AUTOSHIP

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D2.1 - Complete supply chain mapping & identifications of interactions between SSS and IWW demonstrators

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1. LIST OF ABBREVIATIONS AND DEFINITIONS

Abbreviation	Definition
A	Automatic Operation
BLL	Blue Line Logistics
DoA	Description of Action
DP	Dynamic Positioning
DVW	De Vlaamse Waterweg
EC	European Commission
ETA	Estimated Time of Arrival
FCM	Feed Control and Monitoring
H2020	Horizon 2020
IWW	Inland Waterways
M	Manual Operation
PSB	Pallet Shuttle Barge
RCU	Remote Control Unit
SSS	Short Sea Shipping
WP	Work Package

2. EXECUTIVE SUMMARY

A generic supply chain model for a Short Sea Shipping (SSS) use-case and an Inland Waterways (IWW) use-case is developed through an analysis of their respective supply chains. The supply chain models for each of the two use-cases is developed based on interviews with the two demonstrators' operators.

The analysis shows that the two models can be generalized into one generic model with common phases. The following common phases that are applicable to both the SSS and IWW use cases were defined in the generic supply chain model:

- Phase 1: Carry out activities at location.
- Phase 2: Depart from location when necessary activities are completed.
- Phase 3: Sail towards next location.
- Phase 4: Approach location.
- Phase 5: Carry out maintenance in parallel with Phase 1 - 4.

The analysis also shows that it is not possible to define a unified model that connects the two use-cases into one supply chain. The SSS demonstrator transports bulk cargo whereas the IWW demonstrator transports pallets, big-bags and roll-on-roll-off containers. The two demonstrators also operate in separate geographical areas and in markets with no natural link to each other.

However, two proposals for unified supply chain models are developed by assuming that

- the SSS-use case is extended with the distribution of raw material to the fish feed producer.
- the SSS use-case can be used for general cargo transport.

An important result of the analysis is that navigating SSS and IWW ships, in what first appears to be different environments, can be generalized into the same phases when their operations and interactions with other objects are analysed and compared with each other.

None of the demonstrators are involved in the production and consumption processes but may still have an impact on them in case of delays and deviations in the transport system.

The manning level on the ship is the biggest difference between the SSS and IWW demonstrators. The SSS demonstrator has a crew of seven and the IWW demonstrator has a crew of one. This difference has several consequences of which maintenance might be the most important. Maintenance is a major challenge for unmanned ships as many crew members on manned ships have daily maintenance as one of their main responsibilities. The daily maintenance consists of tasks such as signal checks, ship and equipment cleaning, oil and filter changes and minor equipment repair. Although maintenance is performed while sailing for the SSS demonstrator, it is done at quay for the IWW demonstrator. Investigating the differences in how maintenance is handled will be an important continuation of this work, and a valuable contribution towards solving the challenge of maintenance for unmanned ships.

3. INTRODUCTION

This report provides a first study and analysis of the supply chains for the Short Sea Shipping (SSS) and Inland Waterways (IWW) use-cases in the AUTOSHIP project.

The purpose of the report is to provide the foundation for future analyses on

- the impact on regulations, and
- the societal and economic scenarios

which will be performed in WP2, WP3, WP7 and WP8. This report also provides input for determining the detailed test protocols and routes in agreement with the involved stakeholders (ship operators, owners, national flag authorities, classes), so that the operations, functions and controls for the two use cases can be determined along with the vessels routes, including segments with remote controlled/monitored sailing and totally unmanned bridge.

This study and analysis are based on information from semi-structured interviews carried out with staff from Blue Line Logistics and Eidsvaag. The information given in the interviews have been used to map the involved operations of all the supply chain phases and activities for both the SSS and IWW scenarios.

Detailed flowchart models of the supply chain phases have been developed to provide a visual overview of the flow of goods and the flow of information.

Finally, interactions and connecting elements between the two demonstrators' use-cases are analysed. The identified interactions and connecting elements are used to define a generic supply chain model for the SSS and IWW vessels supply chain.

The IWW and SSS use-cases are treated separately in Chapter 4 and 5. First, an introduction to the use cases are given followed by a description of the characteristics and the corresponding market. The supply chain is then analysed and modelled.

The two supply chain models are compared in Chapter 6, and a generic model capturing both supply chains characteristics is defined together with proposals for unifying the two supply chain models.

3.1. METHOD

This report is based on information provided in semi-structured interviews with the two vessels operators' staff. A specific survey was developed for each one of the two demonstrators and used as guideline during the interviews. The survey was built up to capture all stages of the investigated vessels supply chains according to the multi-stage supply chain model described in [1]. The survey was designed with emphasis on distribution and logistics, but also to capture relevant interactions with production planning and inventory control. Table 1 shows the high-level structure of the surveys for both demonstrators.

Table 1: High level survey structure.

SSS Demonstrator	IWW Demonstrator
Feed	Goods
Fish farms	Pick-up and drop-off locations
Factories	Canals and inland waterways
Ships	
Supply chain and distribution system	
Market profile and economy	
Performance indicators	
Regulatory and contractual considerations	

The results of the semi-structured interviews were then used to map the supply chains by using flowchart models that describe both the sequence and relationships between the flow of goods and the flow of information.

4. USE-CASE INLAND WATERWAYS

4.1. INTRODUCTION

Blueline Logistics NV (BLL) is a Belgian company, which has designed and developed two generations of ships, or barges, tailored for transportation of goods on IWW. Generation one is based on a catamaran hull, whilst generation two is based on a monohull design. The barges are called Pallet Shuttle Barges (PSB). Two of each generation have been built and are now owned and operated by BLL [2].

The PSBs load and offload goods at quays along the canals and rivers of the inland water ways. They are relatively small and have taken up competition with trucks for transportation of goods. The PSBs are described further in Section 4.2.1.

This chapter describes the characteristics of this use-case including the market, in which the PSBs service, and an analysis of the supply chain. Prior to delving into the IWW supply chain details, we will provide an overview of the activities and actors in the supply chain, which are shown in Figure 1.

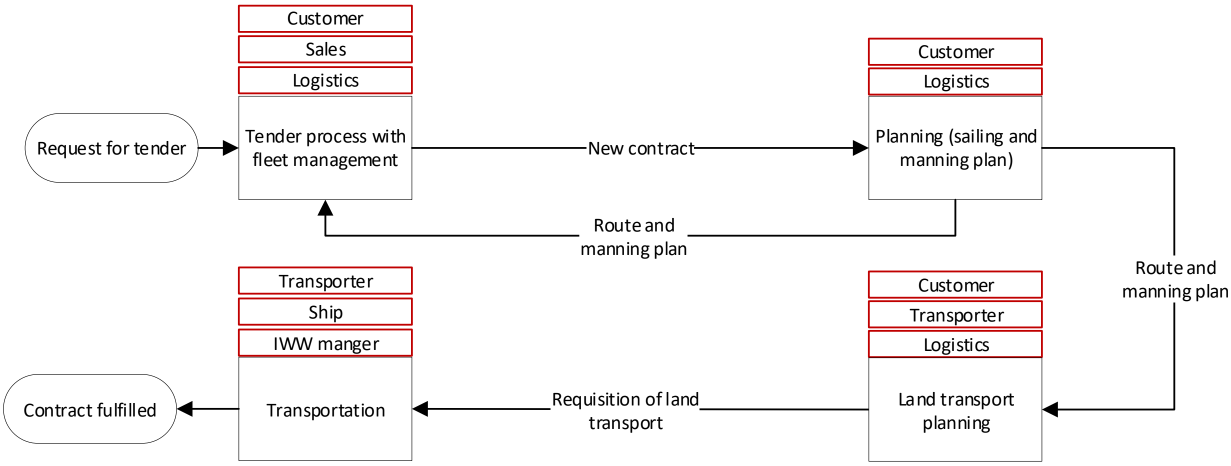

Figure 1 IWW Supply chain overview

The supply chain activities can be categorized into the following four phases:

- Tender process and fleet management.
- Planning (sailing and manning plan).
- Land transport planning.

- Transportation.

The main actors in the supply chain are the following:

- Customers requesting transportation of goods.
- Sales (BLL sales agent) communicating with customers on tenders.
- Logistics (BLL logistics/planner).
- Transporter (BLL and any 3rd party on-land transporter, which sometimes is a role held by the customer).
- Ship (BLL Zulu 4).
- IWW manager (Typically DVW – Flemish waterway).

The first phase in the supply chain is the tender and fleet management. When BLL works on a tender they consider several factors such as client requests, the current status of the fleet, the involved transport distances as well as whether road transport is necessary to be included in their offers. This will be further elaborated on in Section 4.3.

When BLL and the customer sign a contract then BLL will update the sailing plan including job assignments for the PSBs, the manning plan and the transport routes. Fleet management is an important part of the tender process as the current plan and location of the PSBs will influence new contracts.

The next step is to plan the land transport and align it with the sailing plan. This can either be done by BLL or by the customer. The PSB then repositions to start the job according to the planning while at the same time the transport of goods to quay is taking place.

When the PSB arrives at the quay, the procedure of loading, transport and offloading goods can start. This may involve several parties depending on the type of goods/cargo and the specific contract. These three steps will be defined and further detailed in Section 4.4.

4.2. USE-CASE CHARACTERISTICS

4.2.1. Ship

The ship that will be used for the IWW use-case is the BLL owned Zulu 4. Zulu 4 is a second generation (mono-hull) PSB which has a flat cargo deck above the waterline. The control cabin is installed at the ship bow. The ship uses a gantry crane that can reach the entire deck. The barge has one rear and one bow thruster. The PSB, as the name suggests, is specially designed for transportation of palletized goods/cargo. It is also designed to carry 20-feet wheel containers (containers with wheels on one end – more details in Section 4.4.1.1), and goods in big-bags. Figure 2 shows a picture of Zulu04, whereas the main specifications are listed in Table 2.

Figure 2 IWW PSB - pallet shuttle barge

Table 2 IWW Main particulars of BLL Zulu 4

Property	Value / Reference	Unit
Name of the ship	Zulu 4	-
MMSI	205574990	-
Length	50	m
Breadth	6,6	m
Sailing speed	17	km/h
Draft - fully loaded	1,9	m
Carrying Capacity design	300	tons
Carrying Capacity actual	240 tons	# pallets / big bags / other
Deck space for goods	40 m x 6,6 m = 264	m^2
Maximum stable height of compact goods	Gravity point: 0,8	m
Class	Register Holland	-

4.2.1.1. Service and maintenance

In traditional shipping, maintenance is a major part of the crews' daily job and is continuously carried out while sailing and staying at quay. The maintenance procedure is a bit different for the PSB as it is operated by a single person crew. It is therefore not possible to do much maintenance while sailing, and only simple maintenance such as washing the deck and checking oil and water levels is done by the captain while at quay.

Most maintenance tasks are thus carried out as service jobs, by 3rd parties or by BLL technical personnel, depending on the required competence. This also means that service (and repairs) must be scheduled into the sailing plans such that personnel is ready at the quay when the PSB arrives. Ideally, the service job must be completed without extending the PSB stay at quay, however this is not always possible.

Larger jobs are carried out at regular low frequent intervals, such as dry docking with hull cleaning and coating as well as engine overhauls. The PSB will be out of operation during such larger service jobs.

4.2.2. Quays

The PSBs mostly operate between smaller ports and not from the larger ports, such as ports under the Antwerp harbour. This is because the Antwerp harbour requires several onshore personnel to be involved in the loading and offloading processes. This is associated with an extra cost that makes competition for transport to and from the Antwerp harbour almost impossible for the PSBs. As it renders the PSBs transportation cost more expensive in comparison with the competition (transportation by trucks or rail).

The quays along the canals and rivers do not have such regulations, which maintains a relatively low terminal costs thus allowing the PSBs to compete with alternative transportation means. These quays can be sorted into two main categories:

- Quays in tidal parts of the river
- Quays in the canals where the tide has no impact on the water level

Servicing quays in the tidal parts of the river requires careful planning because the tidal difference in water level can be up to 6 meters. This means that the PSB will settle at the riverbank at low tide, which is not desirable for mainly two reasons; a) the ship cannot leave the quay until high tide, b) the ship hull may get damaged from debris on the riverbed. Though these quays and riverbed are typically designed for letting the ships settle on the riverbed, this is a risky ship operation as there is a lot of debris (like lost cargo) sticking up from the riverbed.

4.2.3. Canals and infrastructure

The Flemish Waterways has developed an information portal for the river and canal system of Belgium. The portal, VisuRIS [3], provides live information of the ships (traffic information), notices to skippers and water levels. This information can be viewed from a map interface as well as tables.

VisuRIS also offers information for the fairway (bridges, locks, berths, terminals, canals and regulations), a travel planner and more.

4.2.3.1. Water level in canals and rivers

Sailing in parts of the rivers where the tide has an impact on the water level requires careful planning, as discussed in Section 4.2.2, for avoiding settling on the riverbed at low tide conditions, but equally important to exploit the tidal currents. The tide will cause currents of up to 7 km/h in the river. Sailing with the current, or at least avoiding sailing against the current, is an important cost saving and emission reduction measure.

The parts of the canals which is above the tidal part of the river has a low variance in water depth. It varies in the area of 50 cm over the course of a year, and the waterway operator guarantees a minimum water level.

4.2.3.2. Bridges

VisuRIS lists a total of 670 bridges crossing the canals and rivers. These can be placed in mainly three categories:

- Fixed bridges with a fixed height restriction relative to the normal water level.
- Moveable with no height restriction when open.
- Movable with height restriction relative to normal water level also when opened.

In addition to the height restrictions, the bridges also usually pose a restriction to the width.

Information on bridges is available from VisuRIS. It is possible to search for a specific bridge and find the following information for the bridge:

- Type (moveable or fixed)
- Bridge ID, name, location and operating organisation
- Address
- Permitted ship dimension (height and width)
- Bridge dimensions (overhead distance and width of the navigation channel).

For moveable bridges, the following information can be found:

- Operation mode (automatic or manual) and if the bridge is centrally operated or not.
- Contact information; phone, e-mail, fax
- Radio call sign and channel
- Average passage time
- Permissible height for open and closed bridge

All this information is not available for all bridges. The opening hours of the bridges can also vary and some might be closed during night.

The fixed bridges cannot be opened or moved and poses a fixed height restriction, ranging from 1.56 m to "no restriction". Planning a journey therefore includes checking the restrictions each bridge poses on the planned route. The VisuRIS information portal offers a map where all bridges are indicated, and where information on the bridge can be accessed by clicking on the bridge, as shown in Figure 3.

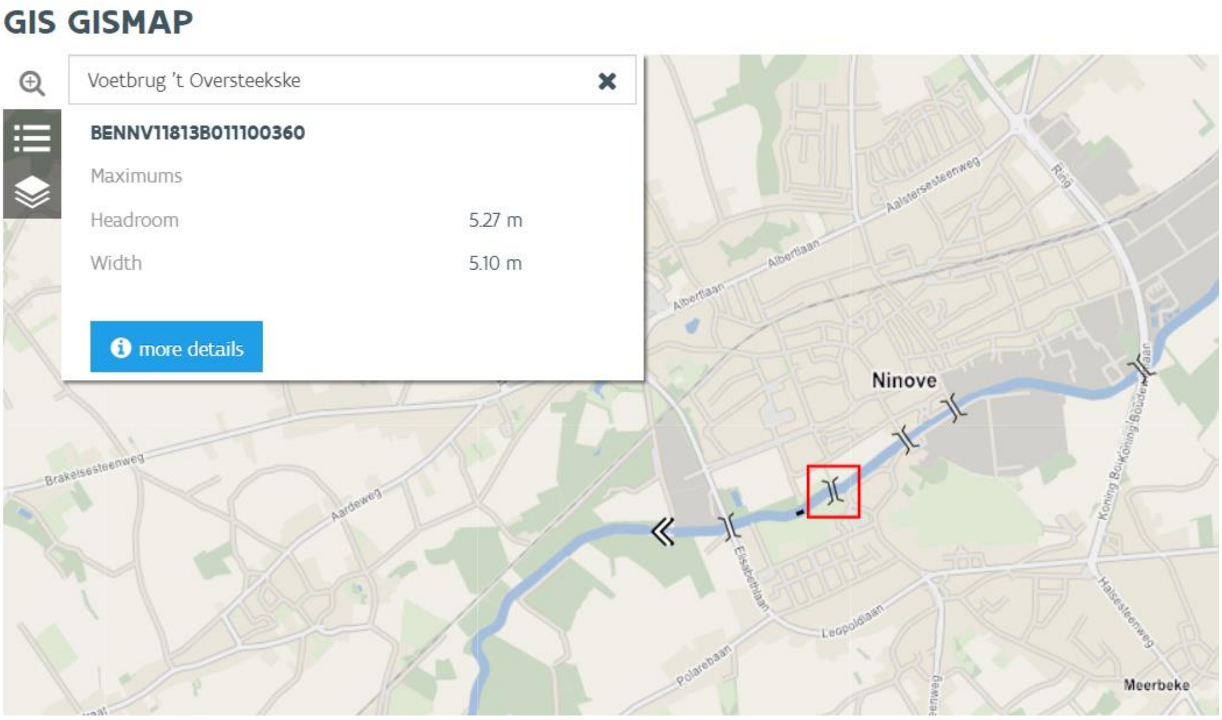

Figure 3 IWW Bridge in VisuRIS map

4.2.3.3. Locks

In addition to the bridges, VisuRIS lists 92 locks. The locks have different capacities and different ways of being operated. It means that a journey planning must include identifying the locks that must be passed and checking the lock capacity. This information is available in VisuRIS and can either be found by searching the lock table under Fairway -> Locks, or by browsing the map and clicking the lock symbol, as shown in Figure 4.

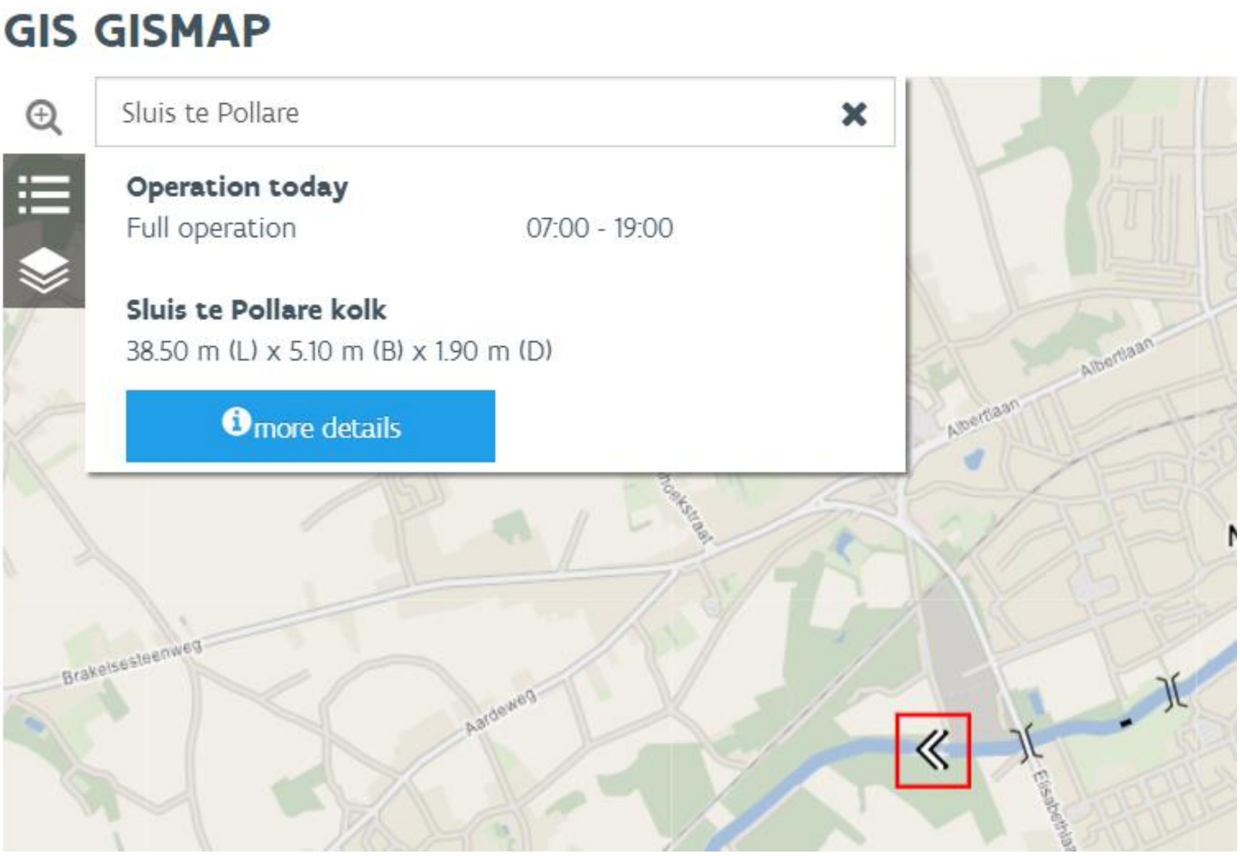

Figure 4 IWW Lock in VisuRIS map

The available information for a lock is:

- Lock ID, name, waterway, location name and organisation
- Address
- Contact (phone, fax, e-mail)
- Radio call sign and channel
- Permissible dimensions per chamber (length x width x draught, single sailing and combined)
- Lock chamber(s) dimension

- Time of operation per day
- Statistics for number of passing ships (per date and time of day)

Note that for some reason the permissible dimension is only available from the preview in the list and map, but not from the "more details" menu, as shown in Figure 5.

