 20

000m^3 using the same power to desalinate water would generate 25 times the volume of water that the ship could deliver.

For these reasons it can be conclude that there is no viable business in shipping water from Finland as bulk product. There is no increase in the value of the water as it's moved from Finland to other destinations compared to just producing the water from seawater and therefore there is no justifications for the cost of shipping.

Therefore, it can be concluded, that the only situation there might be interest in shipping water in bulk amounts from Finland is at the time of crisis. If for whatever reasons the supply and production capabilities are limited at the destination and there is dire need for water while the nearby areas also being unable to provide aid quickly, there could be either humanitarian or economical incentive to ship water from Finland.

3 Building the scenario for the thesis

For the purpose of this thesis, imaginary scenario was used as a tool to figure out the most reasonable and efficient methods of providing water from Finland. The requirements for the scenario were set with expectations that they could be fulfilled but could prove challenging to most ports.

3.1 The scenario

Southern Europe has been heavily affected by drought during the months of June and July and the regional water consumption far exceeds the production capacity. The weather forecast predicts the situation to only get worse during the following month. Furthermore, a chemical spill has rendered the source for the local water production temporarily unusable. The neighboring cities are struggling to provide water to their inhabitants and are unable to help their neighbors in a significant manner. In Finland the opportunity to help with the water crisis is recognized and investigation into the different ways it could help, or if it can help at all, is launched.

3.2 Target destination

Target destination is 2000 nautical miles away from the point where the routes from different Finnish ports roughly converge in the Baltic Sea, 59°N 021°E seen on figure 1. This point was selected so it can easily be estimated how much extra distance the ship will have to travel to and from the different ports in Finland.

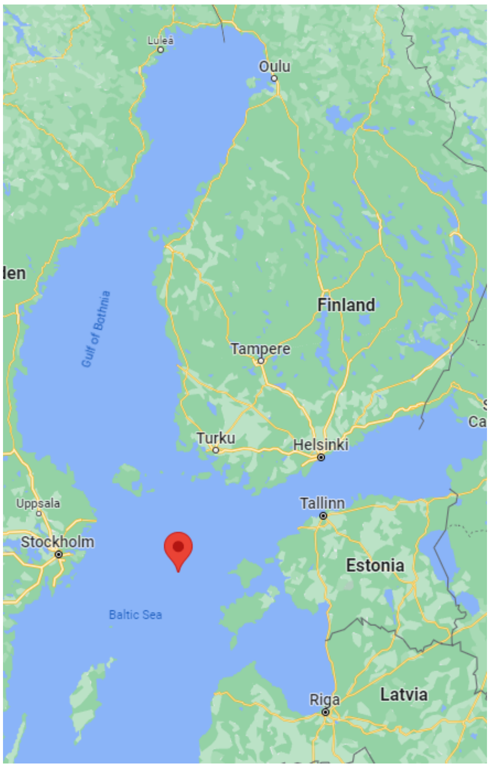

Figure 1 The location of 59°N 021°E on Baltic Sea

The destination has 140 000 inhabitants, is located by the sea, and has modern port facilities that are capable of receiving the water from any ship type or size that is decided to be used.

3.3 Goals for the aid plan

The goal for the aid is set at shipping 14 000m^3 of drinkable water to the destination. This would amount to 100 liters of water per inhabitant if distributed evenly. If used only for drinking, this would result in roughly 30 days supply of water at 3,3 liters of water per person per day. The sooner the water can be delivered the better. The economic costs should also be considered to ensure efficient use of resources. If water was available from elsewhere faster and cheaper, there would be no interest in this kind of aid.

3.4 Costs of the aid plan

The economic costs for the aid plan should also be considered. If unlimited funds were allocated for this kind of project, airlifting bottled water would probably be the fastest way to provide aid. Roughly 280 Airbus A350-900 flights with maximum payload of about 50 tons per plane could deliver the target amount of water (Airbus A350, n.d). It could be estimated that carrying 100L of water per person costs roughly the same as return flight tickets would cost to destination at same distance would. The rough estimate for costs of such operations looking at the flight prices for the late summer would end up in the ballpark of 300-500€ per person and the price of water then being around 3-5€/liter. At this rate more attractive options would probably be available for the target destination.

As the economics during time of crisis can be hard to predict, it was decided to focus on the operation costs estimates and to omit the profits from the arbitrage opportunities presented by such situations. The division of costs, possible profits and the glory for successful aid operation are also omitted, and it's assumed that the parties receiving the aid will eventually cover the costs for the services at the current market rates.

4 Different options for shipping water in bulk

To decide the best method of transporting water in the scenario, various different methods of shipping and transportation need to be looked at. The different ship types have their own pros and cons, the ports have differing abilities to load the water into the ships and the municipal water producers need to also be able to provide the required amount of water to the port.

4.1 Ship options for shipping water in bulk

Choosing the right ship type for transportation is an important factor in determining the feasibility of the plan. In this subchapter the main features of different vessel types, their advantages and disadvantages for the task and make assessment on their viability for the task will be looked at.

4.1.1 Chemical tanker

Chemical tankers are tanker ships designed to carry various chemicals in large quantities on sealed and safe tanks from port to another. Their main benefit is having the storage space for the water already built into the ship as well as having the pipeline and pump systems to load and discharge the liquid cargo easily. On average the chemical tankers hulls are generally built for speeds of 12-17 knots, so at full steam the transportation could happen relatively quickly (Shafran, The Speed of a Cargo Ship at Sea, n.d).

Picture 1 Chemical Tanker Ternholm with carrying capacity of 14 825DWT

The main challenge for chemical tankers such as the one seen on Picture 1 is finding a port facility where they can load enough potable water quickly. The sizes of chemical tankers vary from 5000 DWT to 59 000 DWT and loading such volume of water isn't something port facilities are generally built or prepared for. For the target amount of water a handysize tanker with 14 000 to 20 000 DWT capacity would be needed. The Length Overall (LOA) of the ship would be in the range of 150 meters, draft around 9 meters and the beam of the ship around 20 meters.

