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0.4	23/03/2021	Update with stakeholder meeting insights.

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CONTENTS

List of symbols and abbreviations

BM	Business Model
FV	Follower Vessel
FVO	Follower Vessel Owner
IT	Information Technology
IWT	Inland Waterway Transport
kn	Knot or one nautical mile per hour (1.852 km/h)
LV	Leader Vessel
LVO	Leader Vessel Owner
MMMS	MIXMOVE Match Solution
nm	Nautical miles
PI	Performance Indicator
RoRo	Roll on Roll off
TC	Transportation Cost
T/F ratio	Total to full ratio of vessel
TLC	Total Logistic Cost
ToR	Terms of Reference
VO	Vessel Owner
VT	Vessel Train
VTO	Vessel Train owner

1. EXECUTIVE SUMMARY

This deliverable 2.4 tests and benchmarks the VT transport system concept and its developed assessment model from earlier deliverables. The Antwerp case and the integration of the new developed capabilities in the transport model will further determine if the VT is viable from a business economic perspective and establish Stakeholders Community effects and reactions to the VT capabilities. This deliverable starts with revisiting the Terms of Reference with the findings of the previous tasks.

Additionally, the transport model has been updated with the new findings from D.2.3. With the updated model it was possible to develop a benchmark for the VT concept. In this case two BMs as presented in the previous deliverable (D.2.3) are adapted to additional capabilities and compared with the earlier developed Antwerp case study. The Antwerp case is defined with the transport model. The MIXMOVE Match Solution (MMMS) as described in D.2.3 and the WP4 developments are tested and analysed. Furthermore, a short sea shipping case is analysed and developed.

Based on the performed analysis, one main IWT VT application is developed between Turnhout, Antwerp, Rotterdam, Nijmegen and Duisburg. In this case, the investigated Business Model (BM) includes a platform that organizes and manages the VT compositions. Therefore, the costs and revenue of such a platform are taken into account. The extra costs are estimated to be in total €708,000. These costs need to be recovered from the FVs. These costs will be split over the different FVs in the VT and covered by a yearly fee of €9,800 per year. In this case it can be observed that the average savings per vessel per year are equal to €55,000. Furthermore, the cargo owner benefits are positive. Finally, the VT organizer (or platform) has a positive net benefit which equals the profit margin.

From the analysis of the developments of the MMMS, the WP4 developments with respect to new type of cargo handling and the impact of having two crew members on each FV, it can be concluded that the MMMS and the WP4 developments are contributing to a better business economic VT performance. When it is necessary that at least two crew members are present on each FV then the MMMS in combination with the WP4 developments is needed, otherwise the business economic evaluation of the VT is negative.

With respect to the short sea shipping case it can be concluded that the VT is most beneficial for VT users with fast vessels. However, operators of fast vessels need to be flexible to adapt to slower VT operating speeds (3-8kn slower). Nevertheless, the benefits for slower vessels are significantly smaller, as no fuel savings are achieved on top of the crew savings.

The results suggest that mixing different vessel types in the same train is possible, but naturally poses more options for the faster vessels than the smaller ones. It can also be concluded that while the main initial focus of the concept was set on the reduction of the number of crew, a much larger benefit for this concept can be created by effectively adapting the slow-steaming principle in the VT service for the short sea shipping sector.

There are 48 vessels required to establish a viable Short Sea Shipping VT service system between Hamburg and Le Havre. This number makes up less than 1% of the estimated European short sea vessel fleet, which makes an Short Sea Shipping VT feasible.

The main results of the IWT case is presented to the NOVIMAR project partners that are active in the transport sector (PLIM, DUISB, TOUAX and VMG). According to the project plan also a larger stakeholder meeting should be held, but due to the COVID-19 restrictions this was not possible. From the preliminary review it could be concluded that no major changes are needed in the transport model. A larger stakeholder meeting will be held at a later stage and the validation will be finalized (task 2.4.5) when the COVID-19 restrictions are softened.

1.1 Problem definition

The vessel train (VT) could become a new waterborne transport system, which should fit into the current and well-developed system. To cite the objectives of the Project, the '*Project NOVIMAR strategic aim is to adjust the waterborne transportation such that it can make optimal use of the existing short sea and inland waterways and vessels, while benefitting from a new system of waterborne transport operations that will expand the entire waterborne transport chain up and into the urban environment.*'

The developed BM of the VT concept determines how value can be created for the operators, users and cargo owners. A number of operational issues were already identified in D.2.3 and are now further explored and compared to a baseline scenario.

1.2 Technical approach and work plan

There are three objectives in this deliverable. The first objective is to adapt the developed transport model from task 2.2 which assessed the business economic potential of the vessel train (VT) concept, with the elaborated solutions from task 2.3. Another objective is to benchmark the VT performance in regard to the Antwerp case study and test it in the Antwerp port area together with the findings concerning cargo consolidation port capabilities from task 2.3. The final objective is to establish Stakeholders Community effects and reactions to the capabilities of the VT.

The first step to reach these objectives is to review the Terms of Reference (ToR) from sub-task 2.2.1 and add the vessel train capabilities as developed in task 2.3. The next step is to adjust the model with the mentioned capabilities of the VT concept. In a third step the modified or adapted transport model will be activated with the same conditions, assumptions and cargo flow data of the Antwerp case study. The following step includes the result analysis while including stakeholders effects and reactions to determine requirements for further modification of the VT transport system concept as described in task 2.3.

1.3 Results

This deliverable benchmarks the VT concept and transport business model for task 2.4 in WP2 of the NOVIMAR project. The two BMs as presented in the previous deliverable are adapted to additional capabilities and compared with the earlier developed Antwerp case study.

1.4 Conclusions and recommendation

This deliverable benchmarks the VT concept with the transport model which is further finalized in task .2.4 in WP2 of the NOVIMAR project. The two BMs as presented in the previous deliverable (D.2.3) are adapted to additional capabilities and compared with the earlier developed Antwerp case study. With the transport model the Antwerp case is defined and the MMMS and the WP4 developments are tested and analysed. Next to that also a short sea shipping case is analysed and developed.