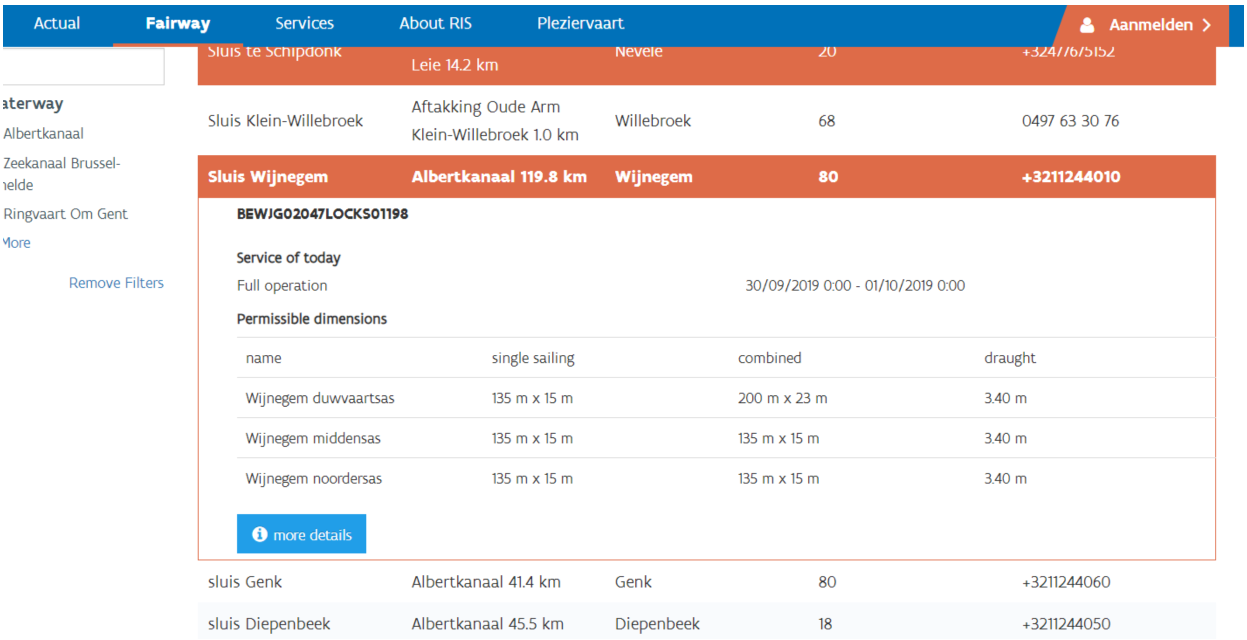

Figure 5 IWW VisuRIS lock preview menu

4.3. MARKET

BLL has found that small barges sailing on the canals of Belgium, Holland and France can compete with trucks. The PSBs transport 20 feet roll containers, pallets, big bags and on rare occasions large break bulk items.

The key factors that enable the PSBs to compete are:

- For short distances the PSBs can offer comparable transport time at the same or lower costs as trucks. For longer distances the transport time becomes too long for some goods or customers, and in addition the PSBs are not made for overnight sailing. Even if they were made for overnight sailing (had sleeping compartments and other facilities), the costs for overnight sailing would reduce the competitiveness.

- Low crew cost. The PSBs are operated by one person, and only at daytime. Much like the truck the barges have restrictions for consecutive hours of operation. The barges are therefore operated by two different captains every day, each working 8 hours. This also means that the barges are moored and not in operation during night.
- Low terminal costs. BLL has found that for some goods and some terminals, it is possible to keep the terminal costs lower than what larger ships are able to. This is partly because the PSBs can visit smaller ports, and partly due to good planning and efficient execution of the loading and offloading. Efficient loading is made possible by using the ships own crane or, as in the case of containers, having the truck load the containers directly on-board the PSB, and by having all the goods to be loaded ready such that the loading can be carried out in one continuous operation. This is in contrast with larger ships, which often depends on the port crane and logistics, thus experiencing higher terminal costs per cargo unit. As an example, BLL estimates a terminal cost of 6 EUR per container for moving a container from back storage and to on-board the PSB.
- Larger items are difficult to move on roads due to size but can easily be moved on the canals.

The market that the PSBs operates in is therefore transportation over smaller distances, where trucks traditionally operates, and for the cases where the pickup and drop-off points are close to the ports.

It is however still a challenge to change people's mind set; BLL is sometimes in discussions with potential customers who assume it is impossible to use ship transport, mostly because traditionally this could not be done at a comparable cost as for trucks, but also for reasons like assuming the transport process itself is too difficult. BLL continuously works to convince and demonstrate that ship transport is practical, more sustainable and competitive by price.

4.3.1. Future markets

BLL is working at expanding their business. Some examples are:

- Intracity transportation of foods and drinks in New York.
- A larger ship planned to sail from Belgium to England.
- Sea container transportation from the harbours into the canals. Today sea containers are transported either by truck or on greater quantities by larger ships. Where trucks are the option for clients who cannot wait for the time it takes to load (and unload) a larger ship. BLL is thus considering a 30 TEU ship to enter this market and compete with trucks.

4.3.2. Goods transported today

A typical scenario for BLL is that they get a contract for transporting a quantity of uniform goods/cargo; it can be building materials on pallets like bricks or plasterboard or containers, and that the quantity is such that the PSB can sail fully loaded when it has loaded the goods. Often, the amount of goods corresponds to several trips. The PSB does however sail for considerable periods with no goods/cargo at all; repositioning to service the new contract, returning empty from delivering goods, or repositioning to bunker or perform service and repairs. As a result, BLL estimates that the PSBs are loaded at 60% on average when sailing.

Examples of typical goods are listed in Table 3, where typical quantity is defined as the typical quantity transported in one shipment by a PSB. A contract can, and often do, have a quantity corresponding to several such shipments.

Table 3 IWW typical goods transported by PSB

Type of Goods	Producer	Transportation Mode	Unit Dimension	Unit Weight	Typical quantity
Bricks, cement, plasterboard, building materials	Several	Pallet	1 pallet	500 – 1500 kg	200 – 300 t
Trash/waste	IOK	Roll container	20 ft	16-18 t	13-14 pcs
Cement	Several	Big bag	1-2 cubic meter	1-2 t	200 – 300 t

4.3.3. Tender

The tender process takes into consideration many aspects including planning. Making a typical tender includes:

- Reviewing the client requests (pickup date, delivery date, amount of goods, any requirements)
- Evaluating the current status of the fleet; where are the PSBs located, what is their current job status, which of the PSBs are capable of performing the job and which one PSB is the best suited. Also, the individual PSB's need for service and repair must be considered.
- The quays that are involved and any associated restrictions (tide, noise, emission, fees, onshore manning).
- The best sailing route for the candidate PSBs to get to the start of the job as well as the sailed distance.
- The best route for transporting the shipment and the resulting distance between the quays.

- If BLL or the customer handles the transport of goods on land to and/or from the quay, or a combination.
- The strategic importance of the job.

4.4. SUPPLY CHAIN - FLOW OF GOODS AND INFORMATION

The process of transporting goods with the PSBs is divided into six main activities:

- Loading or offloading
- Daily maintenance
- Bunker, service and repair
- Depart from quay
- Sail
- Approach quay and moor

The PSBs do not operate at night; they are moored at quay and stay unmanned until the captain arrives in the morning. So, a good starting point for the modelled process in Figure 6 is with the ship moored at quay. There are mainly three activities that are conducted while at quay, these are:

- Loading or offloading
- Maintenance: Tasks such as cleaning, recording engine running hours, etc.; this activity will not be modelled in further detail at this stage.
- Bunker, service and repair, where service and repair are activities requiring an additional 3rd party or company personnel (could be repair of the crane, new filter and oil change for the engines or replacement of parts), while bunkering involves the replenishment of fuel and consumables.

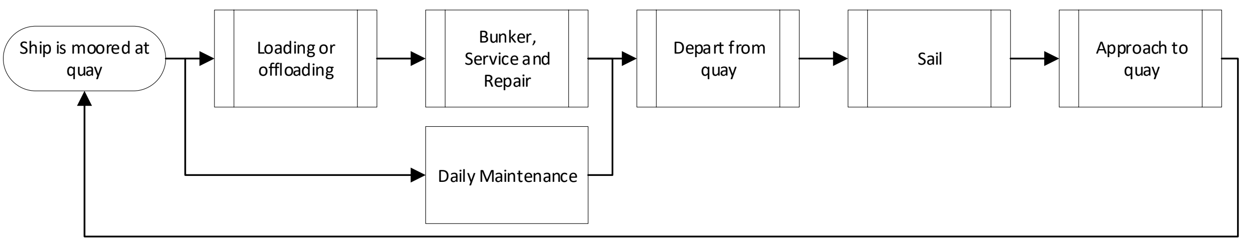

Figure 6 IWW main process diagram for Zulu4 (see Section 9.1 for a description of all flow-chart symbols).

When these three activities have been completed, the PSB is made ready for sailing and manoeuvres out from the quay into the fairway. The ship will then sail to the destination quay, passing locks and bridges, and repeat the activities at that quay. In this way, goods are transported from point to point. The following subsections will detail each of these six main activities. Each activity is either marked as manual (M) or automatic (A). This indicates that the activity is either manually initiated, manually carried out, automatically initiated or automatically carried out depending on the specific context. In addition to this, Annex 0 contains a list of all activities mapped towards autonomy levels as defined in [4].

4.4.1. Loading and offloading

The loading and offloading process is modelled in Figure 7, where it is shown that when a PSB arrives and has been moored the following scenarios can take place:

a) There are no goods to be offloaded and no goods to be loaded.
b) There are no goods to be offloaded, however there are goods to be loaded.
c) There are goods to be offloaded, however no goods to be loaded
d) There are goods to be offloaded and there are goods to be loaded.

Loading and offloading of the different goods are detailed in Sections 4.4.1.1 and 4.4.1.2.

In scenario a), the PSB stops and moors at a quay without having any goods to load or offload. That may be the case when the PSB is moored for the night, if it is waiting for the next job, if it must visit a quay to change crew, to carry out repairs or to bunker.

In scenario b), the PSB stops and moors at a quay to pick up goods, however it has no goods to offload. This may be the case if it has arrived to start the work on a contract, if it is returning from bunker, service and/or repair, or if it is serving a contract where there is only cargo to carry one way or where there occasionally is no return freight.

In scenario c), the PSB stops and moors at a quay to offload goods, but not to load any goods. This may be the case on the last trip on a contract, on a contract where there is only cargo to carry one way or where there occasionally is no return freight, or if the PSB needs to go to a specific location for night lay, bunker, service and/or repair.

Scenarios b) and c) are also relevant if the PSB needs to do an intermediate job whilst serving on a contract, or when the PSB is performing work on independent, possibly one-off, jobs.

In scenario d), the PSB stops and moors at a quay to offload and load goods. This is the ideal scenario where the PSB is serving on a contract where there are goods to be transported back and forth between one or more quays, or where independent jobs can be planned such that the ship carries goods arriving and departing a quay.

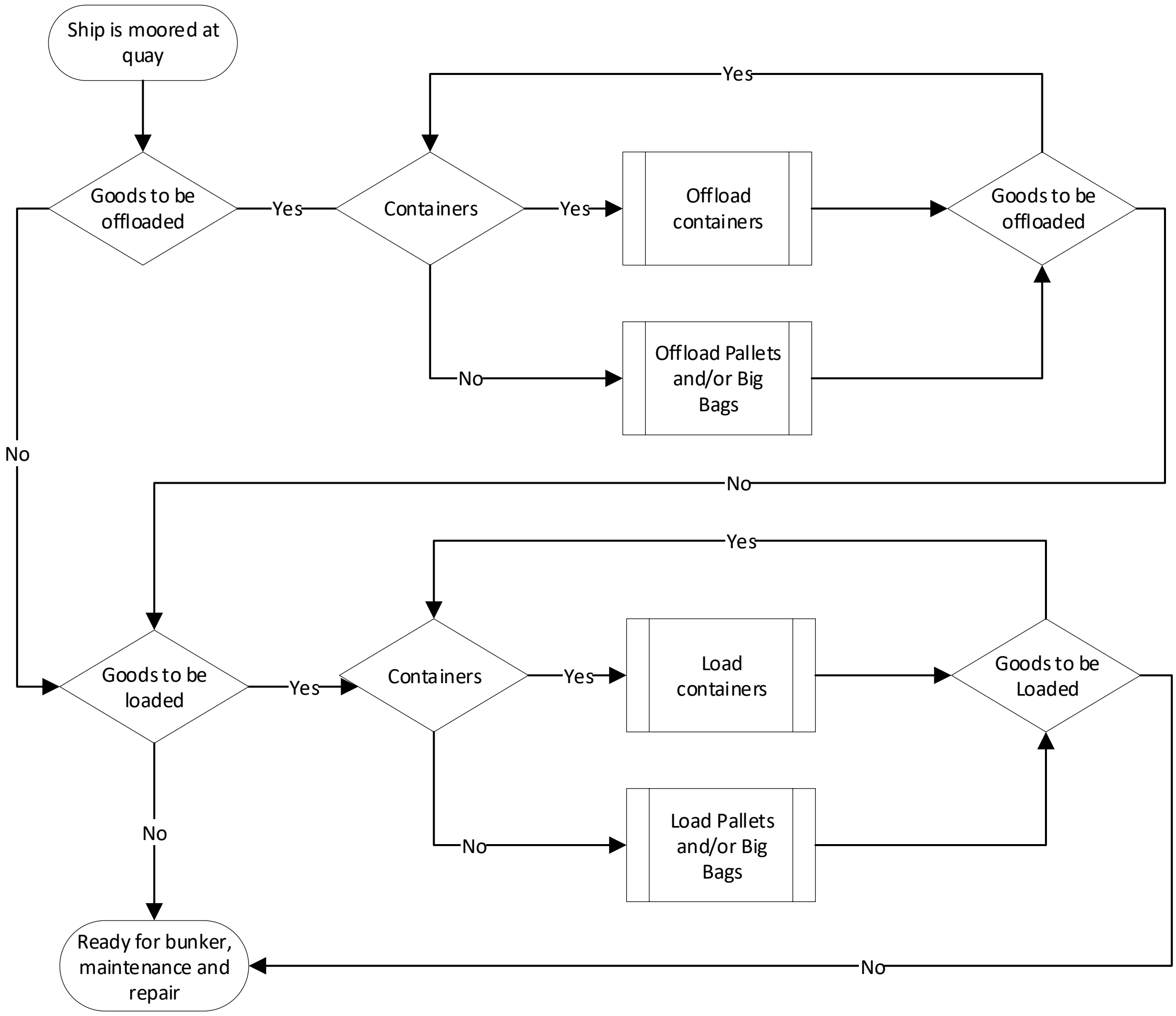

Figure 7 IWW Loading and offloading the PSB

4.4.1.1. Loading and offloading of containers

The containers that the PSBs transport are mainly waste containers. The waste is destined to a furnace plant, where it will be burned. The containers are located at various places where they are filled with waste and then picked up by trucks and moved to a quay where they are stored. Either BLL or the customer arranges for the truck transport to the quay.

The process of loading these containers is modelled in Figure 9. Upon the PSB arrival, there is a truck at the quay (arranged for by BLL) ready to pick up the containers at the storage and load them on-board the ship.

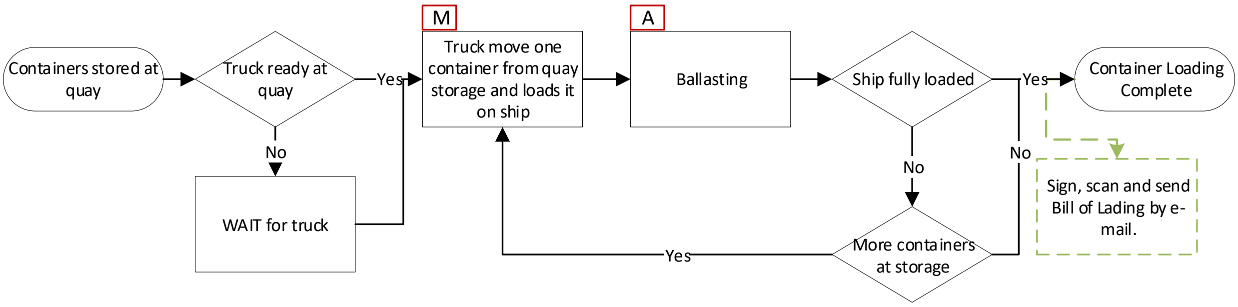

Figure 8 IWW loading of containers

The captain berths the ship controlling it manually; due to the propeller and bow thruster setup, it is relatively easy to control. The captain goes onshore and moors the ship (sometimes in one end only and keeping the ship in position with the thruster). The containers have a hook in one end and wheels in the other. The trucks can therefore pick up the containers at storage, drive them to quay side and roll them on-board the ship (as shown in Figure 9).

Figure 9 IWW Truck loading container onboard PSB

The truck performs this task for each container, one by one. During the loading of containers, the ballasting system operates automatically within limits. When the ship is loaded the Bill of Lading is signed, scanned and sent by e-mail. Then the captain removes the mooring, goes back on-board and leaves the dock. Containers are not secured to the deck.

Often the ship will arrive at a quay loaded with containers, offload them, and then load new containers. The process of offloading the containers is quite similar and is modelled according to the flowchart shown in Figure 10.

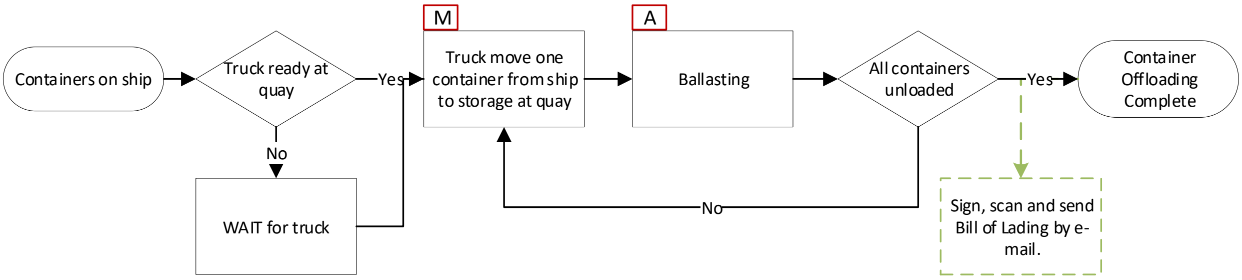

Figure 10 IWW offloading of containers

The truck connects its crane to the container, pulls it off the ship and onto itself (see Figure 11). The truck then moves the container to back storage. The ballasting system operates automatically throughout the process, unless heel is outside limits, in which case the captain must intervene.