The second challenge for chemical tankers is ensuring that the water doesn't get contaminated from remnants of previous cargo. Publications such as Dr. Verwey's Tank Cleaning Guide and Miracle Tank Cleaning Guide and Cargo database offer industry standard guidelines for preparing and cleaning the cargo tanks when shifting cargo from one type to another.

4.1.2 Container ships

Container ships are designed to carry modular containers. They are usually built for higher top speeds at 14 to 20 knots (Shafran, The Speed of a Cargo Ship at Sea, n.d). Their main advantage as vessel type is being able to easily carry various sorts of cargo that are easy to load and discharge with cranes inside the containers. 40' Chemical container unit can carry 26,7m^3 each, meaning that container ship roughly the length of 150 meters with carrying capacity of 14 000 DWT would need 525 units to fill its carrying capacity (freightfindres, n.d). The loading and discharging operations for containership would be straightforward and could be done in just about any port facility with cranes. Loading the ship with single crane operating at 30 containers/hour the loading operations would be concluded in 17½ hours.

Picture 2 Container ship CAPT. KATTELMANN capable of carrying 1440 TEU or 20350 DWT

The main challenge for using containerships like the one in Picture 2 for such operation is finding enough empty and clean tank container units, loading them up with water that's prepared to last over the voyage and delivering them into port. As it is, there simply isn't enough empty and cleaned tankers in the numbers required to fill even single container ship sitting around in Finland and even if there was, leasing, gathering them to the loading facility and filling them up and transporting them into the destination would be very expensive and logistically challenging task.

Containerships also mostly traffic in the designated routes that have their cargo and their logistics planned as part of the larger logistics systems. Finding a containership that's available for the project in short notice could prove challenging.

4.1.3 RoRo ships

Roll on Roll off ships or RoRo ships for short are vessels designed to be quickly loaded and discharged with cargo that is either on trailers or loaded on casettes with wheels. Especially in Finland RoRos are also often used for carrying paper industry products, as they are easy to load and discharge from RoRo ships. RoRos are usually built for 12-18 knots and their advantages are swift loading operations and ease of integrating to truck based logistic systems (Shafran, The Speed of a Cargo Ship at Sea, n.d). RoRo ships are used a lot for transporting fresh produce and food as the schedules for the ships are stable and the trailers they arrive in don't have to sit idly in the port. RoRo ships also offer good capacity to provide electricity for the refrigerated trailers. Often in RoRo ships the practical carrying capacity is measured in lane meters rather than the weight or number of trailers loaded in it.

Picture 3 RoRo ship Bore Sea capable of carrying 13 535 DWT or 2863 lane meters

The disadvantage of using RoRo vessels just as for container vessels is finding the tanks to store the water in and deliver with to the ship. RoRo vessels like the one seen in Picture 3 tend to also be larger in size than containerships with equal carrying capacity as the trailers and casettes aren't stowed into the ship as compactly. Due to the RoRo vessels stable schedule, finding an available RoRo vessel for just the purpose of transferring water could prove challenging. As the amount of cargo imported to Finland is usually greater than the amount exported, some water could be delivered with the available extra capacity on tanker trailers available if the RoRo is on a routine path that is close to the affected area. In such a case any excess space remaining could be filled up with water laden chemical trailers if they were available at short notice.

4.1.4 Oil tankers

Oil tankers like the one seen on picture 4 are designed to carry large quantities of oil safely across the seas. They have wide and long hulls to maximize the volume of cargo and the speed of the vessel isn't a top priority in the design. The average speeds for oil tankers vary between 9 and 15 knots (Shafran, The Speed of a Cargo Ship at Sea, n.d). They are some of the largest ships ever to be built and offer unparalleled amount of liquid cargo carrying capacity.

Picture 4 Oil Tanker Stena Provence capable of carrying 65 125 DWT

Even small amounts of oil left over in the tanks or pipelines and the pump systems can spoil the water it would carry. As cleaning crude oil completely from tanker would be difficult and time-consuming operation, the use of oil carriers can be counted out from any scenario requiring sudden need for water carrying capacity.

There have been some suggestions on converting the older single hulled tankers that aren't considered up to safety standards anymore for oil carrying purposes into water carrying tankers (Song, 2010). However, with the economic and energy costs of producing water from desalination compared to carrying it around in a ship, the economic viability of such conversions would be questionable at best.

Some designs and ideas for converting or building new ships with large amount of desalination capacity have also been made, which could be viable solution for building flexible water desalination capacity to ease stress from local production during time of crisis (The Maritime Executive, 2015). Another idea would be to use the large ballast water capacity of the oil tankers for carrying fresh water. This would require special construction and monitoring for the ballast systems and would severely limit the ports the ship could load and discharge at. As the ideas and designs mentioned would take a long time to bring into reality, they are outside the scope of this thesis.

4.1.5 Bulk Carriers

Bulk carriers are designed to carry large volumes of solid bulk cargo in cargo holds that are essentially large open spaces. Cargo is generally loaded and discharged to and from bulk carriers via the use of cranes. The bulk carriers are built more with fuel economy and carrying capacity than speed in mind as their deliveries are rarely time sensitive enough for higher fuel consumptions of the higher speeds to be worth it. The speeds of bulk carriers generally range in the 8-14 knots on average (Shafran, The Speed of a Cargo Ship at Sea, n.d).