IWT conclusions

Based on the performed analysis one main IWT VT application is developed: Turnhout, Antwerp, Rotterdam, Nijmegen, Duisburg. For this VT application two business models are investigated. The first one if the BM in which all the vessels are owned by one owner. This actor is also the one that is the VTO. The other BM that is investigated is the one where there is a platform that will organize and manage the compositions of the VT, therefore we have to take the cost and a profit of such a platform into account. As explained previously, the extra cost is estimated €708,000 which needs to be recovered from the FVs and split over the different FVs in the VT through a yearly fee of €9,800 per year.

From this case we can observe that the average benefits for the VO for all the considered segments are lower than in the case there is no platform that links the different FV to the LV. The average annual savings per vessel equal as pointed out to €55,000. Furthermore, the cargo owner benefits are lower, but still positive. Also the VT organizer (platform) has a positive net benefit, which is equal to the profit margin.

In estimating the cost for setting up such a platform a conservative approach is used (i.e. expensive subscription fee). So it can be concluded that it is possible to also organize this VT constellation with a platform BM. Also this type of VT is more applicable as there are many small inland shipping companies in the IWT sector. It would also be good if the platform could also offer a freight booking service. There are online application available such as 4Shipping[1] or Bargelink[2] which could offer this type of service.

From the analysis of the developments of the MMMS, the WP4 developments with respect to new type of cargo handling and the impact of having two crew members on each FV, it is concluded that the MMMS application and the WP4 developments contribute to a better business economic VT performance(if all FVs need to have two crew members, the MMMS is needed in combination with the WP4 developments).

Short sea shipping conclusions

With respect to the short sea shipping case it can be concluded that the VT is most beneficial for VT users with fast vessels. However, operators of fast vessels need to be flexible to adapt to slower VT operating speeds (3-8kn slower). Smaller vessels that use the VT, do not need to be as flexible, as their vessels operate in their intended environment. Nevertheless, the benefits for slower vessels are significantly smaller, as no fuel savings are achieved on top of the crew savings.

Furthermore, the route lengths restrictions are larger for the slower vessels. It is most beneficial to use the VT services for longer routes because waiting times have a smaller impact on productivity. Even though the slower operating speeds may cause a productivity drop for the faster vessels, the

[1] https://www.4shipping.com/en/
[2] http://direct.bargelink.com/

fuel savings outweigh any other operating cost created while waiting for the VT. For this case study it was shown that, when no monitoring crew is needed, all assessed vessel types have viable conditions for a distance of 500 nm.

The results suggest that mixing different vessel types in the same train is possible, but naturally poses more options for the faster vessels than the smaller ones. It can also be concluded that while the main initial focus of the concept was set on the reduction of the number of crew, a much larger benefit for this concept can be created by effectively adapting the slow-steaming principle in the VT service for the short sea shipping sector.

The required number of vessels needed to establish a viable VT service system between Hamburg and Le Havre are 48 vessels. This number makes up less than 1% of estimated European short sea vessel fleet.

2 INTRODUCTION

2.1 Task/Sub-tasks

The main task objectives are:

- To adapt the model from task 2.2, to include the VT capabilities as designed in task 2.3
- To benchmark the VT performance with respect to the Antwerp case study
- To establish Stakeholders Community effects and reactions to the VT capabilities

Envisaged activities are:

- Sub-task 2.4.1: Revising the ToR for the multi-modal transport model from sub-task 2.2.1 to include the VT capabilities developed in task 2.3.
- Sub-task 2.4.2: Adjusting the model developed in task 2.2 to reflect the capabilities of the VT concept which were developed during task 2.3 in accordance with the revised ToR from sub-task 2.4.1.
- Sub-task 2.4.3: Activating the newly adapted model by applying the same conditions, assumptions and cargo flow data of the Antwerp case study from task 2.2.
- Sub-task 2.4.4: Analysing the results, including stakeholders effects and their reactions, and determine requirements for modification of the VT transport system concept from task 2.3.
- Sub-task 2.4.5: Modifying (if needed) the VT transport model which is repeated during activities under sub-tasks 2.4.3 and 2.4.4.
- Sub-task 2.4.6: Prepare the task deliverable.

2.2 Analysis

The NOVIMAR project researches the VT concept which is a waterborne platooning concept featuring a manned lead ship and a number of follower ships that follow at close distance under automatic control. Deliverable 2.2 includes the main outline of this concept and deliverable 2.3 presents the operational aspects of the VT which have been developed, along with a method for cargo consolidation which could improve the VT efficiency. In this deliverable the developed cargo consolidation capabilities are now included in the transport model as developed in task 2.2 and benchmarked against the Antwerp case study.

2.3 Approach

Task 2.4 is the fourth task under Work Package (WP) 2 'Transport system model'. It started in month twenty five of the project and runs until month thirty-six. The deliverable is due end of month thirty-six. The basic work consists of desk research and modelling. The work was distributed according to the sub-tasks to different partners. The output of this deliverable will be included and compared with the second case study of the VT in task 2.5.

3 PLAN

The main objective of this deliverable is to develop a first application of the VT concept in the Antwerp case study area.

3.1 Objectives

This deliverable has three main objectives:

- Revising the ToR for the developed model from sub-task 2.2.1 to include the vessel train capabilities as developed in task 2.3 and to adjust the model accordingly.
- Activating/using the adjusted model and develop a new set of results of the VT.
- Present the developed results from the adjusted NOVIMAR transport model to determine the stakeholders effects and reactions, and determine possible requirements for further modification of the VT transport system concept from task 2.3.