Figure 11 IWW Truck offloading containers from PSB

When the PSB is empty the Bill of Lading is signed scanned and sent by e-mail, then the truck starts to load the PSB with empty containers (following the same process as in Figure 8), which the PSB then transports back, offloads and loads full containers.

Utilization during container transport is close to 100% as containers are transported back and forth between locations. However, if the PSB is relocated to do another job, it will sail empty to the new pick-up point.

4.4.1.2. Loading and offloading of pallets or big-bags

The transport of pallets to a quay is carried out by trucks (or forklifts if the customer storage is close to the quay) and is not handled by BLL. When the pallets are transported by truck, they are either loaded from the truck at the quay side at back storage or the truck parks at the quay side. If the pallets are stored at a back storage, then forklifts transport them to the quay side ready for loading onto the ship. BLL is normally not responsible for arranging for forklifts.

The barge berths next to the pallets when it arrives. The loading process is modelled in Figure 12.

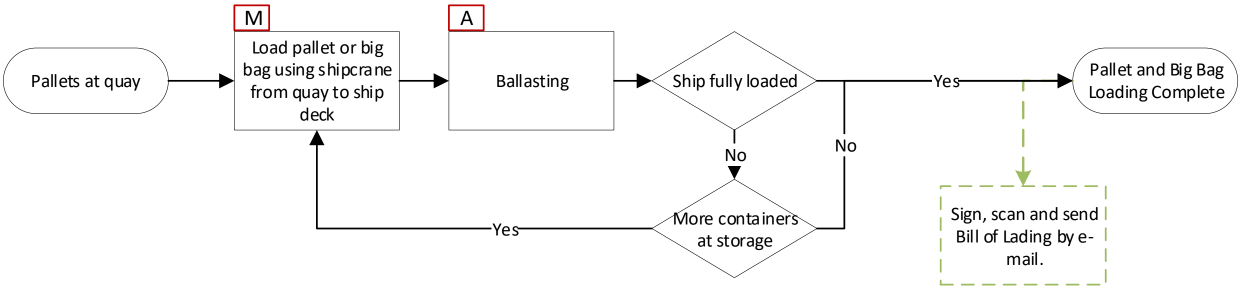

Figure 12 IWW loading of pallets or big-bags.

Figure 13 IWW PSB loading pallets

The ship crane is fitted with a forklift tool. The captain operates the crane and picks up the pallets one by one and loads them on-board the ship. The ship may be moving quite a bit during the loading process. This means that the captain must coordinate the insertion of the forks under the pallet with the ship movement such that the crane does not crash with the goods, and such that the ship motion helps picking up the pallet. Lifting pallets is shown in Figure 14.

After the pallet is picked up the captain steers it to the ship and loads it onto the ship. Pallets are not secured to the deck. When all pallets have been loaded, the bill of lading is signed, scanned and sent by e-mail.

Offloading of pallets is also done using the ship crane and is modelled according to the flowchart shown in Figure 14. Either the pallets are loaded directly onto a truck, or they are placed at the quay. If they are placed at the quay, a forklift picks them up and moves them to back storage. Ballasting is automatically adjusting the ship trim and heel. The bill of laden is signed, scanned and sent by e-mail when all pallets have been offloaded.

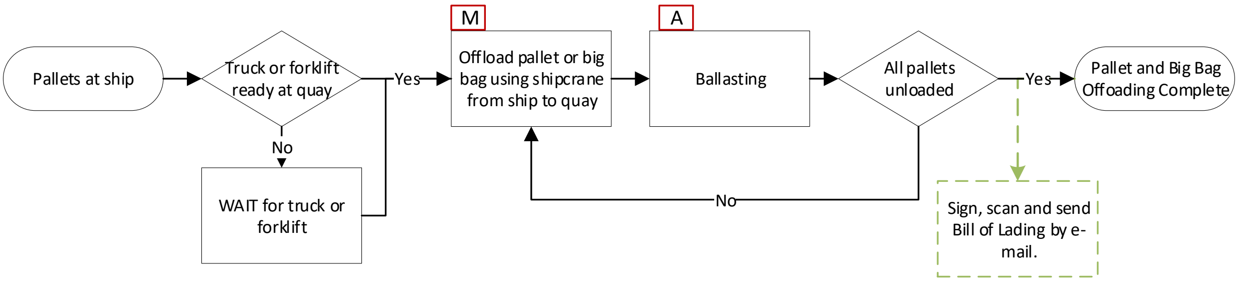

Figure 14 IWW Offloading of pallets and big-bags

Loading and offloading of big-bags follow the same steps as for pallets; sometimes the big-bag is placed on pallets, if not it is picked up by the loop on the top of the big-bag. The captain might also load his car onto the ship and will follow the same steps as for pallets or big-bags.

4.4.2. Daily maintenance

The daily maintenance performed by the captain is very limited as he/she is the only crew member on-board the ship. It includes tasks such as washing the deck, reading and recording various instruments, and checking oil levels etc. All other maintenance task are carried out as service jobs. The daily maintenance has not been modelled in this report.

4.4.3. Bunker, service and repair

After the loading and offloading process is completed, the next modelled process is bunker, service and repair which is shown in Figure 15 and Figure 16. This is not modelled in detail but is included to highlight that these are frequent activities that must be taken into consideration in the planning and fleet management. The model includes the possibility for bunkering, repair and service after any one of the scenarios a) to d) described in Section 4.4.1. Possibly some of these activities may in practice occur in parallel (or in another sequence like bunker prior to loading and repair after loading), however this is not accounted for in the current model.

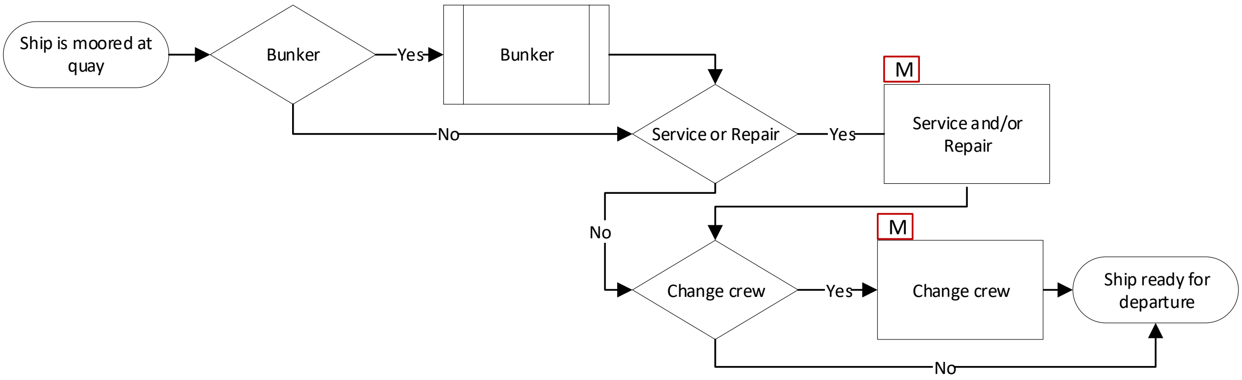

Figure 15 IWW Bunker, service and repair

Bunkering is a manual process (see Figure 16) which is initiated by ordering the bunker service (the process of ordering is illustrated in Figure 18). Bunkering can be carried out from a bunker ship, quay side tank or from a quay side tank truck. In any case, each step is carried out manually (connecting the hose, starting and stopping the fuel transfer pump, disconnecting and reeling in the hose).

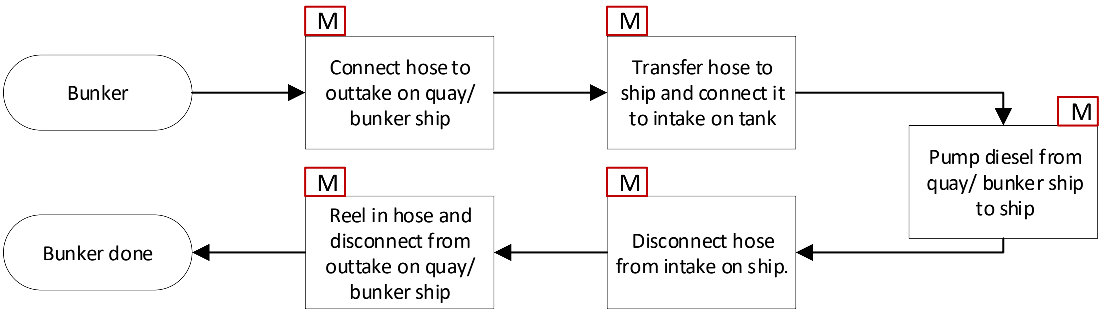

Figure 16 IWW Bunker

4.4.4. Depart from quay

When the offloading, loading, bunker, service and repair activities have been completed, the ship is ready to sail to the next destination. But before it can start navigating towards the next destination, it must be prepared and leave the quay. This process is modelled according to the flowchart shown in Figure 17. It is a fairly straight forward process where the ship systems are started, including the main engine and auxiliary equipment, the mooring is removed and the ship is navigated from quay into the fairway where the sailing can start.

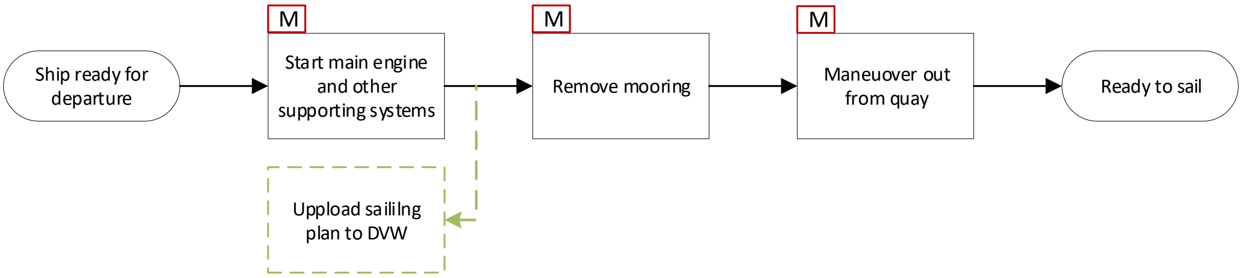

Figure 17 IWW Depart from quay

4.4.5. Sail

The process of sailing the canals is modelled according to the flowchart shown in Figure 18. Whilst sailing the captain maintains position in the canal, heading and speed. On the way to the destination, the PSB may have to pass a bridge or a water lock, or several of each. The process of passing these are further detailed in Sections 4.4.5.1 and 4.4.5.2.

If there is a need for bunkering, service or repair this is notified to the main office. Service need is also tracked by the main office, and so the notification can be sent from the office to captain as well. When there is a need for bunkering, service or repair, these services are requisitioned such that the PSB is serviced at agreed time and quay.

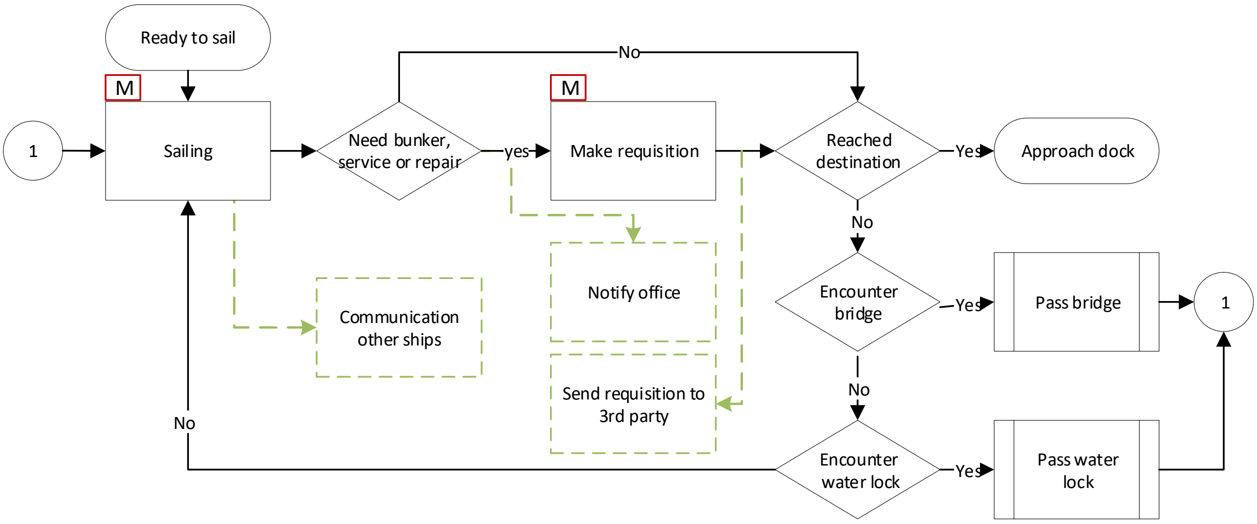

Figure 18 IWW sailing

4.4.5.1. IWW passing lock

When the PSB approaches a lock, the captain contacts the lock operator 30 minutes ahead of arrival and gives notification. The captain again contacts the lock operator when arriving at the lock. If the lock is busy, the PSB sails to a waiting position (possibly moors) and waits until it is its turn to pass the lock.

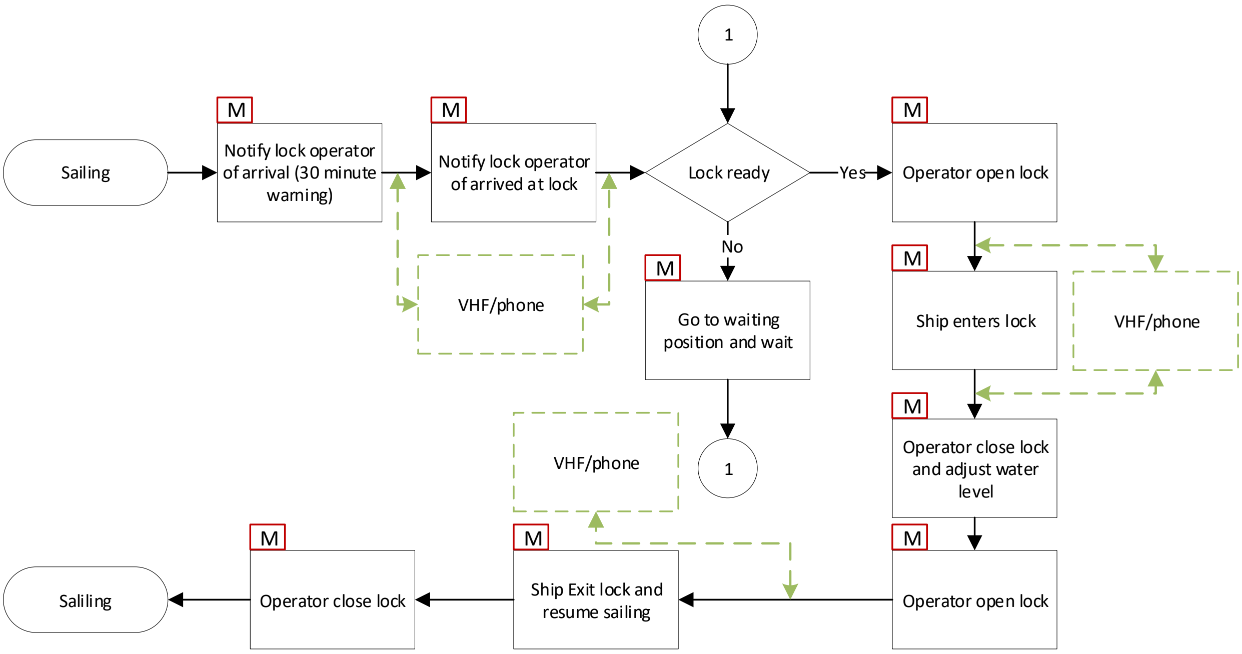

Figure 19 IWW passing a lock

When the lock is ready for the PSB, it is opened by the operator and the PSB enters the lock. This may require delicate manoeuvring as the space may be narrow and short. The lock is closed, the water level adjusted to the correct level and then the lock is opened and the PSB can exit the lock and resume sailing. There is communication between the lock operator and ship during the operation.

4.4.5.2. IWW passing bridge

The steps of approaching and passing a bridge are quite similar to the steps for passing a lock. The PSB needs to communicate with the bridge operator and it may have to wait for the bridge to open. The PSB does not need to be moored while waiting, and when the bridge opens the PSB passes through.

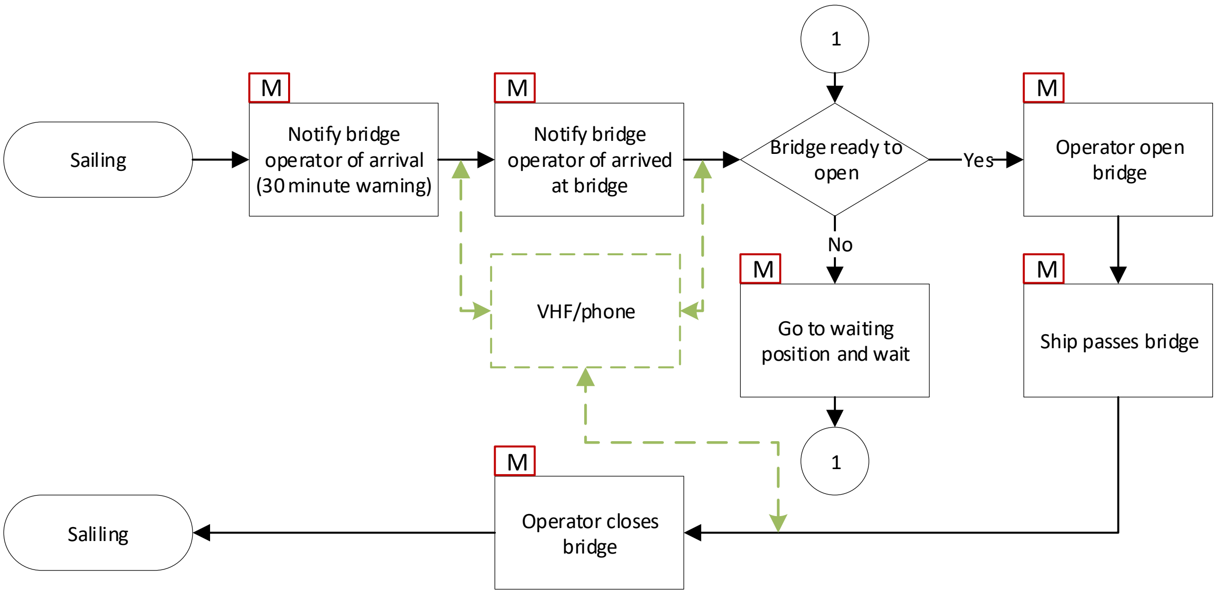

Figure 20 IWW passing a bridge

4.4.6. Approach to quay

The process of approaching the quay is modelled in Figure 21 and is performed by the captain manually by controlling the PSB into the berth. The captain then exits the PSB and moors it. If the stop is short for loading or offloading goods, the captain may only moor one end of the barge and keep the main engine running, however normally the ship is moored in both ends and the main engine is shut down.