Picture 5 Bulk Carrier YANGTZE ETERNAL capable of carrying 32573 DWT

The bulk carriers like the one seen on picture 5 offer no advantages as a ship type in carrying liquid water cargo. The only realistic way would be loading the water into smaller tanks that would be stowed in the cargo hold, and the other ship types offer more advantageous options for the same method of transportation. The open spaces of bulk carriers are not suitable for carrying liquid cargo, as the liquid cargo will be able to move around freely forming waves and rolling motion making the ship unstable. Liquefication of solid cargo is one of the most serious threats for bulk carriers and many ships have ended up sinking because of it (Teoh, 2021).

4.1.6 Choice of ship type

From the different ship types listed, the chemical tanker seems to offer the best combination of advantages and disadvantages. For the use of RoRo vessels and containerships finding enough tanks to hold the needed amount of water would be very challenging if not impossible and the task of filling them up, preserving and doing quality control for water would be large and expensive operation. Furthermore, finding a chemical tanker that's available for the job should on average be easier than using a containership or RoRo vessel, which are mostly on scheduled routes with scheduled cargo that would be difficult to reorganize. Excess cargo space on these routes towards the target destination could easily be utilized on a smaller scale, which would work pretty much like any ordinary logistics shipment.

To progress the scenario of the thesis further, it was decided that a suitable handysize chemical tanker with capacity of 19 200 DWT was available, and Voyage chartered for the project. The ship is anchored waiting for orders in Antwerp Anchorage, an estimated 800 nautical miles away from the reference location, passing through Kiel Channel it should take around 55 hours to reach the reference location at 21 °N 021 °E.

The ship used for the scenario has Length Overall (LOA) of 146 meters, Beam of 23 meters, Draught of 9.4 meters at 19 200 DWT and Gross Tonnage of 12 000, the ship is equipped with 2x 4000 KW engines, has top speed of 15 knots and 18 cargo tanks with capacity of 21 000m^3. The ship is equipped with 14 cargo pumps each capable of discharging 250m^3/hour.

4.2 Ports and their capacity for loading water

The process of looking for a suitable port was done in parallel to choosing the ship. The key factors are availability of potable water and ability to quickly load it to the ship. The port also needs to meet the requirements set by the size of the vessel. The further up the port is on Gulf of Finland or Gulf of Bothnia, the longer the delivery will end up taking. For example, as seen on Figure 2 and 3 the travel distance and time for the closest and furthest port differs by around 30 hours if steaming at 15 knots.

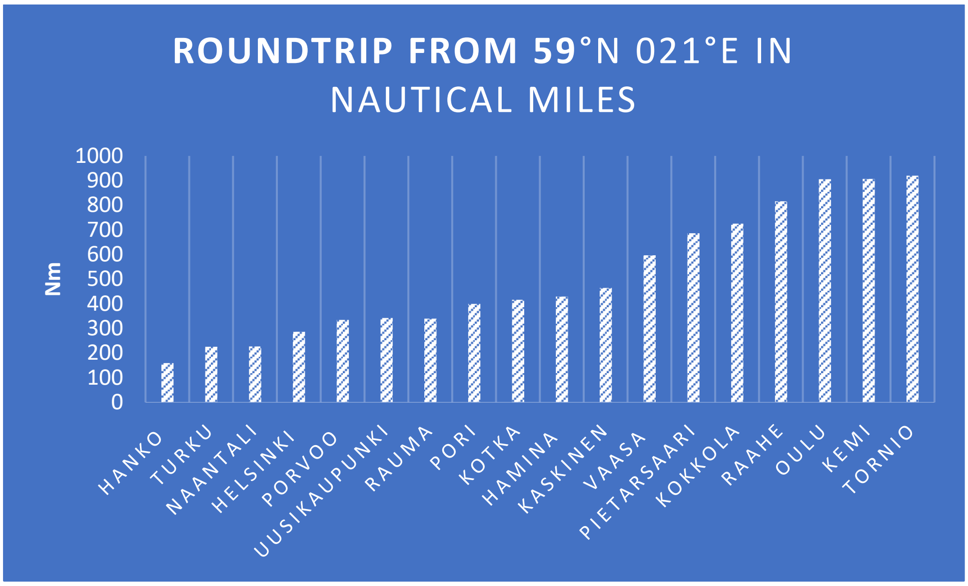

Figure 2 The extra distance the ships have to travel to different ports from the beginning point

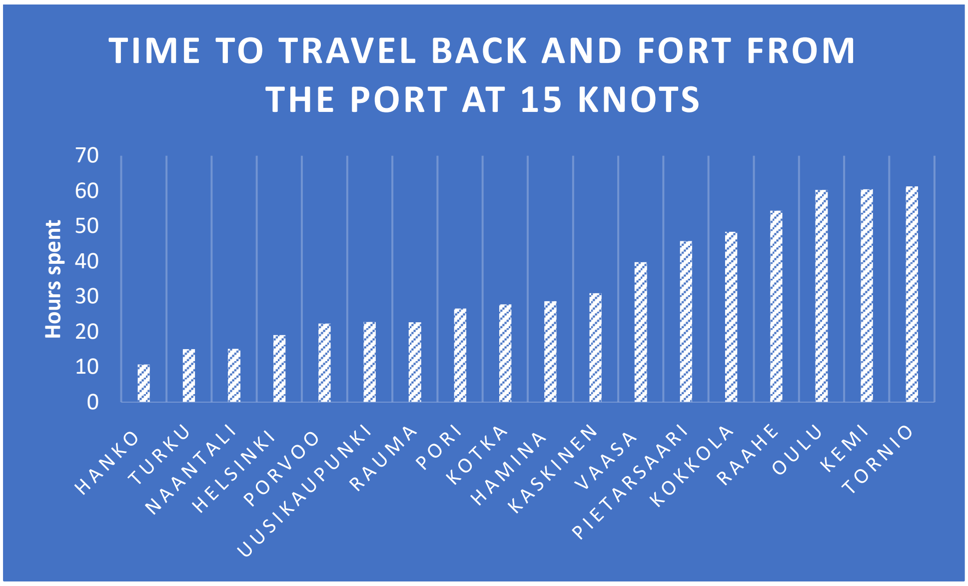

Figure 3 Time of travel from different ports from the beginning point.