3.2 Planned activities

The planned activities of this deliverable are:

- Sub-task 2.4.1: Revising the ToR for the multi-modal transport model from sub-task 2.2.1 with the vessel train capabilities as developed in task 2.3.
- Sub-task 2.4.2: Adjusting the model developed in task 2.2 to reflect the capabilities of the vessel train concept that was developed in task 2.3 in accordance with the ToR from sub-task 2.4.1.
- Sub-task 2.4.3: Activating the newly adapted model by applying the same conditions, assumptions and cargo flow data of the Antwerp case study from task 2.2.
- Sub-task 2.4.4: Analysing the results, including stakeholders effects and reactions, and determine requirements for modification of the VT transport system concept from task 2.3.
- Sub-task 2.4.5: Modification when needed of the VT transport model which is repeated during activities under 2.4.3 and 2.4.4.
- Sub-task 2.4.6: Preparing the task deliverable.

3.3 Resources and involved partners

The distribution of the activities among the project partners in task T2.4 is the following:

UANTW (leader) will review the ToR, adjust the model, prepare the input data, run the model and analyse/present the results (workshop) to the Stakeholders Community with assistance from TUD.

VML, MARLO, PLIMS, TRB, DST and DUISP give support in analysing the results and in modifying the transport model.

3.4 Timeline

According to the Description of Action (DoA), Task 2.4 starts at month twenty-five and ends with deliverable 2.4 at month thirty-six. The development of the content of the first version of this deliverable was finished at project month thirty-six.

4 PLAN EXECUTION

4.1 Introduction

In this section, the short description of the performed activities of deliverable 2.4 are given together with factual deviations of the originally planned activities.

4.2 Performed activities

In order to develop the content of the first part of deliverable 2.4 the needed adjustments to the transport model and their reasons are explained. Secondly, the actual model has been adapted and updated.

Sub-task 2.4.1

During the first sub-task it is determined how the transport model should be adjusted using what is developed in D2.3, i.e. the VT BMs and the cargo consolidation capability, and what is developed in D4.3, i.e. new cargo systems. The main adjustments are the inclusion of new BMs, the cargo consolidation model of D.2.3, and the calculation of the financial net benefits of the private actors involved in the VT concept, which are the VO, VTO, and CO.

Sub-task 2.4.2

In this sub task the initial model was adapted to the needs to analyse the VT. The model is adapted by making use the ToR reference developed in task 2.4.1.

Sub-task 2.4.3

In this sub tasks the main calculations are done where the NOVIMAR transport model is used. Based on these calculations the first main VT for the Antwerp case is designed. Also other NOVIMAR developments are being tested (WP4 applications, MMMS and the impact of minimum crew levels on the FV).

Sub-task 2.4.4

In sub task 2.4.4 the stakeholder responses are determined for the developed Antwerp case. These responses are based on the feedback given by the NOVIMAR partners. The following NOVIMAR partners are asked to provide feedback: Plimsol, Touax, Van Moer & Duisburg port. Each partner was asked to provide feedback on the developed case. This feedback was asked in the form of a SWOT analysis. Next to that also an online digital stakeholder meeting was organized.

Sub-task 2.4.5

Based on the first results we found no major issues where we had to make changes in the WP2 VT transport model.

Sub-task 2.4.6

In this sub-task, the project deliverable will be developed.

4.3 Deviations from the plan

The main deviation from the work plan is that a physical meeting and a large stakeholder meeting was not able to be held due to the limitations imposed by the different European governments to deal with the corona virus. This main stakeholder meeting was held later then initial foreseen.

5 RESULTS

5.1 Introduction

In this chapter the main results are given from the various performed activities in the six sub-tasks as described in section 3 and 4.2. The sub-tasks are structured according to the three explained objectives of this deliverable.

5.2 Development of the ToR for the multi-modal transport model (T.2.4.1)

The aim of this section is to ‘’review the ToR for the multi-modal transport model from sub-task 2.2 to include the vessel train capabilities previously developed during task 2.3.’’ After this review, changes of the transport model are presented as developed during task 2.3, i.e. the VT Business Models (BMs) and the cargo consolidation capability.

The following part describes the evolution of BMs (BMs) throughout the NOVIMAR project and how the transport model is adjusted by these BMs.

5.2.1 The evolution of the BMs throughout the NOVIMAR project

Hoyer et al. (2017) as mentioned in deliverable 2.1, refer to the importance of ‘business concepts’ for the VT and explain three types:

1) a tramp, which is a strongly varying and opportunity-driven composition;
2) a liner, in which there is often a same/similar combination of LVs and FVs and
3) a 'coupled' unit, in which there is a fixed combination of LVs and FVs.

van Hassel et al. (2018) further developed these business concepts, thus coming up with the following three ‘BMs as they are called in Deliverable 2.2. The first BM is a Third-Party Service Company , in which the VT operates as a liner with an LV, which transports either cargo or is only a dedicated leader, and with the owner of the vessel train (VTO) as an intermediary third party logistics service provider (3PLS) who is not a part of a large shipping company. The second BM is the Dedicated Shipping Company, in which the VT also operates as a liner, with again either a dedicated or cargo LV. The difference here lies with the 3PLS. In this BM the VTO is a large shipping company and not an independent party. In the dedicated shipping company , one shipping company owns all the vessels that compose the VT. The third BM is the ‘Uber’type. In this BM, the VT will provide tramp services, with a cargo LV and a 3PLS VTO.

Hekkenberg et al. (2019) used the BMs from van Hassel et al. (2018) as a basis for the VT concept. Thus, by using the three BMs and conducting a literature review about BMs in other transport modes (such as road, air and rail) fourth BMs were developed (Hekkenberg et al.,2019). The initial development of these BMs took place during an internal workshop in Duisburg. As a next step, these BMs were validated via interviews with 13 stakeholders (VOs of both IWT & Short Sea Shipping, freight brokers, intermodal logistics service providers, freight forwarders and waterway authorities). This validation process showed which BMs were close enough to reality to be selected and applied.

The newly developed BM1 is based on the previously developed BM of the Third-Party Service Company of van Hassel et al. (2018), with the difference that the BM1 is not operating with either a dedicated or cargo LV but only with a dedicated LV which provides a liner service. The VTO in BM1 is a shipping company that owns the LV. In other words, the VTO is the LVO and the VTO is paid by the FVs for the service that the VTO provides for organizing and operating the VT. The VTO fee is calculated based on the costs of the LV divided by the number of the FVs and on top of that a mark-up is added. Thus the LV does not only recover its costs but also makes profit from being the VTO.