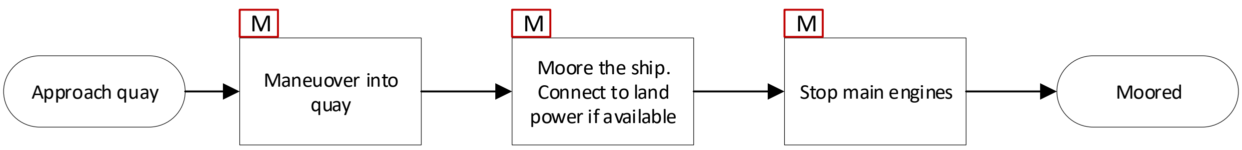

Figure 21 IWW approach quay

5. USE-CASE SHORT SEA SHIPPING

5.1. INTRODUCTION

The core business of the short sea shipping (SSS) demonstrator Eidsvaag is the transportation of feed to fish farms. Figure 22 shows an overview of the activities and actors in the supply chain.

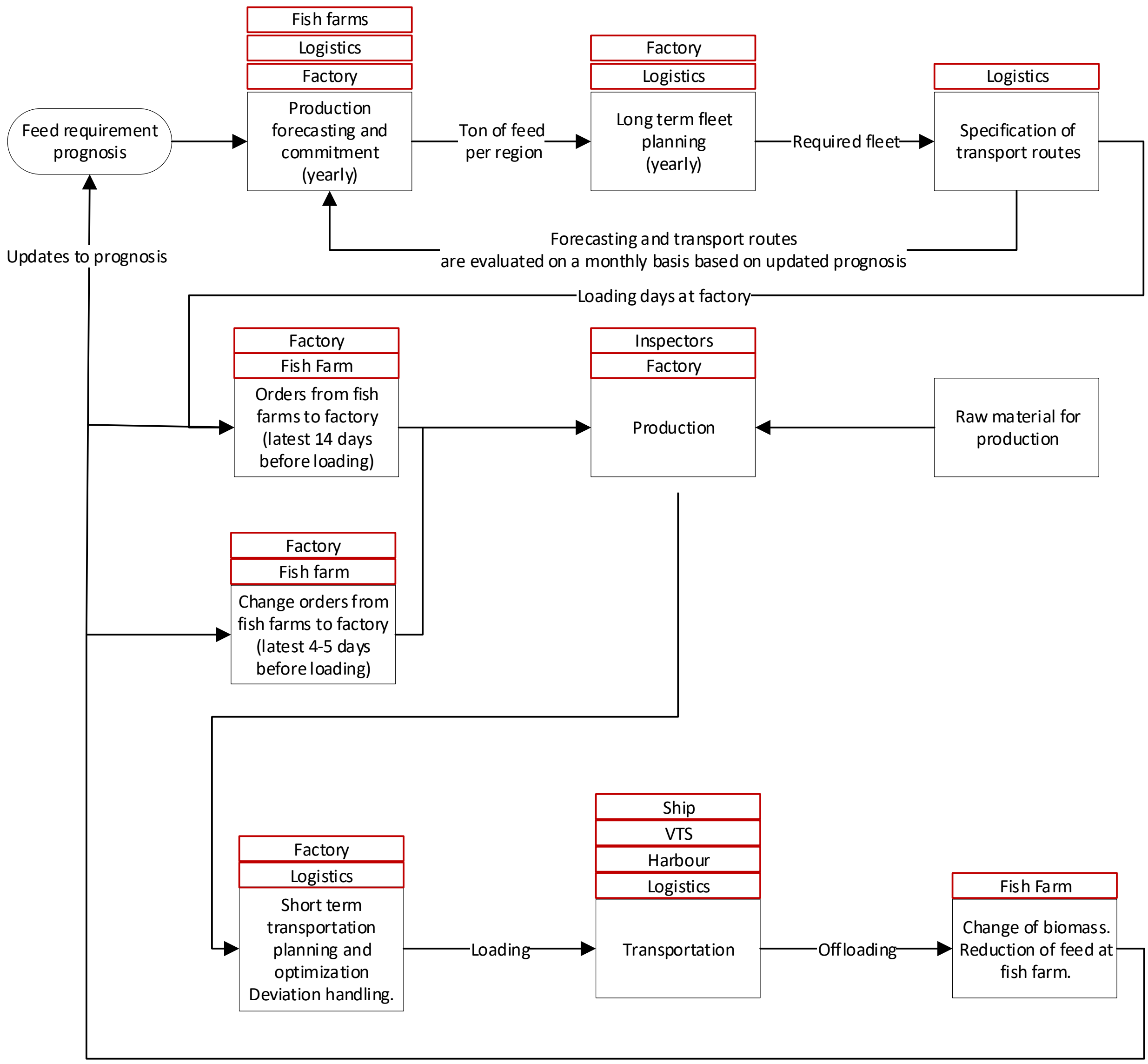

Figure 22: SSS Supply chain overview with main phases and actors.

The main actors involved in the supply chain are the following:

- Factories producing fish feed from various raw material, who are responsible for the fish feed production planning.
- Fish farms generating a demand for fish feed to cover the consumption required to their fisheries; they place orders to the factories.
- The transporter responsible for moving feed from factories to fish farms and planning fleet structure.
- Ships used to transport the feed along with their owners/operators.
- Logistics planner for managing distribution/transport planning and handling operational deviations.

In addition, the following secondary actors are also involved:

- Inspectors, both with respect to the feed quality and operation of the ships.
- Harbours/ports used by the ships.
- Vessel Traffic Services (VTS) that the ship communicates with during operation.

The supply chain activities can be categorized into the following three main phases:

- Long term forecasting and planning
- Short term planning and deviation handling
- Transportation

5.1.1. Long term forecasting and planning

Long term planning is carried out based on a 12-month feed prognosis, in which the factories, the transporter and the fish farms commit to. The prognosis will however continuously be updated, whereas the overall planning is updated on a monthly basis. The outcome of the production planning is the various feed types and volumes for each predefined region. The feed producers employ the prognosis to decide which farms shall be supplied from which factory, so that the load is distributed evenly. The norm is that the producer decides which customer is serviced from which factory.

Based on the prognosis, Eidsvaag will calculate the necessary transport capacity, and determine the required number of ships necessary for handling the summer peak plus ten to twelve percent spare capacity. Important input to this planning is the customer base, the potential new customers, the existing capacity of fleet and rental capacity, the expected volume of feed and the fish disease trends.

The routes are set prior to the season. The target is to service each route weekly such that the pattern repeats on a weekly basis.

5.1.2. Short term planning and deviation handling

The logistics manager is responsible for the short-term distribution and transport planning, that is the transport of feed from the factory to the fish farms. Input to this planning is the feed type, volume and loading date given by the factory, the slot time for ships at the factory quay, the weather forecast and the possible contamination zones around fish farms. The key target is the delivery of the fish feed from the factory quay to the vessel (and not the delivery time to the fish farm).

Routes are primarily fixed for a given period. Changes within a route on a specific trip can occur due to factors such as:

- Weather.
- Contamination zones.
- Customer has miscalculated feed usage and runs out.
- Customer ordered the wrong type of feed.
- Customer storage capacity is too low.

On a longer term, a route can be changed due to the overall fleet planning such as summer/ winter routes, and certain locations dropping in and out of the route.

In a typical case, the ships need to transport the feed at the same rate as it is produced due to the limited storage facilities. Delays in transport of feed from the factory can relatively quickly lead to the shutdown of the factory; such a shutdown is equivalent to loss as the volume cannot be caught up (the fish do not eat twice as much when it gets feed again). If the ships continuously transport the feed, the feed turnover corresponds to emptying the factory storage every 3 to 4 days.

Day-to-day planning primarily deals with deviations handling, where the biggest challenge is predictability. Examples of the expected operational challenges are the following:

- The fish farm will use all feed faster than estimated and needs extra deliveries.
- The fish farm will use less feed than estimated and cannot receive all feed from the ship.
- Under- and overcapacity of the ship according to seasonal variations.

The flexibility in the transport system is a combination of the factory storage size, the production capacity, the transportation capacity and the silo capacity on the feed barges.

Mitigation actions must be handled case by case as follows:

- During the high season downtime of a ship, or delay, can cause the production stop at the factory as the factory does not have a significant storage capacity, and there is almost no reserve capacity in the fleet (approximately 10%).
- Fish farms might have to use their safety capacity until new feed can be delivered.
- It might be necessary to go to the spot-market to find a ship that can be chartered for a short time (but these ships can only handle big-bags and that has an impact on whether the factories capacity can be fully exploited).
- Call the customers and ask them to adjust the amounts to free up some capacity and thereby avoid anyone running out of feed.
- Route changes (moving one or more customers to another ship) might be implemented (easily during low season; it is hard but not always impossible in the high season).
- Worst case includes a customer to be serviced from another factory.

5.1.3. Transportation

The SSS use-case is focused on the Eidsvaag ship and their responsibility as a transporter/operator. Mapping of the supply chain with focus on the feed transportation is described in Section 5.4.

5.2. USE-CASE CHARACTERISTICS

5.2.1. Ship

The ship that will be used for the SSS use-case is the MV *Eidsvaag Pioner.* Pioner is a cargo-ship with IMO number 9660449, MMSI number 25872900 and call signal LFTA. The ship was built in 2013 and classified by DNV GL. Figure 23 shows a picture of the Eidsvaag Pioner, whereas the ship specifications are provided in Table 4.

The Pioner is specifically designed to carry fish feed in bulk. It has 62 silos with a capacity of 20 tons each. The silos are placed in four transverse rows in the cargo space as shown in Figure 24. Each row is connected by pipes. At the aft, each pipe is fitted to a blower, whereas at the bow, all pipes are joined at the bow crane, which is used to offload the feed to the fish farms. Feed is emptied from the silos by using the blower and is blown through the pipes until it exits the crane tip. The ship is also fitted with two tanks used for diesel and freshwater deliveries to selected fish farms.

Figure 23: Picture of MV Eidsvaag Pioner [5].

Pioner has one main propulsor aft and two tunnel thrusters located aft and forward. The main propulsor is driven by one LNG engine and can be boosted by a PTI-PTO motor connected to the main switchboard, which is powered by auxiliary generators running on diesel fuel. Natural gas, which is stored on-board in its liquified form (LNG), is used as the main fuel for the ship propulsion engine.

The bridge is outfitted with three steering positions: Main bridge, port wing and starboard wing. Manual control of the ship is available on all three steering positions, whereas DP is available on main bridge.

The ship has a dedicated Feed Control and Monitoring (FCM) System. There are operator stations for the FCM System at the bridge and on the deck office. The engine control room is located aft on the vessel close to the machinery and switchboard rooms. The FCM System has a wireless connection that is used to interface the factory automation system when moored at factory quay for loading.

Eidsvaag Pioner operates on a seven-day cycle. Each cycle contains two loadings at the factory at Averøy. Pioner has approximately a ten-hour slot time at the factory quay. Starting from the factory in Averøy, two different transport route directions (southbound and northbound) along the Norwegian coast can be followed. The use case will assume one northbound trip and one southbound trip for each seven-day-cycle. On each trip, Pioner delivers feed to approximately 10 fish farms during a period of 30 hours not accounting for delays. After that, Pioneer will have to wait at a public quay until the start of the next seven-day cycle.

Table 4: SSS Main Particulars of MV Eidsvaag Pioner

Description	Value	Unit
Length overall	74,9	meters
Length between p.p.	72,9	meters
Breadth moulded	13,6	meters
Draught max.	5,1	meters
Gross tonnage	2145	tons
Deadweight	1450	tons
Carrying capacity (Feed)	1240	tons
Carrying capacity (Diesel)	35	m^3
Carrying capacity (Fresh Water)	20	m^3
Total volume of cargo space	2030	m^3
Loading rate – theoretical	200	tons/hour
Loading rate – effective	120	tons/hour
Offloading rate - theoretical	400	tons/hour
Offloading rate - effective	130	tons/hour

The ship is operated by a crew of seven persons working at four week shifts on six-hour rotations as follows:

- One Captain (Master).
- One Chief Officer (First Mate).
- One Chief Engineer.
- Two Able Seamen.

- One Chef / Ordinary Seaman.
- One 1st Engineer and One Trainee that rotates every four weeks and will never be onboard at the same time.

Pioner has no defined weather windows for sailing or transit. The captain will however evaluate the weather conditions continuously. Maximum acceptable weather conditions during offloading at the fish farm is as follows:

- Hs 2.0 m.
- 14 m/s lateral wind speed.

The main weather-related challenge during offloading is that both the vessel and the feed barge will move, and the crane must be operated to account for these relative motions.

Current is normally not an issue during offloading but can be critical when the vessel goes from steering speed to positioning, since the bow and aft tunnel thrusters will have reduced efficiency. The crew has experience with locations that have adverse weather conditions. There are no weather-related issues at the factory.

Figure 24: Deck layout of Pioner showing silo hatches distributed in four rows.

5.2.2. Factory and Feed

Eidsvaag transport fish feed for two feed producers having a total of three factories along the Norwegian coast. The use-case will only consider feed produced at the Skretting-factory in Averøy since this is the factory that Pioner uses as base. The feed production process is outside the AUTOSHIP project scope, but a short description of the feed delivery interface between the factory and Pioner will be provided.

The factory has two cranes that can load feed simultaneously on-board the vessel. This is illustrated in Figure 25. The factory stores feed in 40-ton silos in a main building. During loading of the ship, there are two delivery lines in play. Two silos are emptied onto two conveyor belts, each with a capacity of 100 tons/hours, transporting the feed in pellets from the main building to the quay building. During this in-house transport the feed is weighted and run through a filter to remove smaller particles from damaged pellets. The feed is then transported from the quay building to two separate cranes each with a capacity of 125 tons/hour and into the ship silos.

Feed is produced in approximate 1000 variants, where roughly 100 variants are used by fish farms and transported by Pioner on a regular basis. Feed is produced in pellets. The size of the pellets ranges from 3 mm to 12 mm in diameter with an average density of 0,63 kg/m^3. The silos on the Pioner are sized to carry 20 tons of feed for 12 mm pellets, which corresponds to 98% filling percentage.

Figure 25: The two land cranes load feed into the ship silos at the factory quay.

The factory has a turnaround time of 3-4 days and they are dependent on a split between bulk and big bags. The required number of tons feed per day at quay is the dimensioning factor at the factory. The factory produce feed 24/7. Stop in feed production in combination with limited storage capacity will cause the fish farms to tear off their safety margins in short term. In the long term, alternative deliveries from other factories must be considered.

5.2.3. Fish farms

Fish farms have a production cycle of 15-17 months from smolt to finished product. Fish farms are spread along the entire Norwegian coast. Each fish farm has a feed barge with one or more silos used to store feed. The silos have a hatch on top which must be opened and closed either manually or, as is normally the case, by using remote control.

Fish farms may be at weather exposed locations, but today most are situated in sheltered waters. The layout of the fish farms and the feed barges vary and can cause manoeuvring challenges for the feed ships. Some fish farms require ship repositioning, hauling or reversing to complete deliveries and this increases the risk of encountering moorings at the fish farm. In addition, the size of the silo hatches varies. The smaller the hatch, the more difficult it is to position the ships offloading crane into it. Most fish farms are equipped with local weather sensors, although this information is not normally interfaced with the ship systems.

Figure 26: Feed barge at a fish farm located close to land.

Feed can and is normally delivered to the fish farms without fish farm personnel on site, and they have the possibility to deliver 24 hours a day. However, some contractual requirements limit this freedom to specific hours during the day as some fish farms want to have personnel on site e.g. during normal working hours.

5.3. MARKET

The core business of the short sea shipping (SSS) demonstrator Eidsvaag is transportation of traceable products and specifically feed used to raise fish at fish farms located along the Norwegian coast. Feed is a high value product in fish farming and accounts for approximate fifty percent of the fish farms cost.

Eidsvaag is a transporter and logistics planner for two major and competing feed producers. They plan logistics and transport feed for both producers. They have their own fleet of ships. In addition, they are cooperating with two other shipping companies and run all ships under the brand name *Fjordfrende*.

Each producer has several factories located along the Norwegian coast. The producers either deliver the feed as bulk or in big bags.

The feed is transported from the producers to the customers (fish farms) located along the Norwegian coast. The fleet has a variety of ship types with different capacity for bulk and big bags. Some ships can also transport secondary products such as diesel and fresh water to the fish farms.

Fish farms have contracts with the producers. The contractual setup is either a common contract including both the feed itself and the transportation, or separate contracts for feed and transportation. Eidsvaag has one contract with each producer. Orders are placed directly to factories. 50 to 60 percent of the customers use a web system for orders, whereas the remaining customers place orders manually via phone or e-mail. In the latter case, Eidsvaag will place the order into the same system as the orders received via the web. When a customer places an order, this order will automatically be transferred to the ship.

If the fish farms order feed 14 days in advance they will receive a discount. The discount is on the feed price, not the transport. They can change the order volume up to 4-5 days prior to loading without losing the discount. If they want to change product or place a new order, they can do so up to 4-5 days prior to loading but in this case they will lose the discount benefit. The order is fixed at the latest 3 days prior to loading, and changes cannot be made.

The most usual changes to orders are related to the volume of the order. An example of late orders, where the feed type is changed, is when the customer needs special feed intended for fish with diseases.

The demand for fish feed is influenced mainly by the amount of active fish farms, the current state of the fish at the fish farms and seasonal variations as follows:

- The number of active fish farms will directly influence the required feed amount.
- Fish farms have a production cycle of 15-17 months from smolt to finished product. Feed demand increases with the production cycle.
- Fish eat more feed during periods with high sea temperatures. This period is called the high season, and in Norway it lasts approximate 4 months starting from June and ending in October.

Fish farming is also subject to diseases:

- Fish farms will request special feed products during disease outbreaks.
- During a disease outbreak, the fish farms will normally experience a decrease in the feed demand. This is generally related to loss of fish volume, and not due to lack of appetite among the fish.

Eidsvaag has a set of targets to both ensure the customer satisfaction and sustainability whilst running their business in a competitive manner. These targets include:

- Low environmental impact
- Operational economy and efficient operations
- Stakeholder management (customers and charterers)

5.4. SUPPLY CHAIN – FLOW OF GOODS AND INFORMATION

The process of transporting feed from the factory to the fish farms is divided into the following five phases:

- Loading, Bunker, Service and Repair
- Depart from quay
- Sail
- Approach to quay
- Maintenance

The interactions between these phases are illustrated in Figure 27. The analysis starts with the ship moored at quay. Factory quays are busy, and the ship have a predefined timeslot to carry out all the necessary activities. Feed will be loaded from the factory on-board the ship. Additionally, bunkering of LNG and loading of diesel and fresh water might take place. Crew change, stocking of supplies as well as miscellaneous repairs and service tasks are also carried out if needed. When all activities are completed, the ship will depart and manoeuvre out from quay to the open sea. The ship will then sail to all fish farms and deliver the transported feed to them in a sequential manner. Each fish farm is approached carefully. The ship offloads the feed to the fish farm feed barge using the bow crane and then departs the fish farm once the offloading is complete. This cyclic process continues until all deliveries are complete. The ship then sails back to the factory, approaches the quay and the process starts again.

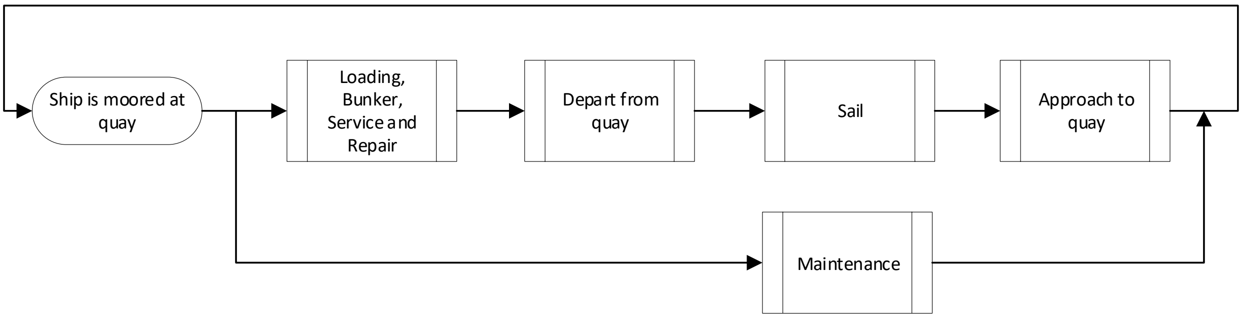

Figure 27: SSS Model of main process (see Section 9.1 for a description of all flow-chart symbols).