Multiple ports, municipal water treatment facilities and companies operating chemical terminals in Finland were interviewed to come to conclusion on the most viable solutions and to find some improvised options. Not all the ports and operators could be reached or could provide the information that was asked about their capabilities and therefore some other viable alternatives might exist or be classified. It could be assumed that an actual aid project seeking to conduct such business would have better success in reaching all the facilities and getting the information required.

The Finnish National Emergency Supply Agency has for example their own pools “vesikuljetuspooli” and “satamakuljetuspooli” for the shipping and port related companies for preparedness reasons (Huoltovarmuuskeskus, n.d). Such existing structures could be utilized to contact and acquire information from the ports and shipbrokers in a more centralized manner. On my interview with Jukka Etelävuori, the contact personnel of the abovementioned pools and Logistics Executive at the National Emergency Supply Agency, he said that it would be good source for expertise, but the competitive procurement requirements would be problematic for organizing such project through them (Phone interview 2023, April 4). There was also no knowledge of existence of prior plans for transporting water in bulk from Finland to other countries at Huoltovarmuuskeskus or other parties and organizations who were interviewed.

4.2.1 Water from the port facilities

Based on the interviews from harbor masters, and technical managers, and my own experiences from different Finnish ports, in general Finnish ports aren't equipped to deal with loading big volumes of fresh water in short period. The current infrastructure is designed for loading freshwater to merchant vessel's needs, which are loaded from the municipal water line using hoses and loading 50-100 cubic meters of water requires multiple hours of loading time, on average the loading rate being around 25m^3/hour. Typical equipment like hoses and connections used to transfer water from port to the ship can be seen in picture 6.

Picture 6 The types of equipment used for routine water supplying operations for merchant vessels seen on visit to Port of Turku

The flowrate is affected by the friction from the length of the hose, its diameter, and the loss of pressure from the height it must travel upwards. At loading rate of 25m^3 /hour filling up 14 000m^3 would take over 23 days, which is inefficient both in terms of providing aid in time of crisis as well as use of the vessels time.

4.2.2 Possibilities offered by water main lines at port facilities

Interviewing the Technical Manager of Port of Rauma, Timo Metsäkallas they raised the possibility that if there was absolute necessity to get the water, the water main line running at the pier could be dug up and a bigger bore temporary pipeline could be used to source the water (Phone interview 2023, March 24). While interviewing the Managing Director of the Rauman Vesilaitos, Jukka Vastamäki from the municipal water provider, they agreed that it could be at least theoretically possible option, but something they didn't seem too excited about (Phone interview 2023, March 24). Such operation would require modifications and possible disruptions to the existing infrastructure, which naturally increases costs and causes disturbances. Similar opportunities could be possible on other Finnish ports as well, but if there are other viable options then there is no need to resort to these kinds of methods.

4.2.3 Chemical terminals in Finnish ports

Using chemical terminals for water transportation seems like an attractive option at first glance. The facilities include large storage capacity to start storing the water even before the arrival of the ship and are equipped with powerful pumps for loading the vessel rapidly (WIBAX, 2023). However, after interviewing the Terminal Operator Merike Sysinoro and Regional Manager Anne Helanto at Wibax, it was found out that multiple logistical problems make this attractive option much less attractive (Phone interviews 2023, March 24).

The first challenge is the availability of tank space. If the facilities don't happen to have loads of empty and cleaned tanks the moment they are needed, then moving the existing fluids away and cleaning them to be suitable for potable water usage is a challenging and time-consuming task. In practice this would be a very tough task to do for quick operation such as the one planned in the scenario.

The second challenge is cleaning the storage tanks, pipelines, and pumps to handle potable water safely. If the required free tank capacity were available, they most probably require a thorough cleaning process to make them clean enough for potable water safety standards. The tanks are usually used to handle all sorts of chemicals, fuels and oils that can end up polluting the water even in trace amounts, potentially spoiling the entire load. The cleaning process would deduce from the time there is to fill the tanks before the ship would arrive.

The third challenge is filling up the tanks. While loading water to the tanker from the tanks using the pumps at the facilities would be one of the fastest options for loading, having a way to fill up the tank. As the tanks are not connected to any big water lines because there hasn't been any practical need to build such connections, the water would need to be transported to the tanks either by tank trucks or with hoses sourced from the municipal waterlines. Filling the tanks up with hose connections from the municipal waterlines would take too long to be viable and with the trucks the same problems are faced as before on availability and cleanliness. On top of this nearby location to load the trucks with water and discharge them in an efficient manner would need to be found.

14 000m^3 of water would require 412 truckloads with the capacity of 34m^3 per truck. At discharge rate of 2m^3 per minute and assuming 30m^3 of each truck's capacity could be used efficiently the number of deliveries would go up to 467. If each truck would take 15 minutes to discharge, and 10 minutes would be spent on swapping the connections and swapping the trucks. Assuming the trucks could be loaded nearby at a rate of 25m^3 per hour then just 4 trucks would be enough to perform 24/7 rotation. At this rate loading the required 14 000m^3 would require a bit over 8 days.

In conclusion lots of things would need to align to make this option viable, and trace amounts of previously stored chemicals left in the tanks, pipelines or pumps could ruin the entire operation. Even if clean tank capacity was available, loading them with potable water would be an additional logistical challenge, and in the end, it wouldn't end up saving all that much time compared to other options. Transporting the water to tanks before transporting it from there to the ship would in most cases end up just being an unnecessary extra step.