The second newly developed business model (BM2) is also linked with the BM of the Third-Party Service Company, but with the difference that in BM2 the VT provides a tramp service, using a cargo LV while the VTO is paid by the FVs with a fixed lump sum.

The newly developed BM3 is linked to the previously developed BM of the dedicated shipping company. In this BM only one single shipping company owns the whole fleet in the VT and provides a liner service using a dedicated LV. There is no VTO fee in this BM because the VTO/LV and the FVs belong to the same shipping company and thus the fee that would be paid to the VTO otherwise, is considered as an internal cost for the shipping company. The difference between the new and old version of the BM3 is that new BM3 operates with a dedicated LV, while the older version of the dedicated shipping company could operate with either a dedicated or cargo LV.

The reasons why in these new versions of BMs dedicated LVs were assigned to do liner services and cargo LVs to do tramp services are the following:

- For liner services, the logistics factor of 'reliability' is very important. The VT that provides liner service needs to be reliable and thus always be on time at the requested port destination. Lead times need to be guaranteed and thus delays should be avoided. Having a dedicated LV reduces the waiting times that would be created from a cargo LV that needs to (un)load and for which the FVs need to wait. Thus, the transport time of the whole VT increases.
- Assigning cargo LVs instead of dedicated LVs for the tramp services is important for the financial economic viability of the concept. Imagine that a dedicated LV sails around to load cargo at short notice to be transported from a port to another port. This means that there would be only operational costs for the dedicated LV and no financial benefits from transporting cargo, because the dedicated vessel only leads the FVs and does not carry cargo. While the cargo LV can also transport cargo and receives benefits.
- Reliability and lead time are less important in a tramp service.

The last BM (BM4) is linked to the previously developed 'Uber' BM, with the difference that in the BM4, the VTO is a virtual service. The payment has to be made by the FVs to the VTO/virtual service with a fixed lump sum. In table 1 the main elements of the four newly developed BMs are presented (for detailed information about the four BMs, see D2.3).

Table 1: An overview of the developed BMs

	Liner		Tramp	
BMs	**BM1**	**BM3**	**BM2**	**BM4**
VTO	VTO=LVO VTO = shipping company owns LV.	VTO=LVO VTO = large shipping company owns VT fleet.	VTO=LVO VTO = shipping company LV.	VTO = a virtual service. VTO does not own vessels.
Charging scheme for FVs to pay to VTO/LVO	Cost plus mark-up	No fee paid to VTO by FVs (internal cost for VTO)	Fixed lump sum	Fixed lump sum

Source: Authors' composition based on Hekkenberg et al. (2019)

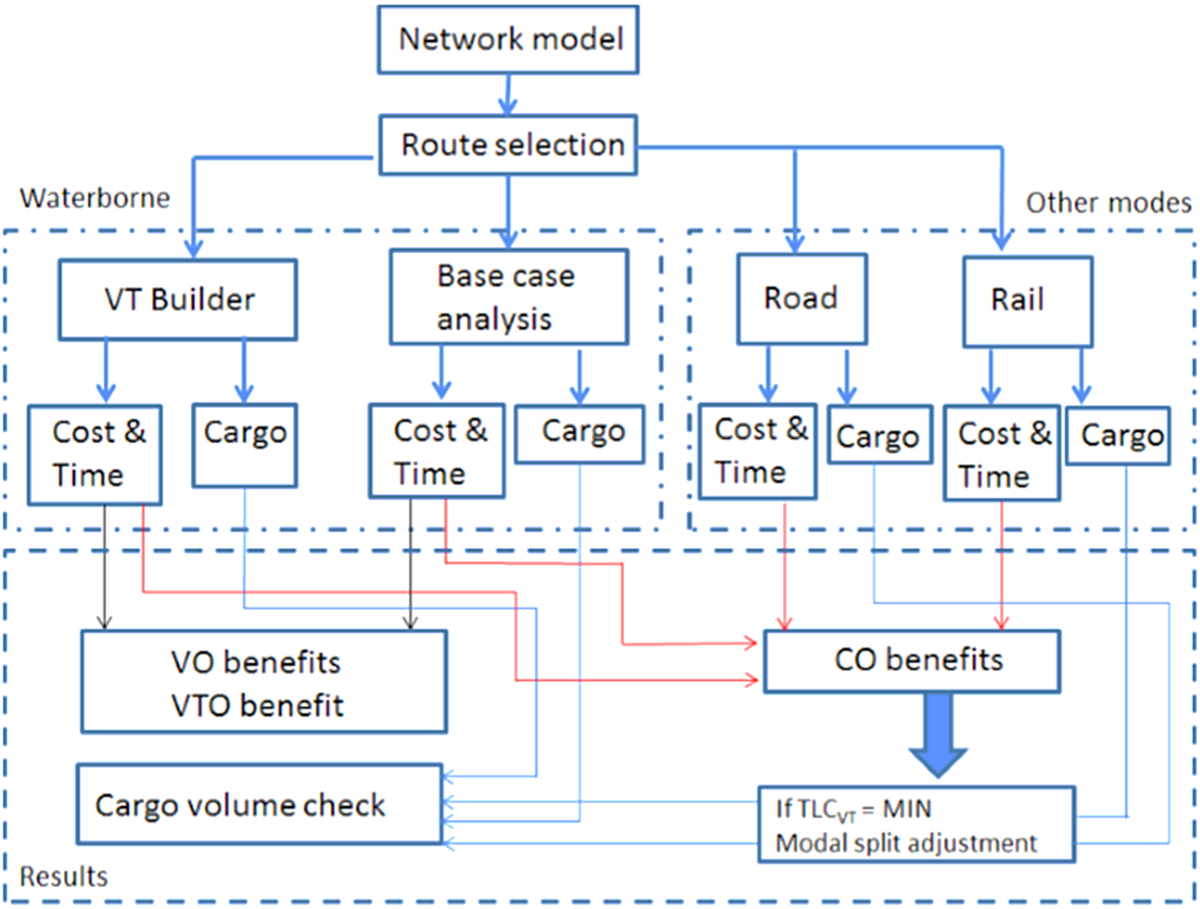
The validation process of the above four BMs via interviews showed that two BMs are the closest to reality. In general, the interviewed VOs believe that the BM3 is the best BM, in which one company owns the whole fleet in the VT. BM3 is followed by BM2 and BM4. The latter was considered to be the worst solution. However, logistic service providers believe that BM4 is in fact the best BM, since it brings an additional innovative technological aspect, from which the waterborne transport sector can benefit. Finally, the scores given to the other BMs were varying; i.e. others consider BM1/BM2 as the 'worst' BMs and others BM3. *''This implies that vessel owners opt for the BM in which they have full control of the VT. While the service providers opt for a more modern type of business model in which there is no direct control of a single large player, but a platform''* (Hekkenberg et al. (2019a).