In the following sections, the particulars of all activities in Figure 27 will be explained to provide a detailed understanding of the supply chain. Each activity is either marked as manual (M) or automatic (A). This indicates that the activity is either manually initiated, manually carried out, automatically initiated or automatically carried out depending on the specific context. In addition to this, Annex 0 contains a list of all activities mapped towards autonomy levels as defined in [4].

5.4.1. Approach to quay

The starting point for the main process model assumes that the ship is moored at quay. Before we continue to explain how loading of the ship is carried out, it is useful to start with process of approaching the quay as loading preparations commences during this phase. Figure 28 shows the transition from sailing until the ship is ready for loading.

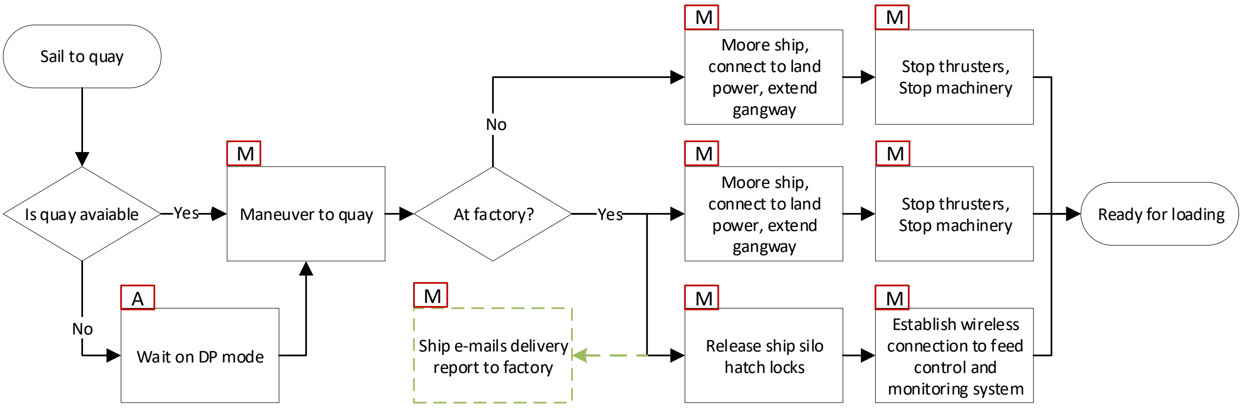

Figure 28: SSS Approach to quay

During the final phase of sailing and approach to the quay, the ship will receive notice whether the quay is available based on the ship's estimated time of arrival (ETA). The ship can proceed to manoeuvre to the quay, if the quay is available and the provided slot time is sufficient to carry out all planned activities.

When the ship approaches the factory quay several activities are started. If the ship arrives from fish farms, it will send a report on e-mail to the factory containing information about all delivered feed to their customers. A crew member will unscrew all locks on the ship silo hatches to save time during the loading process. The ship will be moored, and a gangway extended from the ship to quay. Thrusters and machinery will be stopped once the ship is moored. If land power is available, this will be connected. Otherwise auxiliary engines power the ship. A wireless connection will be established between the factory automation system and the Feed Control and Monitoring (FCM) system on the ship.

The ship might also need to use public quays due to several reasons:

- The factory quay is not available, and the ship must wait at a public quay for a longer period of time.
- The ship needs supplies that are scheduled to be loaded at the public quay.
- The ship needs to carry out service and repair jobs which are too time consuming or cannot be done at the factory quay.
- Crew change is planned at a public quay.

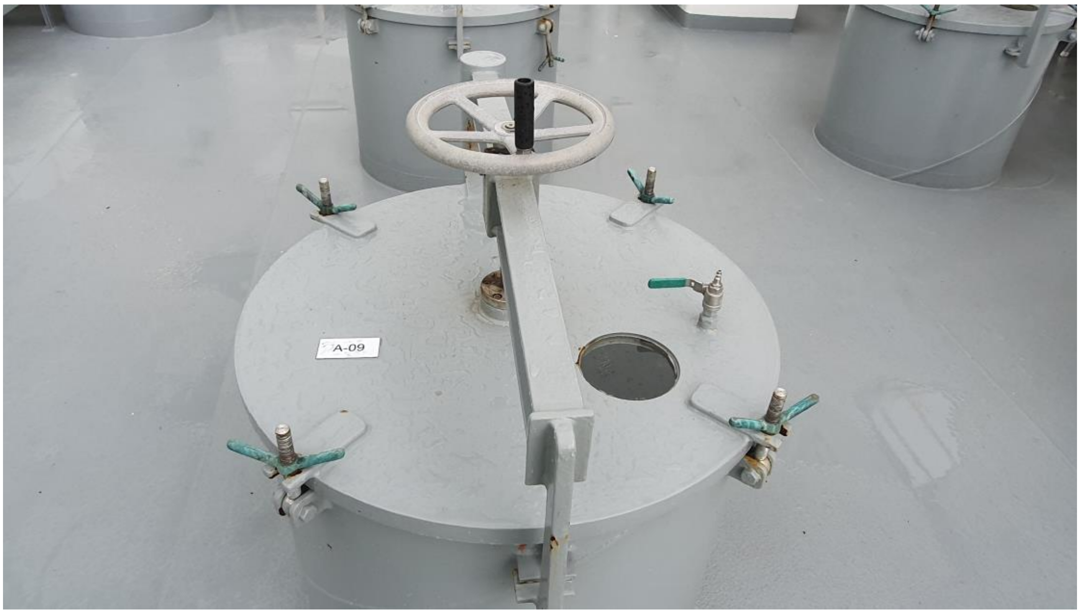

Figure 29: Four fixing points on top of the silo hatch secures the hatch during transport and must be unscrewed during approach to factory quay.

If the ship approaches a public quay the process is similar except for preparations of ship silos and establishment of connection to the factory automation system. In case any of the quays are busy during approach, the ship will normally wait close to the quay and apply station-keeping using Dynamic Positioning (DP)

Figure 30: Pioner is waiting to approach the factory quay.

5.4.2. Loading, bunker, service and repair

We start the description of loading, bunker, service and repair by assuming that the ship is located at the factory quay, which also serves as the primary quay in the supply chain. Figure 31 illustrates that loading activities can be done in parallel and that loading of feed and bunkering of LNG only can be done at factory. The exact goods amount to be loaded is predetermined and coordinated by the logistics manager.

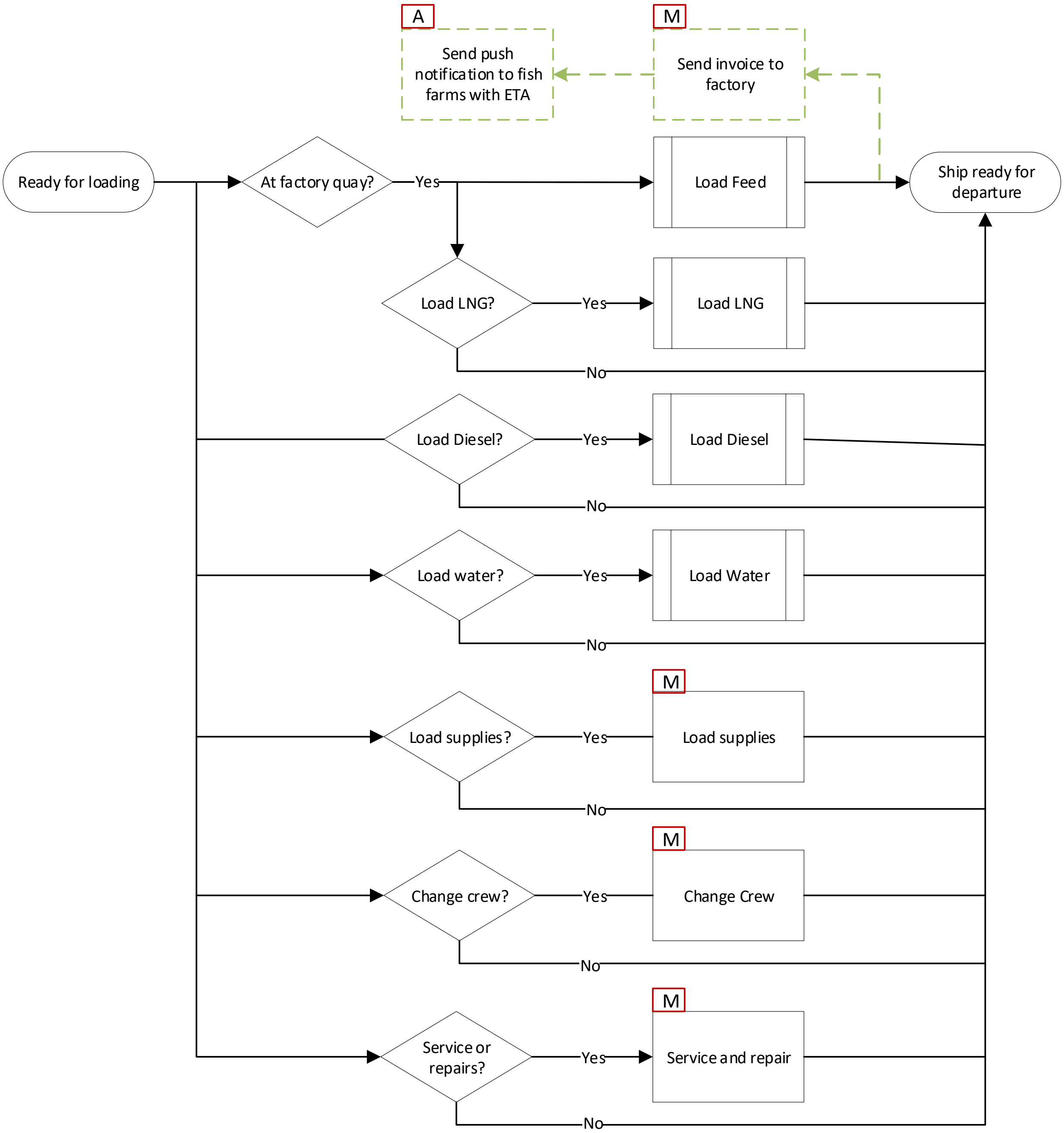

Figure 31: SSS Loading

The process of loading feed is the primary activity. The ship owner will send an invoice to the factory once loading is completed and the ship is ready for departure. Additionally, the ship will issue an ETA push notice to all fish farms with estimated times of arrival.

Secondary activities are bunkering of LNG for the propulsion engine, bunkering of diesel for auxiliary engines and loading of diesel and freshwater for delivery to selected fish farms. The primary and secondary activities will be detailed out, whereas loading of supplies and change of crew will not be treated further.

The use of a public quay comes at an additional cost as the port authorities charges a fee for use of the quay. This is not the case for the factory quay as it is privately owned by the factory itself.

5.4.2.1. Loading of feed

The process of loading feed from the factory to ship is illustrated in Figure 33. The load list contains amongst other information about:

- Amount of feed
- Type of feed
- Customers

This list will be mirrored between the factory automation system and the ship FCM system once the wireless connection is established. There are two cranes on the quay, which are used to transfer feed from the factory to the ship: Land Crane 1 and Land Crane 2. Both cranes are operated by a ship crew member using a single Remote-Control Unit (RCU).

When the factory is ready, the ship crew will start by opening the hatches of the silos that are to be filled with feed. The two cranes are in a sequential manner moved, so that the tip of the crane is lowered into the silo opening on-board the vessel. The silo is fitted with two sets of photocells and the land cranes are fitted with a detector. When the land crane is positioned in the silo, opening the silo is identified and the silo number is registered both in the factory IT-system and the FCM system.

Feed is then transferred from factory to the ship silos through the crane. During, or after filling, the ship crew takes a sample off the feed (approximately 1 kg), puts it in a plastic bag and writes on identification of the feed type and ship silo number.

Figure 32: Feed sample

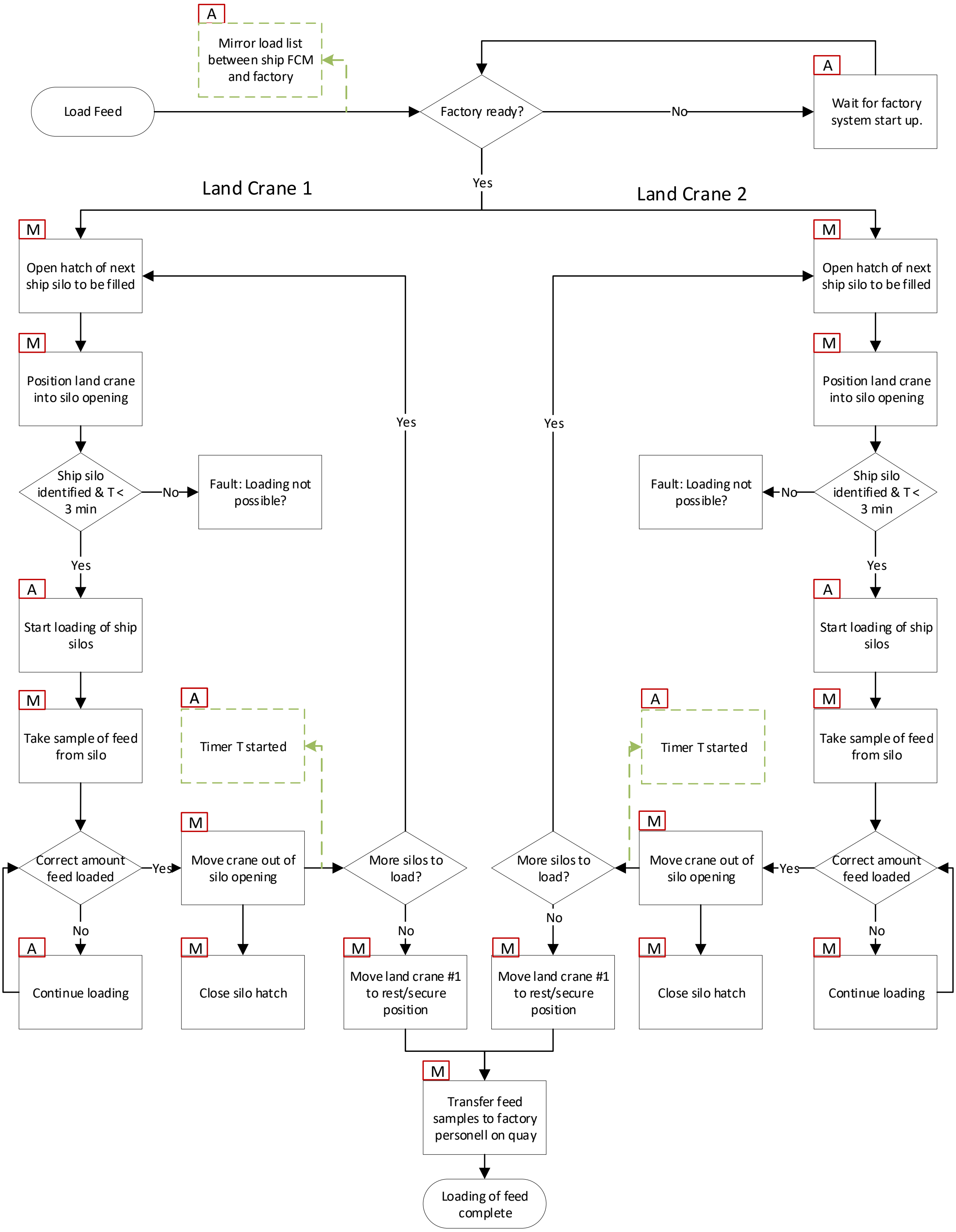

Figure 33: SSS Loading of feed

During loading, the filling grade of the silo is monitored in the FCM system from the deck office. This is done using a level sensor in the silo which is transferred to a filling grade given in percentage. When loading of one silo is completed (i.e. the silo is full, or all planned feed has been transferred) the operator will move the crane tip out of the silo. This triggers a timer *T* in the factory automation system: The operator has maximum three minutes to position the crane tip into the next silo opening. If this does not happen then the factory will stop the feed transfer for that specific crane. It is worth mentioning that the process usually takes one minute.

The crane will then be moved to the next silo opening and the filling process starts again. Opening and closing of silo hatches are done continuously and the overall goal is to have silos open for as little time as possible to avoid external contamination in the silos.

When all feed is transferred to the ship the operator manoeuvres the crane back to a secure resting position at quay. All feed samples are provided to the factory for analysis.

The feed loading process is complete.

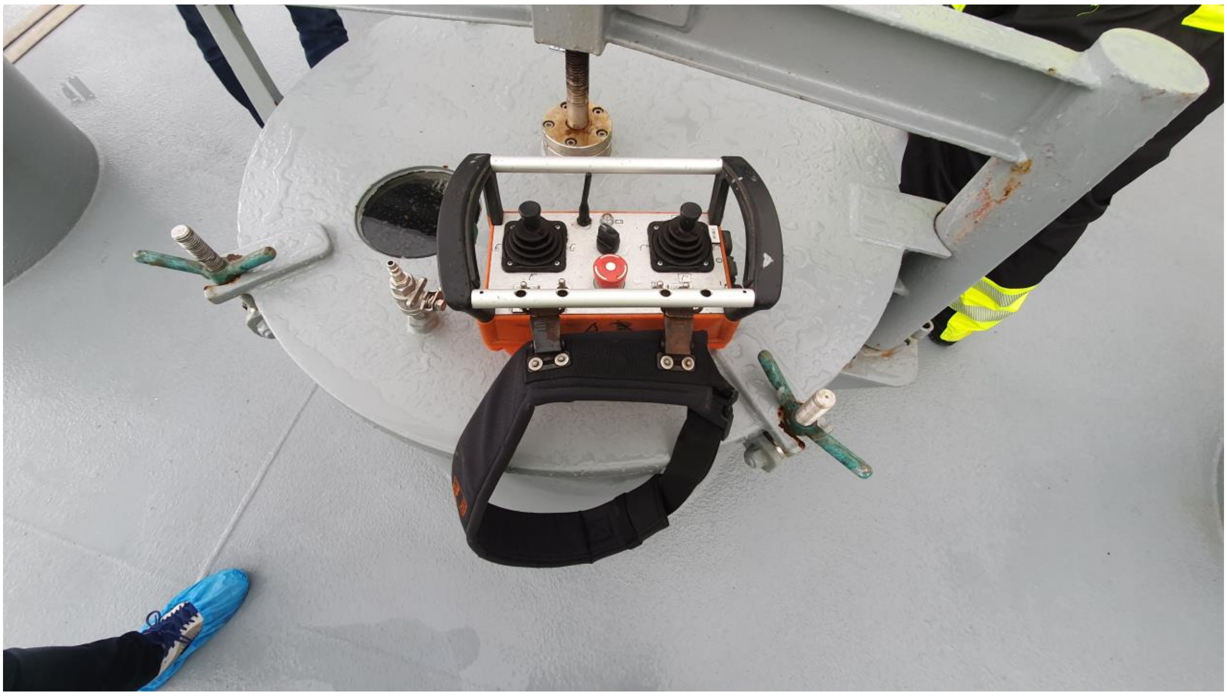

Figure 34: SSS - Remote control used to operate both land cranes.

Figure 35: Land cranes lowered into silo opening. Photocells detected and loading ready to start.

5.4.2.2. Bunkering of LNG

The ship uses LNG for the main propulsion engine. The infrastructure for LNG storage is set up at the factory quay, and thus LNG can only be bunkered there. The process of loading LNG is shown in Figure 36.