4.2.4 Container, Bulk and RoRo ports

The container, bulk and RoRo ports offer no additional benefits or infrastructure for loading water on to the ships. If the capacity and logistics for filling up modular container tanks and their delivery existed, then their use and connections with rail and roads could be utilized. The ports of these types that could be reached all had similar capacities for filling up potable water for merchant vessels and no current needs or plans to develop their water infrastructure to the scale that could be utilized for this kind of scenario.

4.2.5 Cruise line terminals

The terminals operating the cruise lines and the ferries have better infrastructure for providing water to the ships due to their larger water demand than the ports operating just the merchant vessels. For example, in Port of Turku, according to the Harbour Master Timo Aaltonen the pipelines seen on picture 7 can provide roughly 133m^3/hour of water depending on the water pressure. At this rate the 14 000m^3 could be loaded in 105 hours (interview 2023, March 29). However, if the cruise lines and ferries would be using their port keys regularly, there would be multiple interruptions to the loading process during the day where the loading would have to be paused, the chemical tanker unmoored while the cruise liners were conducting their regular business at the port.

Picture 7 Pipelines used to supply water to cruise ferries on Port of Turku

When asked about the plan from the provider of water in the region, Turun Seudun Vesi their hydrogeologist Sami Saraperä also raised concerns about this kind of plan possibly causing problems with the pressures in the municipal water system, as constant and strong flow to unusual direction can cause imbalances in the system (phone interview 2023, April 11). These imbalances can cause pressure to drop in other parts of the system, flow in the wrong direction and produce quality issues to the water from disturbing the built-up sedimentations inside the pipeline. It's not something that would prevent such operation, but they would prefer to know as much in advance as possible if such operation was ever to occur to prepare to mitigate the issues, and in the subsequent cases after they would have figured how to tune their system for the situation it wouldn't be problem. Prior knowledge would help them adjust the amount of water taken from the wells to keep the water distribution steady.

4.2.6 Naantali terminal

Until few years ago in Naantali, Neste oil refinery was operating, and used to be one of the largest water consumers in the region. Large water pipeline providing water to the facility and to city of Naantali runs through the port area there. During my interview with Heikki Telegberg, the Terminal Operator in Neste Naantali when questioning about the possibility of using their facilities for loading water, he suggested that this line could be easily used for such operation (Phone interview 2023, April 11).

Using this water line would also be separate from the tanks and pipelines handing the oil and other products in the terminal. Therefore, the water loaded would be fresh off from the municipal water supply and loaded straight to the ship without extra steps in the terminal.

The pipeline could be connected to a chemical tanker with small extension of around 10 meters and the 10-inch pipeline that can be pressurized up to 8-9 bars would be able to fill the required amount of 14 000m3 in hour and 20 minutes. Much higher volumes of water could also be supplied for vessels with higher capacity. When interviewing the hydrogeologist Sami Saraperä at Turun Seudun Vesi, they also referred to this line as being the optimal choice for them and the kind of pipeline they have the capacity to supply the water and the pressure to without causing problems elsewhere in the system. At daily production rate and storage capacity of over 65 000m^3 this amount wouldn't be that big of a deal for them (phone interview 2023, April 11).

Neste also has distillery in Porvoo but interviewing the Terminal Manager Kimmo Vahanto it was revealed that they don't have similar capacity available as they don't have big waterline running through their port area like the Naantali facility has (phone interview 2023, April 12).

For these reasons this option was selected as the port and water provider of choice for the scenario. It's one of the closest ports in Finland from the target destination, it already has the capacity to quickly load and supply water for the vessel and the port is built with tankers and chemical tankers in mind and is used to dealing with these types of vessels.

Similar solution was suggested from Port of Rauma, and not all the Finnish ports were questioned about such possibility, and similar capacities might exist elsewhere. The other major port closer to Naantali would be Hanko, but according to their water providers website they already struggle with the water sources during the summer months, and therefore Hanko was ruled out (Hangon Kaupunki, 2023). In Åland the production amounts were also less than 1/10thof the amounts produced by Turun Seudun Vesi, and while

Marienhamn is closer than Naantali, they would likely struggle more providing this amount of water (Ålands Vatten, 2023).

4.3 Sourcing the water

To determine the ports that could be utilized for the scenario it needs to be found out if they can supply enough water to the ship in a timely manner. The municipal water facilities supplying water to different ports source their water from different sources. Depending on the time of the year and the source for the water, 14 000m^3 could surpass the limitations set for the water intake. In groundwater areas if too much water is removed, the dried-up ground can collapse on itself reducing its capacity to hold and generate groundwater in the future. Ultimately the goal of the project would be to help export water to mitigate water supply problems elsewhere and not to import water supply problems back to Finland.

After finding the ports with the most potential for the chosen ship type the municipal water producers were interviewed about their capacity to produce enough water and supply it to the ports. The amount of water required in the timeframe it could be loaded wasn't a problem for any of the water providers contacted, but research on some of the options proved that not all the port cities have ability to provide large amounts of water year round (Hangon Kaupunki, 2023).

4.3.1 Supplying the water

There can be large variance in the water availability and production capabilities depending on the method of groundwater production. For example in Rauma during interview with the Managing Director of Rauman Vesi Jukka Vastamäki it was explained that the water is sourced from river water and settled in the artificial lake, the daily water production is around 7000-9000m^3 whereas they have the permits and capability to produce 16500m^3 per day (phone interview 2023, March 23). The 14 000m^3 of extra water could be produced within a couple of days, faster than it could be loaded to the ship from the existing water connections. The water used in Rauma is sourced from Eurajoki, and then settled in artificial lake Äyhönjärvi before being treated further and used for drinking water.