The results of this validation process show that at least BM3 and BM4 need to be included in the transport model. This does not mean necessarily that the other two BMs, i.e. BM1 and BM2 are excluded from being incorporated in the model.

5.2.2 Adjusting the transport model to reflect BMs, capabilities and new cargo systems

The aim of this task and section is to incorporate the BMs (as developed in D2.2), cargo consolidation capability of the VT concept (as developed in D2.3) and new cargo systems (from task 4.3) into the existing transport model shown in Figure 1, and to identify what the impact of this inclusions will be on the transport model.

Figure 1: Overview of the initial transport model[3]



Source: van Hassel et al. (2018)

5.2.2.1 Developed business models and their attributes

van Hassel et al. (2018) state that the type of BMs is set by the VT Builder in the transport model. The developed BMs have the following main attributes:

- type of the VTO (who is the VTO?);
- type of the LV (dedicated or cargo?)
- type of operation/service (liner or tramp?).

The additional ''new'' attributes of the BMs which are noted in D2.3 among the three above characteristics, relate to the charging schemes between the VTO and the FVOs, which include either the cost plus mark-up or a fixed lump sum. Therefore, the VT Builder or in other words the VTO is in charge of building the VT (i.e. composing the VT by bringing together the FVs and the LV) and deciding which of the above four BM attributes will be selected each time when composing a VT.

[3] before incorporating the BMs and cargo consolidation capabilities developed in D2.3

An overview of these BM attributes are presented in Table 2 which shows the three BM attributes that are incorporated in the model. The only one of the four BM attributes that is ‘not directly inserted’ in the model is the ‘type of the VTO’. It is not directly inserted because the type of the VTO, which is a qualitative attribute, is indirectly taken into consideration via the BM attribute 1 which is the charging scheme between the VTO and the FVOs.

Although, for BM2 and BM4 the charging scheme type is the same, i.e. fixed lump sum, the way of calculating the lump sum for BM4 will differ from the way of calculating the lump sum for BM2 (which will be presented in the following sections). This is because of the different type of the VTO. In BM2, the VTO is also the LVO (of a cargo LV). Therefore, the VTO receives this fee to cover the costs of operating the LV which leads the FVs (although part of these operational costs will be covered by transporting own cargo) with some profit.

The VTO in BM4 is a digital platform, i.e. a virtual service that makes use of an application for organizing the VT. Therefore, the lump sum in this case will be a fee like a ‘subscription’ fee to allow actors make use of it. This virtual service might be cheaper because it is provided by a platform and thus it could possibly require less labor costs than conventional services. However, the LV does not remain unpaid. The LV takes a fee for providing the service of leading the VT (without organizing it like in the other BMs). The extra fee that needs to be paid to the LV results from the following facts:

1) the LV has full crew[4] on board and thus cannot benefit from the reduced crew on board as the FVs do and
2) the LV needs to do a longer trip than the FVs for reaching one or a few ports. However, this fee to the LVO is not expected to be high, since the LV is a cargo LV and part of its costs is recovered by the transportation of cargo (similarly with BM2, but without paying this time the LVO for organizing the VT but paying the digital platform for that).

Therefore, indirectly, the type of the VTO is also incorporated in the model. Directly the BM attributes that can be quantified and used as input to the calculations are incorporated.

For the BM1, *‘’VTO charges the FVs for the service provided which is based on how long a FV stays in the VT & by knowing the operation costs of the LV divided with the number of FVs plus the mark-up’’* (Hekkenberg et al., 2019; D2.3). PI2 is used here as well.

For the BM3, for which no fee is paid by the FVs to the LV, since one company owns all the fleet, the PI1 is used. The only difference between PI1 and PI2 is that PI1 does not include the fee to be paid to the VTO/LVOs because the VTO in this case is a big shipping company that owns all the vessels in the VT (for more information about the PIs, see D2.1 and D2.2). The impact of this BM attribute on the transport model and thus its importance is the following. This BM attribute has an impact to the benefits of the LVOs/VTOs (BM1, BM2, BM4) and costs of the FVOs and COs.

[4] It might be needed that an ADN certificate could be needed for the LV boatmaster when dangerous goods are onboard of a FV.

A new actor is added now in the VT concept in the supply chain, being the VTO and/or LVO, thus increasing the transportation costs for the FVOs and COs. However, these extra costs are compensated by the financial economic benefits of the VT concept being:

1) less crew and alternative sailing regime (sailing in B regime with an A1 crew) on board for the FVs, thus less crew costs;
2) reduced total transport time thanks to high frequency of transport liner services (the waiting time for a lead vessel), cargo consolidation capability of the VT (pre-sorting of cargo at the port of origin; see section 1.2), thus vessels need to stop only at one or a few terminals instead of all (less waiting times at the terminals of ports) and new cargo systems that contribute to *"improved flow of cargo (containers, trailers and other wheeled cargo) through the terminals"* together with faster cargo handling (Ramne and Fagerlund, 2019; see D4.3).
3) efficiency of the vessels in the VT thanks to longer operational hours (because FV crew does not navigate, only other tasks such as maintenance, emergency situations, (un)mooring…) Thus during the resting hours of the crew, the ship does not anchor but keeps sailing;
4) more cargo units loaded on vessels as result of the cargo consolidation capability of the VT (D2.3 and in the section 1.2 below) and as a result of the improved RoRo cargo systems that will improve cargo density on-board compared to other existing RoRo vessels (D4.3).