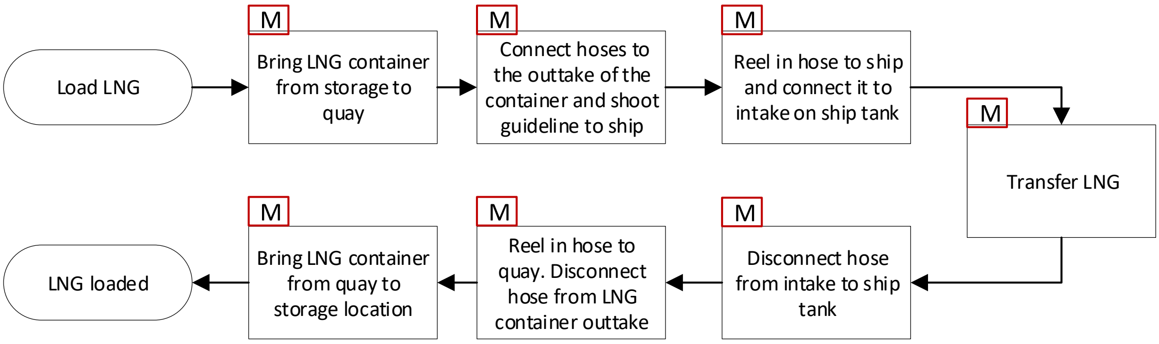

Figure 36: SSS Loading of LNG

LNG is stored in specialized containers at the main quay located some distance away from the factory quay. If the ship shall bunker LNG, the containers must be brought to the quay. Hoses used for transferring

LNG is permanently placed at the quay. The crew must first connect a hose to the outtake of the container and then shoot a guideline to the ship so that a hose can be reeled onto the ship and fixed to the intake on the ship tank. LNG is then transferred from the container to the ship tank. When the cargo (feed) loading is complete the process is reversed. The hose on the ship tank intake is disconnected and reeled back to the shore. The hose on the outtake of the container is disconnected and the LNG container is brought back to the storage site off the quay.

5.4.2.3. Loading and bunkering of Diesel

The ship is fitted with a separate tank used to deliver diesel to selected fish farms. In addition, the ship's auxiliary engines are fuelled by diesel (bunker). The loading process for both are identical and shown in Figure 37.

First, a hose must be connected to the outtake of the tank on quay. A guideline is then thrown to the ship and used to transfer to the hose onto the ship. The hose is connected to the intake of the ship diesel tank and diesel is pumped from the quay to ship storage tank. When all the required diesel fuel amount is transferred, the hose is disconnected from the intake, reeled back to quay and disconnected from the outtake.

Pioner can also receive diesel from bunker barges. In this case the same procedure will apply, with the exemption that the hose is connected to the outtake of the bunker barge.

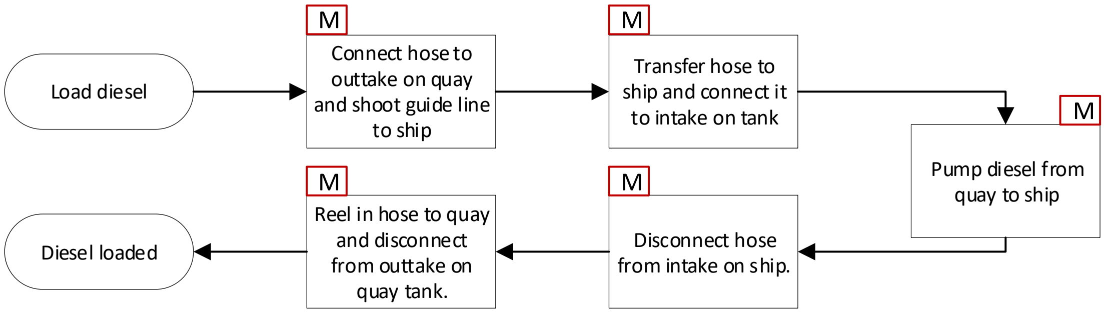

Figure 37: SSS Loading of Diesel

5.4.2.4. Loading of Water

The ship is fitted with a separate tank used to deliver fresh water to selected fish farms. In addition, the ship has tanks for fresh water as needed by the on-board crew. The loading process for both are identical and shown in Figure 38.

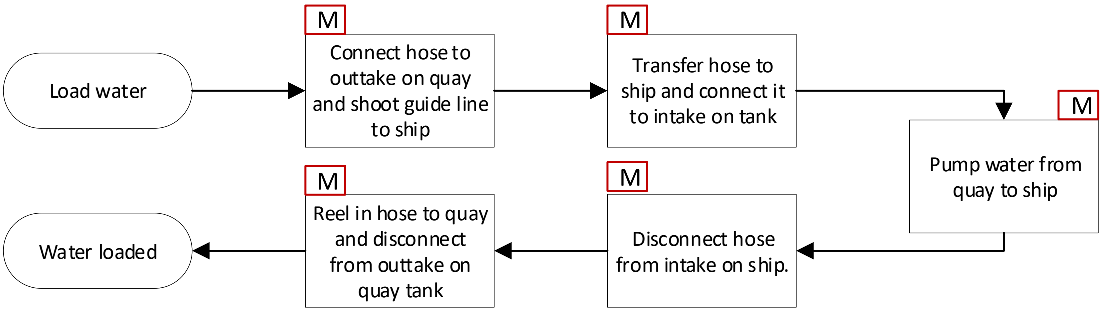

Figure 38: SSS Loading of water

First, a hose must be connected to the outtake of the tank on quay. A guideline is then shot to the ship and used to transfer to the hose onto the ship. The hose is connected to the intake of the ship water tank and water is pumped from the quay to the ship. When all water is transferred, the hose is disconnected from the intake, reeled back to quay and disconnected from the outtake.

5.4.3. Departure from quay

The ship is ready for departure from the quay when all goods are loaded as described in Section 5.4.2. The departure process differs slightly from factory compared to the public quay as is illustrated in Figure 39.

In both cases, the main engines as well as other necessary equipment and systems must be started. If land power is used, then this must be disconnected, and moorings must be removed. The ship is then ready to manoeuvre out of the quay.

Some additional activities are carried out when departing from the factory quay. The factory will issue a weight report to the ship via e-mail. The wireless connection between the factory automation system and the ship FCM system will be disconnected. Deck crew will lock and secure all hatches on deck and then all the silos will be over pressurized.

The ship is ready to sail upon completion of all these steps.

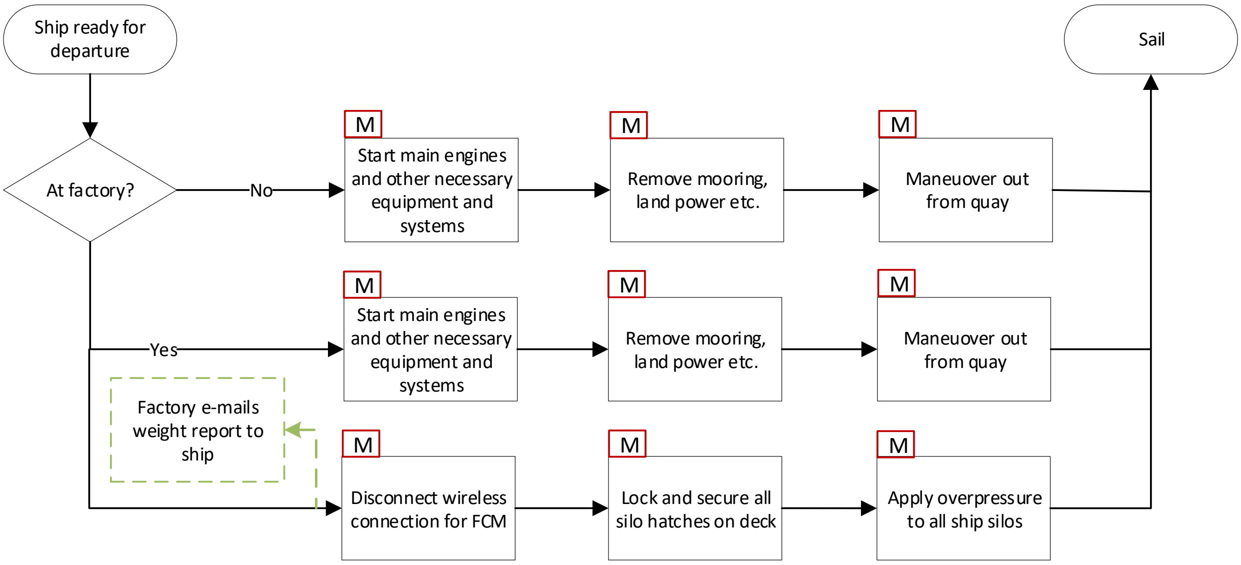

Figure 39: SSS Departure from quay

5.4.4. Service and Repairs

Service and repairs are not described with a flowchart model as these activities mainly are considered as disruptive and time-consuming from the supply chain perspective, and not contributing directly to either flow of goods or flow of information.

The ship regular maintenance activities are the following:

- Yearly drydocking with hull cleaning, machine overhaul and required class activities. Duration is 1-2 weeks during low season.
- Inspection and cleaning of pipes are carried out every second week when the vessel is at the factory quay.
- Other service and maintenance activities are carried out while loading or waiting for loading.

5.4.5. Sail

The ship is ready to sail once it has departed from a quay or a fish farm. During sailing, the ship is manually steered by the Captain or Chief Officer. They communicate with the Vessel Traffic Services and other ships when needed and keep in close contact with the logistics manager for continuous planning updates.

Depending on the route the ship will perform on of the following activities:

- Sail to the next fish farm, approach the fish farm, offload and depart from the fish farm.

- Wait in open waters if it has visited contaminated waters.
- Sail to the factory quay.
- Sail to the public quay.

This is illustrated in Figure 40. If the ship accomplishes the feed deliveries to the fish farms, the overpressure in the ship silos will be released.

It is also important to notice that if the ship has visited a fish farm within a contaminated zone, the ship will have to wait a given amount of time in open waters before it is allowed to proceed to the next fish farm. This is a safety measure to avoid spreading diseases from farm to farm.

If the factory is ready to receive the ship at the estimated arrival time, then the ship will proceed to the quay. If not, the ship will sail to a public quay.

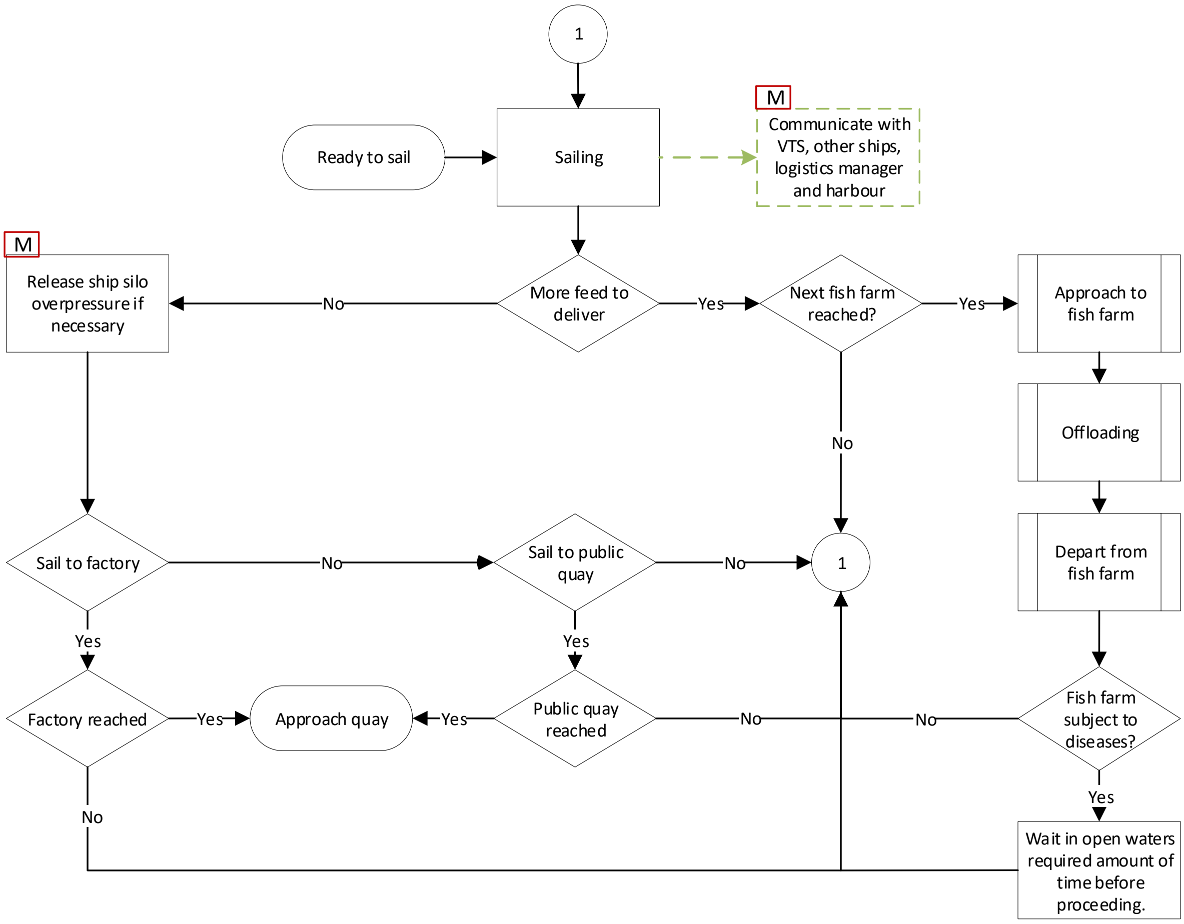

Figure 40: SSS Sail

5.4.5.1. Approach to fish farm

Figure 41 shows the transition from sailing until the ship is ready for offloading at a fish farm. The ship reduces the speed and starts manoeuvring towards the feed barge. The layout of the fish farms varies from location to location and the manoeuvres are carried out based on the captain's knowledge on local conditions.

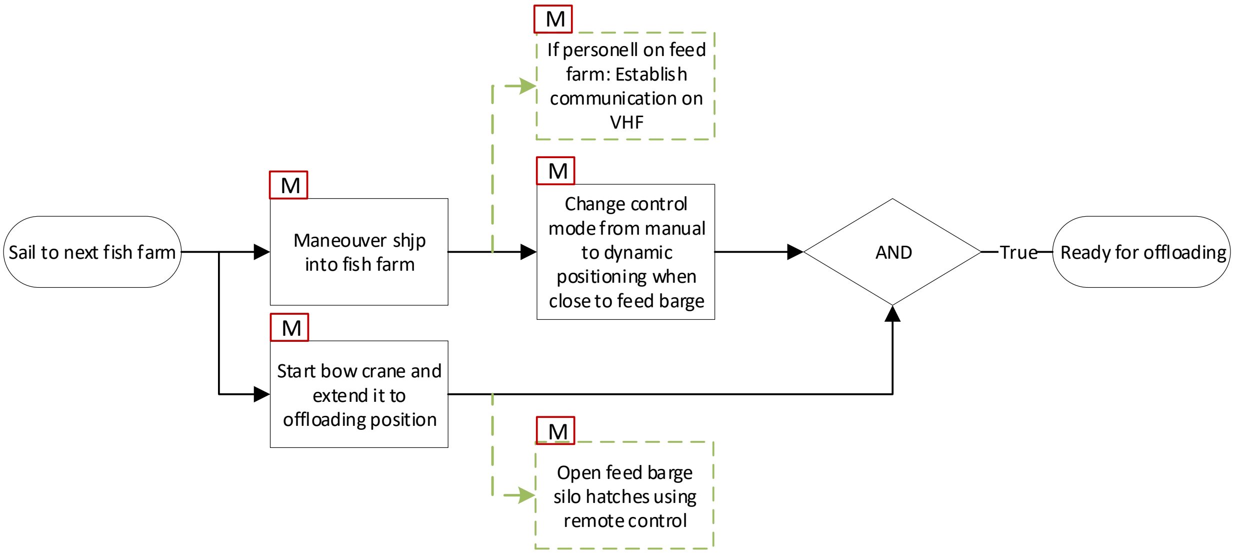

Figure 41: SSS Approach to fish farm

Communication may be established between the ship and the fish farm crew if they are on site. If the fish farm is equipped with automated silo hatches, the ship crew will use a remote control or similar approach to open the hatches. While the ship is manoeuvred towards the feed barge, a crew member on bridge will start the bow crane and extend it to offloading position using a remote-control unit. When the ship is positioned sufficiently close and the crane tip is above the feed barge silos the ship will be put into dynamic positioning mode with both heading and position control enabled. The ship is then ready for offloading.

Figure 42: Approach to fish farm with bow crane extended.

Figure 43: SSS - Remote Control Unit used for controlling the bow crane.

5.4.5.2. Offloading at fish farm

Feed is the main product in the supply chain, and the ship will deliver feed to every fish farm on the transport route. Fish farms also require diesel and fresh water to run their day-to-day business. Most fish farms acquire this by other means, whereas some selected fish farms are provided with this from the feed transport ship. Figure 44 illustrates how offloading of feed, diesel and water processes are carried out in parallel.

Offloading of feed can be done without personnel present at the fish farm if the ship has access to a RCU or a similar mean for opening and closing of the feed barge silos hatches. Offloading of diesel and water requires personnel at the fish farm.

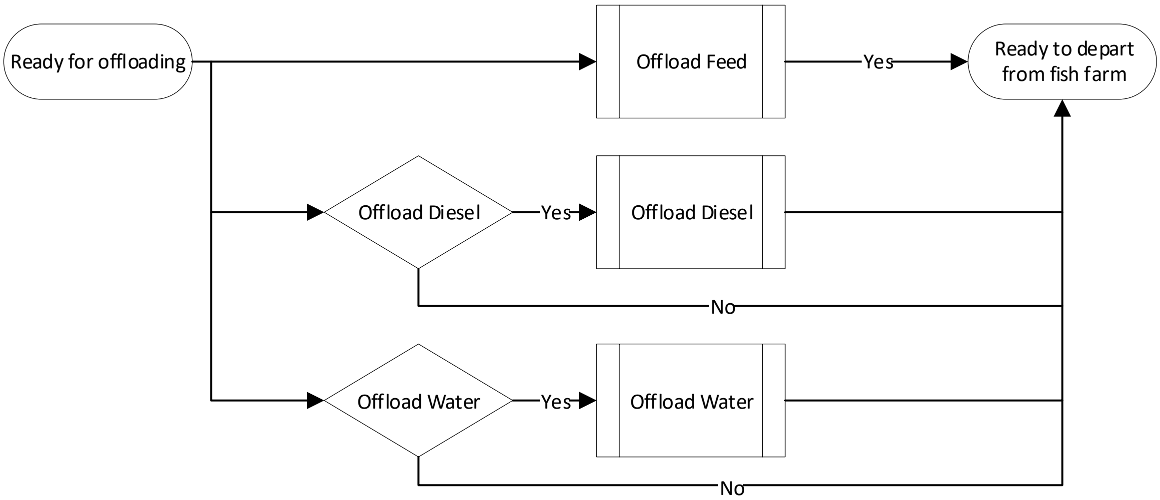

Figure 44: SSS Offloading at fish farm

5.4.5.3. Offloading of feed

Figure 46 illustrates the feed offloading sequence. When the ship is positioned with the crane above the feed barge and the silos hatches on the feed barge are open. The crane is then positioned above the feed barge silo opening and lowered into it using the remote control operated by a crew member on the bridge.

The crane has a camera on the tip and two monitors on bridge showing live video. During offloading, the crew must constantly adjust the crane position to account for the relative movement between the ship and the feed barge.

Figure 45: Offloading from ship to feed barge silo.