The water that would be used in Naantali Terminal is from the Turun Seudun Vesi, the municipal water provider for the region. The water is artificial groundwater sourced from Kokemäenjoki, which is screened, settled, and filtered before being transported through pipeline to Virtakangas to be absorbed through the sandy ground and collected again at the production wells after flowing through the ground for 3-4 months. The water is then pumped into tanks from which it flows gravitationally the distance of 60 km to Turku. There the water is stored underground in Saramäki rock cisterns. The water is finally disinfected with UV-light and Chloramine to maintain the quality of the water (Turun Seudun Vesi, nd).

4.3.2 Price of the water

The price of the water isn't a very significant part of the total costs. The listed price for water from Turun Vesihuolto is 1.50€/m^3 with 0% VAT which would make the total cost of the 14 000m^3 of water 21 000€. Additional costs could come from the services provided by the port for providing the water, though since it's the municipal water line running through their facilities this might fall bit into grey area on who is actually providing the water. (Turun Vesihuolto, nd)

4.3.3 Treating the water for the voyage

While the tap water in Finland is quite clean and safe to drink, it's won't necessarily stay that way during the whole voyage if nothing is done to preserve it. The quality and properties of the water should be monitored during the voyage and chlorinated to stop microbial growth if necessary.

4.4 The sea voyage

The duration of the sea voyage can be altered by multiple factors such as the weather conditions, tides, and currents. The total distance spent steaming for the ship in the scenario would be around 9 days considering the 8 knot speeds limits at Kiel Channel, and during the pilotage, and time spent for mooring operations. The total distance would be roughly 3000 Nautical miles of which 106 Nautical miles would be in Kiel Channel. A lot could be written about different steps and factors that go into the voyage planning, but it can be assumed that the ship is crewed by professionals, who can handle those tasks with ease.

4.5 Discharging the water

The chemical tanker in the scenario is equipped with its own cargo pumps with high capacity to move water. At 14x 250m^3/h discharging the water could be done in roughly 4 hours. The discharging of the water from tanker would either happen to a big tank prepared for the purpose at the location or to tanker trucks that could distribute the water locally. If there is enough capacity to load the water into, the water should be discharged from the tanker within a day or so. The logistics of distributing the water further than the port of destination should be dealt with by the locals. Some supervision of the aid reaching its intended targets would probably be a good idea.

4.6 The cost and time estimates for the operation

The total costs of shipping at an unknown time can be hard to estimate. This is another topic where an entire thesis could easily be written on the different factors contributing to the costs, different chartering options and what is and isn't included in them. The variety of costs with port visits, the Kiel channel fee, the insurance for the cargo, the relationship between speed and fuel consumption, crewing costs, nautical charts, pilotages, possible demurrage fees and so on.

4.6.1 Differences of Voyage and Time chartering

The easiest way to avoid most of the headache of aforementioned details is to simply make the contract as voyage charter through a shipbroker. In voyage charter the payment is simply agreed from delivery of the cargo from port A to port B either on per-ton basis where the ship owner is paid for the amount of cargo transported, or on a lump-sum basis where the amount of cargo doesn't affect the payment. At the destination if the discharging is late demurrage fees might have to be paid to the ship owner as compensation, or if the cargo is unloaded early a despatch payment can be collected from the shipowner as sort of bonus (Menon, 2021).

Time chartering a vessel would be generally cheaper and more suitable option especially for longer continued operation if multiple loads of water was transported. Time chartering essentially means renting a ship for given duration at set cost per day, and the party chartering the vessel is responsible for fuel, and other expenses such as cargo operations and port costs during the voyages (Menon, 2021).

4.6.2 Cost estimate for the operation

To come up with a cost estimate for the operation, prices for time chartering were used as they were more readily available. Some estimates and assumptions had to be made. The costs presented here only reflect what the price range for the operation could currently cost, and in reality, the costs could be very different.

According to price charts the time charter rates of 1–5-year-old handysize tankers vary from 29500$ to 22500$ per day (Alibra, 2023). According to bunker price the price of MGO is 590$/ton at Rotterdam statistics (Ship and Bunker, 2023). The ports prefer to keep their current costs to themselves due to competitive law reasons, so rough estimates will be used. Port free of 0.25€/Gross tonnage amounting to 6000€ in total on both ports. 1€/T of cargo handling fees are assumed, amounting to 28000€ in both ports total. The mooring costs would be roughly 1000€ in total. The pilotage costs to and from Naantali would cost roughly 11 400€ based on Finnpilot Pilotage fee calculator (Finnpilot, 2023). Assuming similar rates for pilotage but much shorter distance at the destination fees come to about 3600€ in total, combined the pilotage fees would be 15 000€ in total. The cost of water from the municipal water provider would be at 1.50€/m^3 while the harbors prefer to charge closer to 4€/m^3 for it. Depending on which one it's bought from, it would either be 21 000€ or 56 000€. 2000€ of other miscellaneous fees were expected during the port stay.

To estimate the fuel costs, a fuel consumption of 150g/BHP/hour was used. 8000KW engines produce 10728 BHP, consuming 1609kg of fuel per hour at full steam. At estimated 9 days or 216 hours of voyage the ship can be expected to burn roughly 350 tons of MGO, costing us 206 500$ which is 188 500€ at current exchange rates. Assuming 1 days would be enough to conduct cargo operations in Naantali and 4 days would be used discharging in target destination, the operation would require 14 days of time chartering, which would cost roughly 350 000$ or 320 000€ assuming rate of 25 000$/day.

The Kiel channel canal fees are roughly the same as what going around Skagen would cost in added fuel and time costs. As the channel saves roughly 250 NM this equals to about 32 hours of operating costs during both crossings. On the proposed ships fuel consumption this comes to roughly 30 000$ and the time charter savings from 32 hours at 25 000$ per day come to 33 333$. Therefore, the channel costs can be assumed to cost in total roughly 60 000$ or 55 000€.