The second BM attribute that needs to be included in the transport model is the 'type of service', i.e. a liner or tramp service. Thus, the VT builder selects the BM, and according to that specific selected BM, the VTO , the respective charging scheme and the type of service of the VT are determined.

If the BM includes a liner service that is used for transporting cargo from one port to another (fixed schedules and ports to which cargo is transported), this attribute is inserted in the model by the frequency of transport services.

Frequency of departures is important for the VT concept and is related to the calculation of the 'cargo volume check' and the 'modal split adjustment'. The frequency of transport services depends on the transport volume of the VT and the number and sizes of the FVs and the LV (if the LV is a cargo LV) whereas the frequency of departures equals here the annual cargo volume divided by VT cargo capacity. Before this calculation is made in the model, it needs to be ensured that the VT cargo volume is less than the maximum available cargo volume on a certain transport link (van Hassel et al., 2019; D2.2). This is the 'cargo volume check' and is calculated by dividing the VT cargo capacity by the new waterborne market cargo volume.

The frequency and composition of the VTs will depend on the VT cargo volume/new waterborne market cargo volume. We refer to ''new'' cargo volume for the VT because if the expected TLCs of the VT are lower than the ones of the current situation, then the waterborne transport is expected to gain modal share and thus the VT cargo volume needs to be adjusted, i.e. being higher than the cargo volume of the current situation. This increase of modal share in favour of the waterborne market will also increase the frequency of the transport services (and vice versa). The PI3 (TLC) is used for the calculation of the total logistics costs. High frequency of transport service means less waiting time.

Less waiting time means less total transportation time (lead time) and less lead time means less in transit inventory cost and safety stock cost for the CO. As a result, the TLC decreases.

For the tramp service, frequency of transport services is of less importance, in the sense that tramp service is a service that is demand-based and thus the frequency of the service depends on the demand. For examining the tramp service in the model, different frequencies of transport services will be examined to find which of them give the highest business economic benefits.

As a result by selecting a liner or tramp service, the VT builder needs to select the appropriate types of vessels for operating in these services which are RoRo and feeder vessels for the liner and coasters for the tramp service. The design speed of RoRo and feeder vessels is relatively higher because they are bound to a schedule and they need to be on time to their destination, in contrast to other vessels, providing tramp services, such as coasters (respectively for the sea-river and inland waterway market). This is important because the VT is composed out of vessels of similar operating speed, with the operating speed of the whole VT being equal to the speed of the slowest vessel in the VT. The impact of this BM attribute to the model is the following: High frequency of departures will have an impact on the reliability of the waterborne transport service and on guaranteeing lead times. On the contrary, for demand-based frequency (tramp service), reliability and lead time are less important, while flexibility is its main advantage (i.e. transporting cargo without the ‘restriction’ of fixed time schedules). These parameters will impact the TLCs (PI3).

The third BM attribute to be included in the transport model is the type of LV, being either dedicated or cargo. A dedicated LV has no cargo carrying capacity and only leads the FVs. A dedicated LV needs to be built accordingly. Thus, an investment for building a dedicated LV is needed, which will increase the out-of-pocket costs of the VOs and create an extra cost that would not be needed in the current situation. Additionally, the investment for the IT equipment of the VT also needs to be made.

For the cargo LV, an existing vessel can be used. In this case, no investment is needed for a newly-built vessel. For a cargo LV, the only investment cost needed is for IT equipment of the VT, which is equal to roughly 40,000 euro[5].

A dedicated LV will have a twofold impact to the model; firstly, to the investments costs and thus to the PI1, PI2 and PI3 and secondly to the waiting time and as result to the transportation time, thus affecting mostly the TLCs (PI3) (but also PI1, PI2). There is less waiting time because the FVs do not need to wait for the LV to (un)load; in contrast with the cargo LV for which this is the case[6]. Although waiting times increase for a cargo LV, investment costs are considerably lower, since an existing vessel can be used by installing IT equipment of the VT. Also, the cargo LV is more economic viable because part of its costs as a LV are recovered by transporting cargo itself.

[5] The investment cost of the equipment is estimated based on expert insights from WP3 and WP4.

[6] In this case it was not consired that the LV doesn‘t switch underway as a business option.

Table 2: BM attributes to be incorporated in the transport model

BMs / Attribute	BM1	BM2	BM3	BM4	Inclusion of attribute	Impact on model
Type of LV	Dedicated or cargo	Cargo	Dedicated or cargo	Cargo	Dedicated: increased investment due to newly built vessel (plus VT IT equipment) Cargo: no investment needed, existing vessel is used (only VT IT equipment) PI1, PI2, PI3	Dedicated: less waiting times but newly built vessel. Cargo: more waiting time because cargo LV must (un)load. Low investment cost: VT IT equipment on existing vessel. More economic viable because part LV costs covered by transporting cargo.
Charging scheme between VTO& FVOs	Cost plus mark up	Fixed lump sum	None	Fixed lump sum Extra fee for LVO as well	**PI2 (BM1, BM2, BM4)** **PI1 (BM3)**	Benefits for VTO & LVO for BM1 & BM2). Costs for FVOs. Costs for Cargo Owners. new actor = VTO, transportation costs increase for VOs & cargo Owners Extra costs are expected to be compensated by VT benefits)
Type of service	Liner	Tramp	Liner	Tramp	Frequency of departures <u>Liner:</u> dividing annual cargo by VT cargo volume <u>Tramp:</u> testing different frequencies to find the one with highest benefits. Liner: RoRo & feeder vessels Tramp: coasters PI3 (TLC)	<u>Liner:</u> high frequency of departures is critical for improving reliability of IWT and guaranteeing lead times. <u>Tramp:</u> demand-based frequency. Reliability and lead time are less important. Flexibility is main advantage (i.e. cargo IWT without ‘restriction’ of fixed time schedules). These parameters will impact the TLCs (PI3).