The crew selects the customer (fish farm/location) on the control and monitoring system and the product that shall be offloaded. This will give a visual indication on the monitor showing the silos that can be offloaded. The other silos are then interlocked. If several silos can be offloaded, then the crew will select each silo manually by pressing them and then start offloading. The offloading rate is adjusted on-board by setting the speed of the blowers that blows the contents in the ship silos into the feed barge silos. There is a total of four silo rows on the vessel, each one serviced by one blower. A total of two silos on two rows can be offloaded at the same time.

When the feed barge silo is filled, the operator presses a stop button and manually confirms that the silo is empty. The silo indication on the monitor is then updated accordingly. The operator then repeats the procedure until all the feed is delivered. The operator makes a note in the system explaining which silos on the feed barge that was fed from each ship silo.

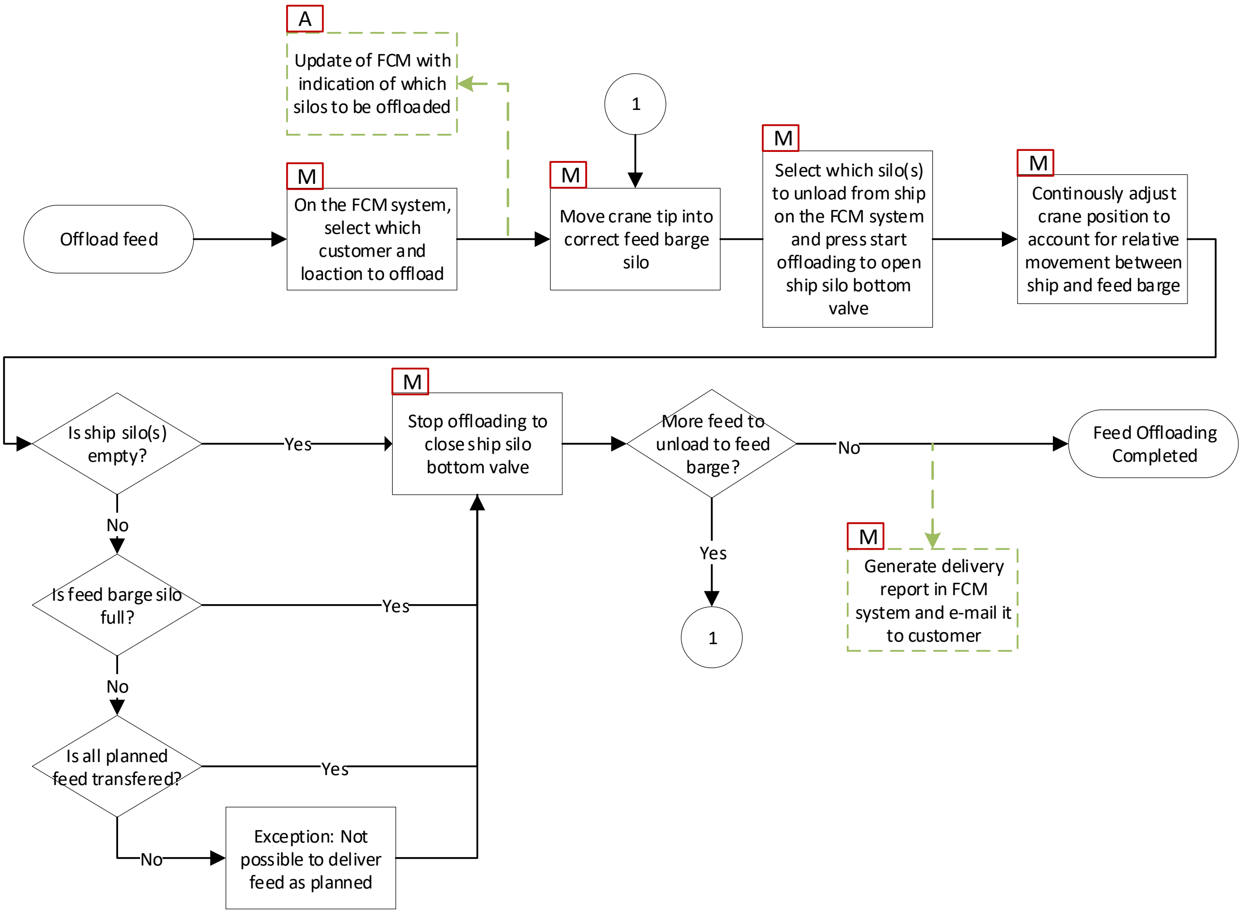

Figure 46: SSS Offloading of feed

Upon end of offloading, a delivery report is generated and compared with the weight report from the factory, and then sent to the customer by e-mail.

If for some reason the silos on the feed barge cannot receive the contents of the silos on the vessel, the crew must manually input this into the computer system, so that only a partial delivery is acknowledged. The feed will normally remain on the silo until the ship returns to the fish farm to deliver it.

5.4.5.4. Offloading of diesel

The ship has two outtakes that can be used for offloading of diesel; one at the bow and one at the starboard side. This is to increase the possibility of being able to offload diesel in parallel with the feed. The process of offloading diesel is shown in Figure 47. First, a hose must be connected to the outtake on the ship. A guideline is then shot to the feed barge and used to reel the hose onto the feed barge. The hose is then connected to the intake of the feed barge diesel tank and the diesel is pumped from the ship to the barge.

When all the diesel fuel is transferred, the hose is disconnected from the outtake, reeled back to the ship and disconnected from the intake.

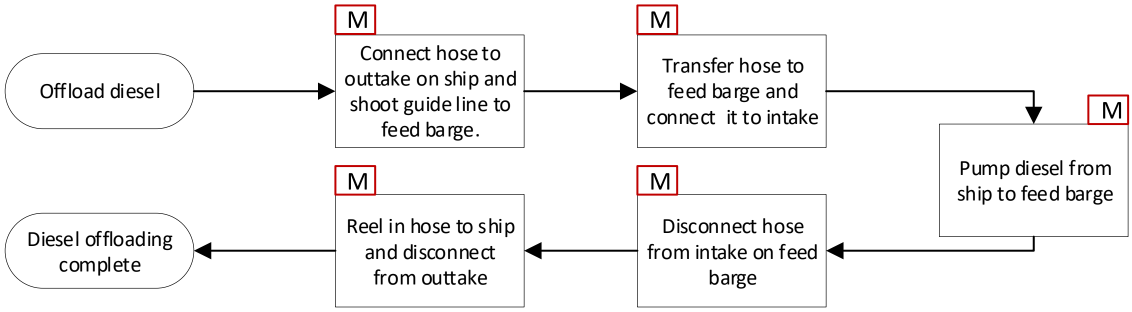

Figure 47: SSS Offloading of diesel

5.4.5.5. Offloading of water

The process of offloading water is similar to offloading diesel. The ship has two outtakes that can be used for offloading of water. One at the bow and one at the starboard side. This is to increase the possibility of being able to offload water in parallel with feed. The process of offloading water is shown in Figure 48.

First, a hose must be connected to the outtake of the fresh water tank on-board the ship. A guideline is then shot to feed barge and used to reel the hose onto the feed barge. The hose is then connected to the intake of feed barge water tank and water is pumped from the ship to the barge. When all the water amount is transferred, the hose is disconnected from the outtake, reeled back to the ship and disconnected from the intake.

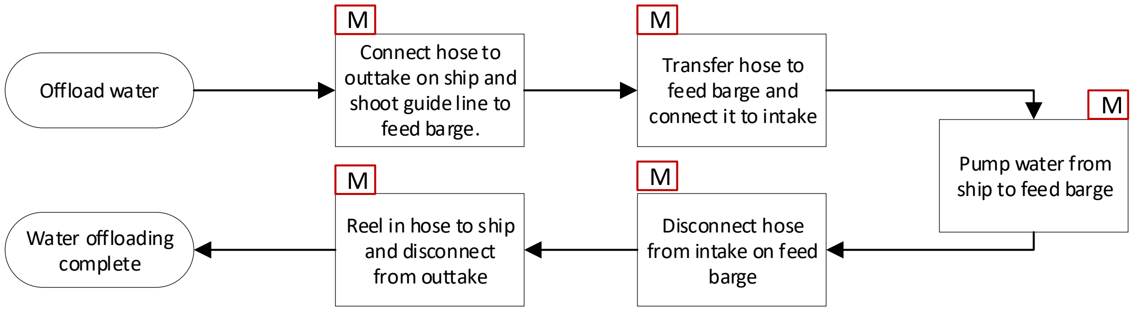

Figure 48: SSS Offloading of water

5.4.5.6. Departure from fish farm

The ship is ready to depart from the fish farm when the offloading of feed (water and diesel) is completed. As shown in Figure 49 the captain will change the steering mode from DP to manual control and slowly move away from the feed barge and out of the fish farm area. In parallel, a crew member will retract the bow crane and place it in a secure resting position using the RCU. The ship is then ready to sail to the next destination.

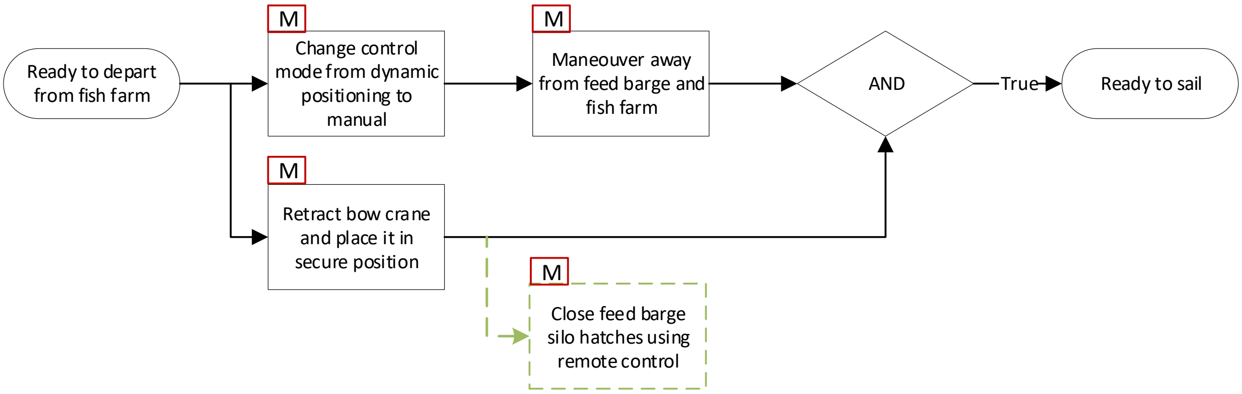

Figure 49: SSS Departure from fish farm

5.4.6. Maintenance

Daily maintenance is normally carried out by the crew while the ship is sailing. This includes, but are not limited to, the following tasks:

- EO signal checking.
- Change of filters.
- Change of oil in machinery.
- Replacement and minor repair of equipment using on-board spare parts.
- Washing and cleaning activities on outer deck.

Some regular maintenance activities are also carried out while the ship is at a quay. This includes, but are not limited to the following tasks:

- Inspection and cleaning of pipes are done every second week when the vessel is at factory quay.

6. GENERIC AND UNIFIED MODELS

In this chapter, the SSS and IWW use-cases are analysed to identify interactions and connecting elements. The result of this analysis is used to develop a generic supply chain model.

6.1. IDENTIFICATION OF INTERACTIONS AND CONNECTING ELEMENTS

6.1.1. Limitations

None of the demonstrators have any impact on the production of the goods that is transported nor the use or consumption of the goods. The description of the supply chain is therefore limited to the transport system with corresponding explanations on the goods that are transported and how these are consumed.

6.1.2. Maintenance

Daily maintenance is handled differently in the SSS and IWW use-cases. The PSBs cannot perform maintenance during sailing since the captain must focus on the navigation task, whereas Pioner has crew dedicated to carry out maintenance during sailing.

6.1.3. Repair and Service

Both demonstrators carry out repair and service jobs whilst moored at quay. Pioner operates on a cyclic schedule and service and maintenance jobs are planned into fixed time slots at the quay. This is more flexible for the PSBs, as it can be carried out on different locations, but still must be planned such that service personnel are called out to the correct time and location.

6.1.4. Bunkering

Pioner only has the option to bunker at the factory quay. The PSBs must order a bunker barge or truck to a given location.

6.1.5. Sailing

The PSBs usually load goods on one quay and transport them to another quay where everything is offloaded. After having offloaded all gods they may or may not load new goods to transport to the next destination. This differs from the SSS use-case, where goods are loaded at the quay and then offloaded at several fish farms in sequence.

6.1.6. Fish farms, bridges and water-locks

Considering the sailing patterns, there are similarities between the SSS and IWW use-cases. The PSBs must pass bridges and water locks on the way to its destination, whereas Pioner must visit fish farms. Passing a bridge, passing a water lock and visiting a fish farm requires an approach, manoeuvring, seakeeping, and a departure where one must communicate and perform given actions. This is also a situation where the ships stay idle (at zero speed), whilst not being moored. One can therefore consider these as similar operations. The only difference is that Pioner will offload goods at each node whilst the PSBs do not.

The approach to and departure from the fish farms are very similar to sailing in canals and rivers. The ships must be manoeuvred to avoid

- Nearby visible obstacles.
- Running into the river bottom, the bottom of a channel or the seabed, which can be shallow.
- Submerged and non-visible moorings and other objects in the water.

6.1.7. Quays

Another similarity in both the SSS and IWW use-cases, where the ships stay berthed/moored at the quays. The activities performed while at quay may be different, as described in the following Section, however the stay at quay has similar characteristics; main engines are not being used to keep the position such that the power demand profile differs from station keeping and is independent on weather and environment conditions such as waves and currents.

6.1.7.1. Activities at quays

The following activities are conducted while the PSB is at quay:

- Loading
- Offloading

- Service and repair
- Bunkering
- Crew change
- Wait (night stay = wait for day)

The following activities are conducted while Pioner is at quay:

- Loading
- Service and repair
- Bunker
- Crew change
- Wait (for weather to improve or for time slot at factory)

6.1.8. Geographical Areas

The two demonstrators operate in separate geographical areas. PSBs operate on the inland waterways in the Flemish region, whereas Pioner operates along the west coast and northern parts of Norway. None of the demonstrators have a natural geographical link connecting them together.

6.1.9. Goods

The PSBs mainly transport pallets, big-bags and roll-on-roll-off containers. Pioner transports bulk in silos, and water and diesel in tanks. Transhipment between the ships cannot naturally take place unless at least one of them are rebuilt or converted.

6.1.10. Market

The two demonstrators operate in different markets. BLL can carry all cargo fitted on pallets, big bags and roll-on-roll-off-containers, which also can withstand outdoor environment. Pioner is specifically built to carry fish feed in bulk, although other ships in the fleet can carry feed in big bags as well. There is no natural link between the markets that the demonstrators operate in.

6.2. GENERIC MODEL OF SUPPLY CHAIN

A generic model of the SSS and IWW supply chain has been developed based on the interactions and connecting elements identified in Section 6.1.

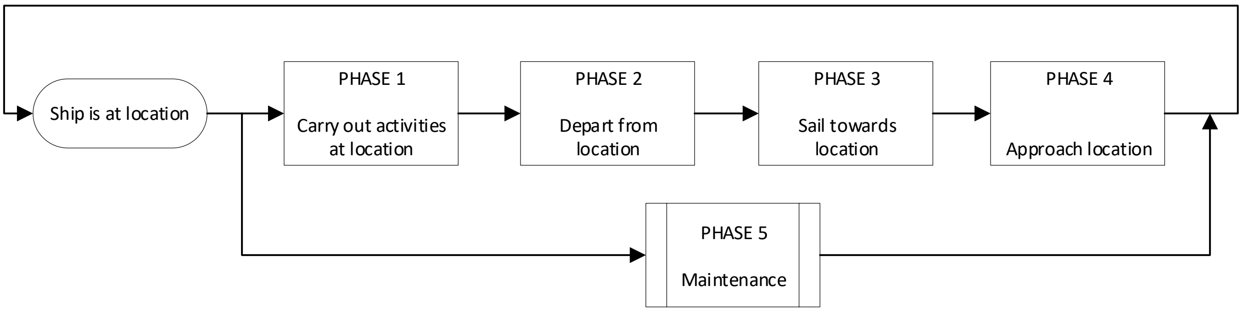

Figure 50: Generic supply chain model for SSS and IWW use-cases

The model is shown in Figure 50 and it assumes that the ship initially is at a specific location. The following five distinct model phases are defined:

- Phase 1: Carry out activities at location.
- Phase 2: Depart from location when necessary activities are completed.
- Phase 3: Sail towards next location.
- Phase 4: Approach location.
- Phase 5: Carry out maintenance in parallel with Phases 1 - 4.

Each phase in the generic model is defined by generalized characteristics that are applicable to both the SSS and IWW use cases.

6.2.1. Initial Condition - Location

Quays, water-locks, bridges and fish farms are generalized to the term location in the generic model. *Ship at location* is selected as an initial condition in the model since this is a known geographical position and the ship will have zero speed. Zero speed is obtained by

- Mooring.
- Station-keeping using DP.
- Station-keeping using lever control.

6.2.2. Phase 1 – Activities at location

Phase 1 is generalized into *Activities at location* in the generic model. The ship is at a location to perform one or several activities. These activities are grouped into the following subcategories:

- Loading of goods
  - Type of goods to load
  - Amount to load
  - Effective loading rate
- Offloading of goods
  - Type of goods to offload
  - Amount to offload
  - Effective offloading rate
- Pass Obstacle
  - Type of obstacle to pass (e.g bridge, water-lock, other ships)
- Bunkering
  - Amount to bunker
  - Effective bunkering rate
- Service and Repair
  - Time required for service and repair
- Crew change
  - Time required for crew change
- Wait
  - Time until activities can commence, or ship is ready to depart
- Cost:
  - Staying at a location can incur a direct cost to the ship owner.
- Energy usage
  - Staying at a location and executing the various activities will result in different power consumption profiles.

Whether or not activities can be carried out at a specific location depends both on the characteristics of the ship and the location itself.

6.2.3. Phase 2 – Departure from location

Phase 2 is generalized into *Departure from location* in the generic model. Although the necessary steps required to depart from a location will differ depending on the ship type and the location itself, the following characteristics are associated with this phase:

- The ship will increase speed from zero to nominal sailing speed.
- This ship will have to take into account environmental forces.
- A sailing plan will be issued once departure is ready.

6.2.4. Phase 3 – Sailing

Phase 3 is generalized into *Sail to next location* in the generic model. The following characteristics are associated with this phase:

- The ship consumes energy to obtain speed. The energy consumption depends on
  - Loading condition.
  - Environmental forces; sea, river and canal conditions.
  - Ship speed.
- The ship must communicate with traffic services and other ships to ensure safe navigation

6.2.5. Phase 4 – Approach to location

Phase 3 is generalized into *Approach to location* in the generic model. Although the necessary steps required to approach a location will differ depending on ship type and the location itself, the following characteristics are associated with this phase:

- The ship will decelerate from steering speed to zero speed.
- The ship will initiate communication with the location if necessary.
- The ship will start preparing for the activities that is to be carried out at the location.

6.2.6. Phase 5 – Maintenance

Phase 5 is generalized into *Maintenance* in the generic model. This phase runs in parallel with Phase 1 to Phase 4. Whether or not maintenance work is carried out in parallel with all phases depends mainly on the manning level of the ship. Maintenance work during departure, sailing and approach requires that dedicated crew is on-board the ship to carry out the required tasks. Maintenance work while the ship is moored/berthed at a location does also require dedicated personnel, either ship crew or land-based personnel. Both alternatives come at a cost and must be aligned with measures to operate the ship in a safe manner.

6.3. UNIFIED MODEL OF SUPPLY CHAIN

Although the SSS and IWW use-cases in the AUTOSHIP project cannot be unified as-is-today, it is possible to define a unified model that connects the two use cases by

1) including the distribution of raw material to the fish feed producer in the SSS use-case, or

2) abstracting the SSS use-case to general cargo transport.

Two proposals are given for a unified SSS and IWW supply chain mode. Both proposals act as input to further work and elaboration in WP7. The proposals capture transnational sailing between several territories (including different national authorities and international water) and the flow of information associated with this must also be mapped and investigated in future work.