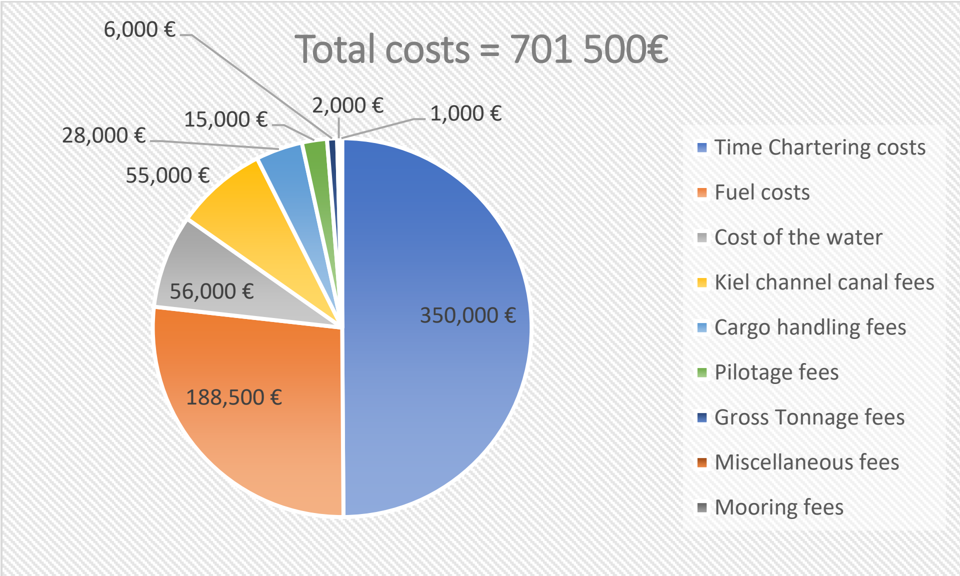

Figure 4 The estimated total costs for the operation

According to these rough estimates seen on Figure 4, the total price for the operation would be roughly 700 000€. Dividing this with the 140 000 people assisted, the cost per person would be 5€/person, and therefore the price of water would end up at 0.05€/liter not accounting for the costs of distributing the water at the target destination. This price seems very reasonable. Even though it’s not able to compete with desalination, when it’s able to be operated normally, there could be some business opportunities in transporting water during time of crisis as well.

5 The physics of loading water through pipelines

Due to the complexity of fluid dynamics, there still aren’t exactly accurate methods to calculate the flowrate of water through a given pipeline. The turbulent and laminar flows act differently, friction from the material of the pipeline causes energy losses to friction and curves in the pipelines exacerbate this effect. Different formulas derived from empirical testing can be used for calculating the flow rate to satisfactory accuracy. Hazen-Williams equation can be used to calculate the velocity of water in pipeline, and then the flowrate can be solved with the simple volumetric flow rate formula when the velocity is known.

$$V = 0.849CR^{0.63}S^{0.54} \text{ (1)}$$

Where:

V = Velocity in meters per second (m/s)
C= Roughness coefficient for the material, can be found for different materials in engineering tables, using roughness for 135 given for fire hoses
R= hydraulic radius in meters, in full pipe this area is diameter of the pipe/4 (m^2)
S= slope of the energy, head loss per the length of pipe, unitless using meters/meter

The formula for volumetric flow rate is:

$$Q = vA \text{ (2)}$$

Where:

Q= volumetric flow rate (m^3/s)
V= flow velocity (m/s)
A= cross-sectional vector area (m^2)

Using these formulas 1 and 2, the estimated output for pipelines given in the case of Naantali and from the hoses seen in Port of Turku can be calculated. From the results it can also be seen that the results are quite different from reality when lots of turns and constrictions are present in the hoses.

$$V = 0.849 * 135 * 0.0635m^{0.63} * 7^{0.54} = 57.7\frac{m}{s}$$

$$Q = 57.7\frac{m}{s} * 0.0507m^2 = 2.925\ m^3/s$$

For the values given for Naantali port, at pipe diameter of 10 inches or 25,4 cm, hose length of 10 meters and head drop of 7 bars or roughly 70 meters equivalent a flow velocity of 57.7 meters/second and using that result the volumetric flow rate will be 2.925m^3/second or 10 530$m^{3/}$hour. To fill up 14 000m^3 at this rate would take roughly 1 hour and 20 minutes.

Calculating the output for firehose with diameter of 52mm, using two connected hoses at length of 40 meters and the head drop of the pressure at 40 meters, or drop from 5 bars at the line to 1 bar in the tank.

$$V = 0.849 * 135 * 0.013m^{0.63} * 4^{0.54} = 7.43\frac{m}{s}$$

$$Q = 7.43\frac{m}{s} * 0.002124m^2 = 0.01578\, m^3/s$$

Which is roughly 57 m^3/hour, double the rate at which the hose ends up outputting with the same values in the real world. These formulas can be used to calculate the speed at which the vessel can be filled if the pressure difference, the size of the pipe, the material and length of the pipeline is known. These formulas apply in the ideal conditions but ultimately, the true loading rate would be known only when it would be conducted in reality. As can be seen in Figure 5, the water throughput drops quickly when adding more length to the line.