Source: Authors’ composition

5.2.2.2 Pre-sorting Cargo consolidation capability

The cargo consolidation capability (as it is called in D2.3) or the pre-sorting of cargo capability (as it is referred to in D2.2), which starting from now (D2.4), will be used interchangeably, is a new capability that is under development in order to allow the consolidation of all cargo in one vessel or of all other cargo units in containers that have to be transported to the same discharge port.

This capability of pre-sorting/consolidating the cargo going to the same discharge terminal in the discharge port into one vessel leads to less waiting times because the vessel does not need to stop at multiple terminals. Reducing waiting time is the main working principle/benefit of the cargo consolidation capability. Another benefit is the increased effectiveness of the VT concept. During the pre-sorting, it could be that the cargo will need to wait at the port terminal (loading port) or intermediate storage, until a vessel is 'enough' filled to depart. When vessels depart (almost) fully loaded, more volume is transported and the cost per transported cargo unit decreases, profiting from the economies of scale (see Table 3 below).

This capability is introduced in D2.2 as a 'newer updated version' of the regular liner services that are currently provided. When using the regular liner service, a vessel needs to call at ''all'' ports. This increases waiting time. When using the 'new' liner service, the vessel in the VT does not need to call all ports but only at one. All cargo goes to the same discharge port which reduces waiting times.

The cargo consolidation capability will be incorporated into the transport model. Taking into consideration that this capability is a 'new' liner service that is provided by VTs, it will be incorporated under the VT builder (Figure 1) and under the selected BM. One of the main BM attributes that need to be specified and inserted as input into the transport model is the type of service that the VT will provide, being other liner or tramp (see Table 2). Therefore, when the liner service is selected, there will be also an option for selecting either the 'regular' liner service or the 'new' VT liner service. This choice will be made by the cargo owner (consignor) and consignee, who should inform the VTO with respect to their choice. By selecting this 'newer' liner service, some cargo might need to wait and stored at the port terminal (intermediate storage), until there is enough cargo that fills a vessel of the VT (or containers) for the same discharge port. This means that some cargo might be late to be delivered. This should also be taken into account as one of the ''costs'' of the cargo consolidation capability. Another cost is the fee that needs to be paid to the actor that does the pre-sorting of cargo at the loading port (e.g., NOVIMAR partner MARLO Consultants using its planning tool).

The mentioned benefits and costs of the cargo consolidation capability will affect the three PIs of the transport model, but mostly the PI3. More particularly, there will be an impact on PI1 and PI2 because of the reduced lead time. If waiting times are reduced at the port terminals, the lead time will be reduced as well and thus the out-of-pocket costs of the VOs will also reduce. There will be an impact on the PI3 (TLCs), since the TCs and the average lead time will decrease, together with the variance of lead time, and therefore the reliability of the VT concept. Finally the safety stock cost and in-transit inventory stock will decrease. All these parameters will lead to lower TLCs thanks to pre-sorting cargo capability at the port of loading. Lower TLCs can attract more cargo and thus a potential modal shift towards IWT. Therefore, this capability of pre-sorting cargo focuses mostly on the benefits of the cargo owner (Figure 1) As a consequence, social benefits are expected because of the potential of modal shift. These benefits are examined in WP1.

Table 3: Cargo consolidation capability to be incorporated in transport model

Cargo consolidation capability	Way of inclusion of cargo consolidation capability in the model	Impact to/importance for the model
	PI1 **PI2** **PI3 (mostly)**	Benefits for the VOs &mostly for the cargo owners: Reduced waiting times Increased effectiveness of VT vessels (FVs & cargo LVs) A new actor is added now in the supply chain, being the actor that will be in charge of consolidating the cargo at the loading port. Thus, there will be an extra fee that the cargo owners need to pay apart from the fee that they would pay to the VOS, being the fee that is paid to the actor that is doing the pre-sorting of cargo. These costs (fee) cannot be higher than the difference of the TLCs of the VT regular liner service minus the TLCs of the VT new liner service: $TLCs_{VT} – (TLCs_{VT\ pre\text{-}sorting\ cargo} + fee_{cargo\ pre\text{-}sorting} > 0$
		Affecting the BM attribute 1 of the ‘cost plus mark-up’ to be paid by the FVOs to LVO/VTO. ‘Cost plus mark-up’ is expected to be reduced.
		Route selection (see Figure 1) will also be modified thanks to the cargo consolidation capability, the vessels of the VT will not call at ‘’all’’ ports but the same discharge port.

Source: Authors’ composition

What needs to be ensured is that the TLCs for the cargo owner when using the VT are lower than the TLCs of the baseline (current situation) and that the TLCs of the new liner VT service are less than the TLCs of the regular liner VT service[7]. On top of that, it needs to be ensured that the fee that should be paid by the cargo owners to the actor that will be in charge of the pre-sorting of cargo, will not be

[7] new liner service is the service with inclusion of the cargo consolidation and the regular liner is without the cargo consolidation

higher than the difference $TLCs_{VT}$ - $TLCs_{VT\ pre\text{-}sorting\ cargo}$. If not, there will be no financial benefit for the cargo owners to make use of the new liner VT service.

The following conditions need to be fulfilled:

$$TLCs_{baseline} - TLCs_{VT\ regular\ liner} > 0$$

$$TLCs_{VT\ regular\ liner} - TLCs_{VT\ pre\text{-}sorting\ cargo} > 0$$

$$TLCs_{VT} - (TLCs_{VT\ pre\text{-}sorting\ cargo} + fee_{pre\text{-}sorting\ cargo}) > 0$$

The following income streams among the VT actors will help us understand the above boundary conditions:

1. FVs pay the VTO/LV (payment to the 'VT management', see Figure 6 in D2.3).
2. Cargo owners pay FVs (regular VT liner service).
3. Cargo owners pay FVs (new VT liner service with cargo consolidation). This payment is expected to be lower than the one of the regular services, since the transportation time will be less, and the vessel will be used more effectively (filled as much as possible).
4. Cargo owners pay the actor that will be in charge of pre-sorting the cargo at the loading port (payment to the 'Port of loading management', Figure 6, D2.3).