6.3.1. Proposal 1

This proposal unifies the SSS and IWW use-cases through integration of the distribution of fish feed raw material in the SSS use-case. The raw material producer loads the materials in containers, big-bags or in packets stored on pallets. The cargo then is loaded on the inland waterways ship which transfers the cargo to a sea-port operation hub in e.g. Rotterdam, Antwerpen, Zeebruges or Amsterdam. A short sea ship would then transfer the cargo to the other big ports (Port of Edinburgh, Port of Felixstowe, Port of London, Port of Hamburg, Port of Bergen, Port of Oslo, Port of Ålesund, Port of Aarhus, Port of Copenhagen) or directly to the fish feed producers. After the production of the fish feed, the fish feed is transferred to the fish farms using the Pioner. This is demonstrated schematically in Figure 51. This model could potentially capture the *Production Planning and Inventory Control* level of the multi-stage supply chain model in [1].

Figure 51: Unified Supply Chain Model.

6.3.2. Proposal 2

This proposal unifies the SSS and IWW use-cases by abstracting the SSS use-case into general cargo transport. A number of port hubs, which allow for more automated loading/unloading processes as well as the manoeuvring and berthing of autonomous ships of various sizes and types, is proposed to be established in various countries/geographical locations. SSS autonomous vessels connect each port hub with other ports in the narrower geographical area transporting cargo in both directions. Larger size (container feeders) autonomous vessels connect the various port hubs, thus connecting a wider geographical area (e.g. Baltic sea, north sea, English channel, Norwegian coastline, etc.). The IWW ships service a number of routes between the closest port hub and the mainland quays transporting cargo in both directions although transportation by other means may be required to connect the IWW destinations with the closest hub port.

A similar logistics concept could potentially be implemented in the Thames river and other ports located at estuaries of big navigable rivers. One of the partners in the AUTOSHIP project has a parallel project, where a 3000 tons autonomous cargo ship is being developed to cross the English Channel. This unified model could potentially capture the *Distribution Centre* component in the *Distribution and Logistics* level of the multi-stage supply chain model in [1].

Further investigation will be carried out in WP7 to analyse potential routes and propose the hubs locations as well as recommended routes for the involved autonomous ships of various types. Other geographical areas, e.g. Mediterranean Sea will be included in this investigation.

7. CONCLUSIONS

The SSS and IWW use-cases have been investigated through semi-structured interviews with follow-up communication and clarifications. The information has been structured into topics and used to identify the different phases of transporting goods from one place to another. The phases have been modelled by using flow-charts, and together they form the supply-chain models.

These supply chain models have been compared to find the properties that can be used to describe the different phases of the models, and which can be abstracted into a generic model. The result is a generic model consisting of five phases:

- Phase 1: Carry out activities at location.
- Phase 2: Depart from location when necessary activities are completed.
- Phase 3: Sail towards next location.
- Phase 4: Approach location.
- Phase 5: Carry out maintenance in parallel with Phase 1 - 4.

Each phase in the generic model is defined by generalized characteristics that are applicable to both the SSS and IWW use cases. As an example; a stay at a location has an associated time and energy (fuel) consumption, whether it is station keeping at a fish farm or mooring at a quay.

Intuitively, navigating canals are quite different from navigating along the coast from fish farm to fish farm. The canals are more like roads in terms of route planning and navigation, whilst sailing along the coast is not. Another unique property of navigating canals is encountering locks and bridges. However, some common properties for navigating IWW and SSS can be derived. The navigation process of approaching and passing a lock is similar to approaching, offloading goods to and leaving a fish farm. Both sequences have the following steps:

- Approach to object
- Station keeping
- Depart from object

Thus, an important result of the analysis is that navigating SSS and IWW ships, in what first appears to be different environments, can be generalized into the same phases.

The manning level on the ship is the biggest difference between the SSS and IWW demonstrators. The SSS demonstrator has a crew of seven and the IWW demonstrator has a crew of one. This difference has several consequences of which maintenance might be the most important.

Maintenance is a major challenge for unmanned ships as many crew members on manned ships have daily maintenance as one of their main responsibilities. The daily maintenance consists of tasks such as signal checks, ship and equipment cleaning, oil and filter changes and minor equipment repair. Whereas maintenance is performed while sailing for the SSS demonstrator, it is done at quay for the IWW demonstrator. Investigating the differences in how maintenance is handled will be an important continuation of this work, and a valuable contribution towards solving the challenge of maintenance for unmanned ships. The following research questions should be included in the further work:

- What are the maintenance tasks carried out for the SSS use-case ship?
- What are the maintenance tasks carried out for the IWW use-case ship?
- Which tasks are common for the two use-cases and which are unique?
- What is the key reason that the IWW ships do not need to perform maintenance while sailing?

None of the demonstrators are involved in the production and consumption processes, but they can influence them in case of delays and deviations in the transport system. This is not included in the generic model. However, the consequence (or cost) of such deviations should be added to the model as it will be an important variable in the cost analyses to be delivered in WP3.

The analysis also shows that it is not possible to define a unified model that connects the two use-cases into one supply chain. The SSS demonstrator transports bulk and the IWW demonstrator transports pallets, big bags and roll-on-roll-off containers. The two demonstrators also operate in separate geographical areas and in markets that has no natural link to each other.

Although the SSS and IWW use-cases in the AUTOSHIP project cannot be unified as-is-today, two proposals for unified supply chain models is developed by assuming 1) that SSS-use case is extended with the distribution of raw material to the fish feed producer and 2) that the SSS use-case is abstracted to general cargo transport. Both proposals capture transnational sailing between several territories (and national authorities) and should be used as a basis for further work in the AUTOSHIP project.

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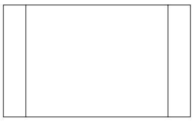
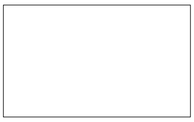
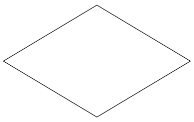
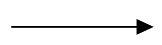
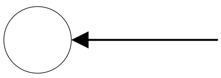
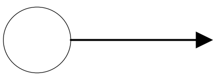
9. ANNEXES

9.1. DESCRIPTION OF FLOWCHART MODEL SYMBOLS

Table 5: Description of flowchart model symbols.

	Indicates the start and end of a phase.
	Phase. Contains sub-processes and activities.
	Activity.
	Decision. Usually has one input and two possible outputs.
	Transition from one phase, activity or process to another.
	On page reference.
	On page reference.
M	Indicates that an activity is carried out or initiated manually by the crew.
A	Indicates that an activity is carried out or initiated automatically by the control system.
	Indicates a communication point.
	Indicates which actors are involved in a phase or activity.

9.2. AUTONOMY LEVELS

The flowchart models in Chapter 4 and Chapter 5 indicate whether an activity is initiated or carried out manually or automatically. It is also useful to relate the activities to the following autonomy levels as defined for merchant ships in [4]:

- AL0-1 Operator controlled ship.
- AL2 Automatic.
- AL3 Partly and constrained autonomous.
- AL4 Constrained autonomous.
- AL5 Fully Autonomous.

The purpose of relating each activity with the present autonomy level is to clearly identify and communicate the automation level of the supply chain as-is-today. The supply chain model has for this purpose been transferred into a tabular format where each activity is related to the present autonomy level.

The autonomy levels considered for the inland waterways use-case are given in Table 6, whereas the autonomy levels for the short sea shipping use case are provides in Table 7. These tables also provide a basis to both establish and communicate the future ambitions of the demonstrators and the AUTOSHIP project itself.

9.2.1. Autonomy levels for inland waterways use-case

Table 6: Mapping of supply chain activity towards autonomy level for IWW use-case.

a/a	Operational phase	Id	Task	Id	Subtask	Present Autonomy Level
0	Supply chain management	0.1	Development of the whole logistic chain	0.1.1	Get the requisition	AL1
				0.1.2	Check the current fleet status	AL1
				0.1.3	Check the transport distances	AL0
				0.1.4	Check if the road transport is required	AL1
				0.1.5	Sign the contract	AL0
				0.1.6	Update the sailing plan	AL0
				0.1.7	Align the road transport plan with sailing plan	AL0
				0.1.8	Send the vessel to the loading point	AL0
1	Loading	1.1	Loading rolling containers	1.1.1	Waiting for truck	AL0
				1.1.2	Loading the container from truck using truck	AL0
				1.1.3	Ballasting	AL2
				1.1.4	Verifying stability	AL0
				1.1.5	Signing, scanning and sending bill of lading	AL0
		1.2	Loading pallets, big-bags, other containers, cars	1.2.1	Transferring of pallets to quay using forklift	AL0
				1.2.2	Loading the pallets from quay using crane	AL0
				1.2.3	Ballasting	AL2
				1.2.4	Verifying stability	AL0
				1.2.5	Signing, scanning and sending bill of laden	AL0
2	Departing from quay	2.1	Departure from quay	2.1.1	Start main engine	AL1
				2.1.2	Disconnect from land power	AL0

a/a	Operational phase	Id	Task	Id	Subtask	Present Autonomy Level
				2.1.3	Upload sailing plan to DVW	AL0
				2.1.4	Remove mooring	AL0
				2.1.5	Manoeuvre out from quay	AL0
3	Sailing	3.1	Sailing	3.1.1	Selecting/updating the selected route	AL0
				3.1.2	Communicating with other ships	AL0
				3.1.3	Situational awareness	AL0
				3.1.4	Following the selected route	AL0
				3.1.5	Avoiding obstacles	AL0
		3.2	Passing through lock	3.2.1	Notify lock operator 30 min in advance	AL0
				3.2.2	Notify lock operator at lock	AL0
				3.2.3	Check if the lock is ready	AL0
				3.2.4	Standing at waiting position	AL0
				3.2.5	Operator open locks	AL0
				3.2.6	Ship enters lock	AL0
				3.2.7	Operator closes lock and adjusts water level	AL0
				3.2.8	Operator open locks	AL0
				3.2.9	Ship obtains permission to get out	AL0
				3.2.10	Ship exit lock	AL0
				3.2.11	Operator closes lock	AL0
		3.3	Passing through/ under bridge	3.3.1	Notify bridge operator 30 min in advance	AL0
				3.3.2	Notify bridge operator at the bridge	AL0
				3.3.3	Check if the bridge is ready	AL0
				3.3.4	Standing at waiting position	AL0
				3.3.5	Operator open bridge	AL0

a/a	Operational phase	Id	Task	Id	Subtask	Present Autonomy Level
				3.3.6	Ship passes bridge	AL0
				3.3.7	Operator closes bridge	AL0
				3.3.8	Ship obtains permission to go on	AL0
4	Approaching to quay	4.1	Approaching to quay	4.1.1	Manoeuvre to quay	AL0
				4.1.2	Connect mooring	AL0
				4.1.3	Connect to land power	AL0
				4.1.4	Stop main engine	AL1
5	Offloading	5.1	Offloading containers	5.1.1	Waiting for truck	AL0
				5.1.2	Offloading the container from ship to truck	AL0
				5.1.3	De-ballasting	AL2
				5.1.4	Verifying stability	AL0
				5.1.5	Signing, scanning and sending delivery receipt	AL0
		5.2	Offloading pallets, big-bags	5.2.1	Offloading the pallets from quay using crane	AL0
				5.2.2	Transferring of pallets to quay using forklift	AL0
				5.2.3	De-ballasting	AL2
				5.2.4	Verifying stability	AL0
				5.2.5	Signing, scanning and sending delivery receipt	AL0
6	Maintenance and service	6.1	Daily maintenance	6.1.1	Washing the deck	AL0
				6.1.2	Reading and recording instrument	AL0
				6.1.3	Checking oil level	AL0
		6.2	Service/repair	6.2.1	Determine need for service/repair	AL0
				6.2.2	Ask for service/repair	AL0
				6.2.3	Implement service/repair at quay	AL0

a/a	Operational phase	Id	Task	Id	Subtask	Present Autonomy Level
				6.2.4	Verify the quality of service/repair	AL0
		6.3	Dry-docking	6.3.1	Hull cleaning	AL0
				6.3.2	Engine overhaul	AL0
7	Bunkering	7.1	Order the bunking service	7.1.1	Check the fuel level	AL0
				7.1.2	Notify office	AL0
				7.1.3	Make requisition	AL1
		7.2	Bunkering process	7.2.1	Approach the quay/bunker ship	AL0
				7.2.2	Connect bunkering hose to quay/bunker ship	AL0
				7.2.3	Connect bunkering hose to ship	AL0
				7.2.4	Pump fuel to the diesel tank on ship	AL0
				7.2.5	Verify the amount of fuel transferred	AL0
				7.2.6	Disconnect hose from intake on ship	AL0
				7.2.7	Disconnect hose from quay/bunker ship	AL0

9.2.2. Autonomy levels for short sea shipping use-case

Table 7: Mapping of supply chain activity towards autonomy level for SSS use-case.

a/a	Operational phase	Id	Task	Id	Subtask	Present Autonomy Level
0	Supply chain management	0.1	Development of the whole logistic chain	0.1.1	Production yearly forecasting	AL0
				0.1.2	Long term fleet planning	AL0
				0.1.3	Specification of transport routes	AL0
				0.1.4	Forecasting and transport routes update on monthly basis	AL0
				0.1.5	Receiving order from fish farm	AL1
				0.1.6	Update fish farm order	AL1
				0.1.7	Short term transportation planning and optimisation	AL1
1	Approaching to quay	1.1	Mooring	1.1.1	Manoeuvre to quay	AL0
				1.1.2	Waiting on DP mode	AL2
				1.1.3	Connect mooring	AL0
				1.1.4	Connect to land power	AL0
				1.1.5	Extend gangway	AL0
				1.1.6	Stop thrusters	AL1
				1.1.7	Stop main engine	AL1
2	Loading	2.1	Prepare for loading feed	2.1.1	Release ship silo hatch locks	AL0
				2.1.2	Establish connection to feed control and monitoring system	AL1
				2.1.3	Inform the factory	AL1
				2.1.4	Mirror load list between FCM and factory	AL2
				2.1.5	Check if factory is ready	AL0
				2.1.6	Wait for factory system start up	AL1

a/a	Operational phase	Id	Task	Id	Subtask	Present Autonomy Level
		2.2	Loading feed	2.2.1	Open hatch of the next ship silo	AL0
				2.2.2	Position land crane into silo opening	AL0
				2.2.3	Verify the position	AL0
				2.2.4	Start loading	AL1
				2.2.5	Take a sample of feed from silo	AL0
				2.2.6	Check the amount of feed loaded	AL1
				2.2.7	Move crane out of silo opening	AL0
				2.2.8	Close silo hatch	AL0
		2.3	End loading feed	2.3.1	Check if more silos are to be loaded	AL0
				2.3.2	Move land crane to rest	AL0
				2.3.3	Transfer feed samples to factory personnel on quay	AL0
				2.3.4	Disconnect wireless connection for FCM	AL1
				2.3.5	Lock and secure all silo hatches	AL0
				2.3.6	Apply overpressure to all ship silos	AL1
		2.4	Loading diesel	2.4.1	Connect bunkering hose to quay	AL0
				2.4.2	Connect bunkering hose to ship	AL0
				2.4.3	Pump fuel to the diesel tank on ship	AL0
				2.4.4	Verify the amount of fuel transferred	AL1
				2.4.5	Disconnect hose from intake on ship	AL0

a/a	Operational phase	Id	Task	Id	Subtask	Present Autonomy Level
				2.4.6	Disconnect hose from quay	AL0
		2.5	Loading water	2.5.1	Connect connecting hose to quay	AL0
				2.5.2	Connect connecting hose to ship	AL0
				2.5.3	Pump water to the water tank on ship	AL0
				2.5.4	Verify the amount of water transferred	AL1
				2.5.5	Disconnect hose from intake on ship	AL0
				2.5.6	Disconnect hose from quay	AL0
3	Departing from quay	3.1	Departure from quay	3.1.1	Start main engine and necessary equipment	AL1
				3.1.2	Disconnect from land power	AL0
				3.1.3	Upload sailing plan to EID	AL1
				3.1.4	Remove mooring	AL0
				3.1.5	Manoeuvre out from quay	AL0
4	Sailing	4.1	Sailing	4.1.1	Selecting/updating the selected route	AL0
				4.1.2	Communicating with other ships	AL0
				4.1.3	Situational awareness	AL0
				4.1.4	Following the selected route	AL0
				4.1.5	Avoiding obstacles	AL0
5	Approaching fish farm	5.1	Prepare for unloading feed	5.1.1	Manoeuvre ship into fish farm	AL0
				5.1.2	Establish communication with feed farm personnel	AL0
				5.1.3	Change control mode from manual to dynamic positioning	AL1
				5.1.4	Start bow crane and extend it to offload position	AL0

a/a	Operational phase	Id	Task	Id	Subtask	Present Autonomy Level
				5.1.5	Open feed barge silo hatches using remote control	AL1
6	Offloading	6.1	Unloading feed	6.1.1	Select the location to unload	AL0
				6.1.2	Update FCM which silos to be offloaded	AL1
				6.1.3	Move crane tip into correct feed barge silo	AL0
				6.1.4	Start offloading silo	AL0
				6.1.5	Adjust the crane position	AL0
				6.1.6	Check the unloading conditions (remaining silo's cargo, barge silo's load, planned transferred silo's load)	AL1
				6.1.7	Stop offloading	AL1
				6.1.8	Generate delivery report	AL1
		6.2	Unloading diesel	6.2.1	Connect bunkering hose to feed barge	AL0
				6.2.2	Connect bunkering hose to ship	AL0
				6.2.3	Pump fuel to the diesel tank on ship	AL0
				6.2.4	Verify the amount of fuel transferred	AL0
				6.2.5	Disconnect hose from intake on ship	AL0
				6.2.6	Disconnect hose from feed barge	AL0
		6.3	Unloading water	6.3.1	Connect connecting hose to feed barge	AL0
				6.3.2	Connect connecting hose to ship	AL0

a/a	Operational phase	Id	Task	Id	Subtask	Present Autonomy Level
				6.3.3	Pump water to the water tank on ship	AL0
				6.3.4	Verify the amount of water transferred	AL0
				6.3.5	Disconnect hose from intake on ship	AL0
				6.3.6	Disconnect hose from feed barge	AL0
7	Departure from fish farm	7.1	Departure from fish farm	7.1.1	Change control mode from dynamic positioning to manual	AL1
				7.1.2	Retract bow crane and place it in secure position	AL0
				7.1.3	Manoeuvre away from feed barge and fish farm	AL0
				7.1.4	Close feed barge silo hatches using remote control	AL0
8	Maintenance and service	8.1	Maintenance on ship	8.1.1	Washing the deck	AL0
				8.1.2	Scoping of piping	AL0
				8.1.3	Other	AL0
		8.2	Service/repair	8.2.1	Determine need for service/repair	AL0
				8.2.2	Ask for service/repair	AL0
				8.2.3	Implement service/repair at quay	AL0
				8.2.4	Verify the quality of service/repair	AL0
		8.3	Dry-docking	8.3.1	Hull cleaning	AL0
				8.3.2	Engine overhaul	AL0
9	Bunkering	9.1	Order the bunking service	9.1.1	Check the LNG level	AL1
				9.1.2	Notify office	AL0
				9.1.3	Make requisition	AL0

a/a	Operational phase	Id	Task	Id	Subtask	Present Autonomy Level
		9.2	Bunkering process	9.2.1	Bring LNG container from storage to quay	AL0
				9.2.2	Connect bunkering hose to LNG container	AL0
				9.2.3	Connect bunkering hose to ship	AL0
				9.2.4	Transfer LNG	AL1
				9.2.5	Verify the amount of fuel transferred	AL1
				9.2.6	Disconnect hose from intake on ship	AL0
				9.2.7	Disconnect hose from quay	AL0