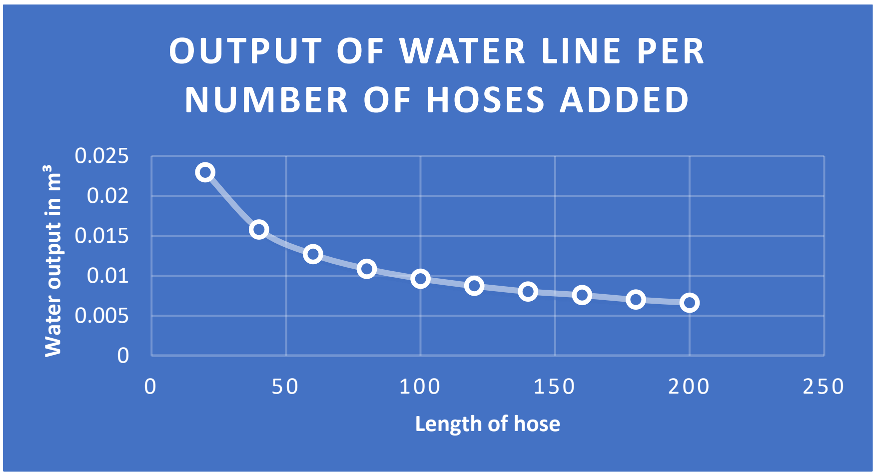

Figure 5 The calculated output of water drops with each 20 meter hose added to it

The calculations from the formulas 1 and 2 can be used to draw an estimate seen on figure 3 on what kind of loading rate can be expected depending on the water pressure that can be maintained at the pipeline given the large volume of water being loaded on to the ship. Based on these calculations seen on Figure 6, maintaining high pressure wouldn't be crucial for the success of loading the ship quickly.

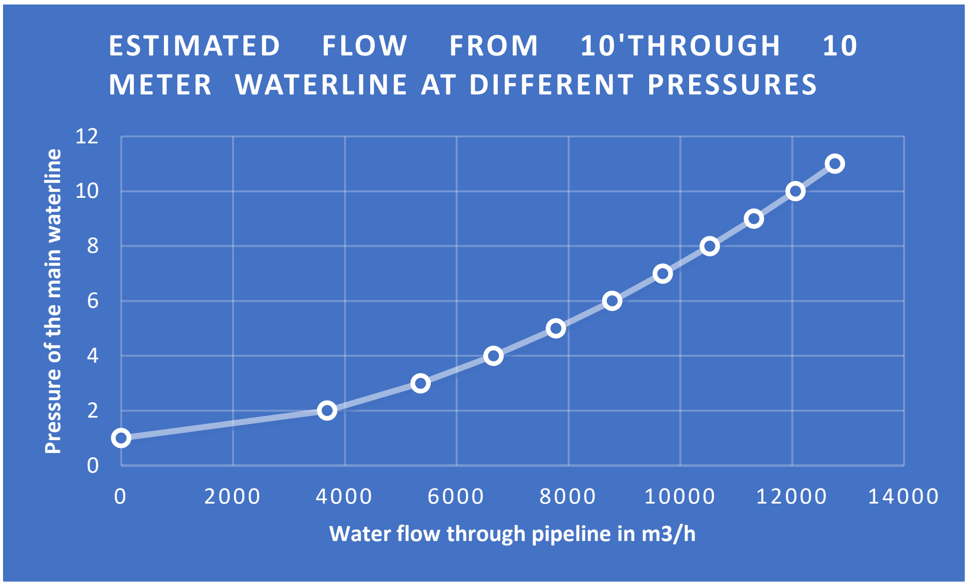

Figure 6 The estimated flow at different pressures from pipeline in Naantali

6 Conclusions

It was found that the business model of shipping potable water from Finland during regular times is not commercially viable due to much cheaper economic and energy costs from desalination over shipping. The capacity for desalination, however, can't be increased overnight and due to extreme drought or other unforeseen circumstances Finland could find itself in a situation where the ability to source water quickly would be very valuable.

Lots of issues with conducting the proposed plan were found. Supplying enough tank capacity to deliver water with vessels other than chemical tanker ruled the other vessel types out, while loading the water to the ship quickly enough was the main problem for chemical tanker. The main remaining concern is the availability of chemical tanker with clean enough storage tanks that it can transport potable water without it being contaminated. Similar projects have been conducted before, so it can be done again.

A suitable method of supplying, loading and transporting water in a relatively short time was discovered. Transporting water with chemical tanker from Neste terminal facility using the municipal water line to fill the ship quickly could deliver 14 000m^3 or more water in less than two weeks to destination 2000 nautical miles away. The costs of operation would be around 700 000€ amounting to 0.05€ per liter transported. An even larger amount could be easily supplied and transported at roughly the same time if larger or multiple vessels were available. Similar capabilities for loading large amounts of water were found at least on Rauma Port facility, though some modifications to the water lines would be required. Some other Finnish ports could have same capabilities, but not all the ports could be reached or were interviewed.

7 Discussion

At the beginning of this thesis process I set out to search for ways to utilize the Finnish freshwater resources and the port infrastructure. As it turned out that there was no viable business in it when everything worked normally, I reset the scope on finding solutions when everything didn't work normally. The aim was set at finding out if water from Finnish ports could be quickly supplied at time of crisis.

After running into different issues with different types of plans, a surprisingly easy and viable option was discovered that wouldn't just barely fulfil the requirements set but could easily surpass them. Finding such a solution and after ruling out the other options that could be as viable as using the main waterline running through Neste Naantali terminal, I felt that the question I set to answer had been answered. More viable options probably exist, but I doubt anything as good as the option presented in this Thesis exists in Finland.

The main challenge for making this kind of project reality is the availability of chemical tankers that have suitably clean cargo tanks, or that can be cleaned to the standards required for potable water transportation during the transit to Naantali. Many of the experts also pointed out this as their main concern as a flaw in the plan. Also, the possibilities of conducting similar operation from countries closer to the destination, such as Norway or the UK could prove themselves to be more efficient. However, if no plans exist beforehand in locations that are closer, then a preplanned operation would probably end up being faster. I feel like it could be worthwhile for the future to spend a bit of resources planning or charting out the capabilities and readiness for this kind of project.

Working on this thesis topic was a deep dive into various fields and topics, and I wish I could have made compact package of all the information I've gained during the process.

I’d like to express my gratitude to all the parties and people who I’ve interviewed during the creation of this thesis. Both those who have been mentioned in this thesis and those who haven’t have all helped in the process of coming to conclusions and finding the solutions that it found.

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