Therefore, the ''bill'' that needs to be paid by the cargo owners to the VOs to transport their cargo to the desired port destination is expected to be lower when using the VT new liner service.

The cargo consolidation capability will also have an impact to the BM attribute no.1 of the 'cost plus mark-up' as presented in Table 2. The reason behind the latter, is situated in the calculation of the fee ('cost plus mark-up') that has to be paid by the FVOs to the LVO/VTO. For this calculation the time when the FV stayed in the VT, should be taken into consideration. Therefore, since the cargo consolidation capability will reduce waiting times and thus the total transport time, also the fee for the LVs/VTOs will decrease.

'Route selection' (see Figure 1) will be modified because of the cargo consolidation capability. The vessels of the VT will not call at ''all'' ports but at one same discharge port which causes the modified route selection.

To sum up, the cargo consolidation capability has two benefits, i.e. reducing waiting time due to calling to one/less ports and improving the effectiveness of the vessels, and two costs, the fee that needs to be paid to the actor that will do the pre-sorting of cargo at the loading port and the waiting time when some of the cargo might need to wait until the vessel is fully loaded. Both costs and benefits that are incorporated in the transport model have an impact on the cargo owner benefits and the respective TLCs (PI3). The aim is to examine the three scenarios respectively: one scenario in which the TLCs of the baseline will be calculated (current situation), one scenario in which the TLCs of the VT situation using the regular liner service will be calculated, and one scenario in which the TLCs of the VT using the new liner service will be calculated and compare these results for different VT compositions to conclude how beneficial the new liner service is from a financial economic perspective. This will bring more benefits to the cargo owners and as a result also generate a potential modal shift, thanks to the reduced TLCs. Thus bringing societal/environmental benefits that are examined in WP1.

5.2.2.3 **New cargo systems of the VT concept**

The task 4.3 'Cargo systems development' focuses on finding technical solutions for improving the cargo systems to increase IWT. The two suggested improved cargo systems are:

1) the RoRo cross transfer platform and

2) the NOVIMAR cargo handling vehicle.

These new cargo systems are developed to increase the attractiveness of IWT compared to road haulage, which has the advantage of door-to-door transport and no need for mode-to-mode transfers of cargo (Ramne and Fagerlund, 2019; see D4.3).

The RoRo cross transfer platform will allow cross docking of vessels, i.e. direct transfer of cargo between short sea vessels and inland waterway vessels. The RoRo cross transfer platform will be provided by establishing a "fast track lane" for RoRo to provide a short-cut through otherwise congested terminals. Using a cross transfer platform for transferring RoRo reduces congestion at the terminal and the road infrastructure in the larger port areas by replacing trucks. This platform is applicable to short sea, sea-river and inland waterway vessels and will typically be constructed as a floating structure without own propulsion, but it can also be self-propelled. *"It will have at least one mooring position for a larger RoRo vessel, i.e. a short sea RoRo vessel and one or several mooring positions for smaller vessels."* (Ramne and Fagerlund, 2019; see D4.3).

The cross transfer platform that has been concluded in D4.2 was a floating platform. A floating platform for collection and distribution of cargo between terminals allows the reduction of the time that the ships stay at the port. Therefore, instead of the vessel making a journey between different terminals, the floating cargo transfer platform (e.g. a Port Feeder Barge) will do this work. Thus, the ship will need to call at one port only (i.e. docking to the cargo transfer platform) instead of several calls at different terminals. This floating cargo transfer platform concept contributes to the D2.3 capability of cargo consolidation/calling at less terminals thanks to consolidating cargo. This capability of the VT to reduce waiting times because the FVs (or cargo LV) will call at one port is also enhanced by the new cargo system of D4.3 that recommends a floating platform for collection and distribution of cargo between terminals. Thus, in the model, calculations will be performed with and without using the cargo consolidation capability (i.e., the planning tool from NOVIMAR partner MARLO Consultants) that will reduce waiting times because vessels will need to call at fewer ports and thus spend less time waiting at terminals. Calculations will also be added with and without[8] using the new cargo system of a floating platform, that provides the same advantage to the concept of cargo consolidation by reducing waiting times. The vessel will not need to do several calls at different terminals but at one terminal (i.e. docking to the cargo transfer platform). Furthermore, the cross-transfer platform can also be designed for RoRo handling, thus contributing to faster and cheaper

[8] ''In the base case, the existing vessels along with the current method of cargo handling (LoLo) and no pre-sorting of cargo are taken into consideration''. (Ramne and Fagerlund, 2019; see D4.3).

cargo handling. Finally, the new cargo system of a RoRo cross transfer platform mainly has an impact on reducing waiting times and as a result the total transport time will be reduced (impact on PI1, PI2, PI3). However, respective adjustments need to be made in the transport model.

The second improved cargo system as suggested in D4.3, is the NOVIMAR cargo handling vehicle. The NOVIMAR cargo handling vehicle can lift a stack of two containers and transport the package into the ship across the terminal area and position it in a pre-defined cargo space. Conventional vehicles to lift loaded containers (e.g. reach stackers and straddle carriers) cannot do this, i.e. they cannot handle a double stack and cannot operate in a RoRo ship cargo space (Ramne and Fagerlund, 2019; see D4.3). The system has the following benefits:

1) Improved cargo space utilization on a RoRo ship through the elimination of the intermediate cargo carrier that steals volume and dead weight (main drawback of the current way of handling containers in RoRo operations) and through more efficient block stowage capability and

2) RoRo handling with only one type of cargo handling equipment, thus reducing the investment cost for the terminal.

The first benefit will be incorporated in the transport model by increasing the loading factor of RoRo ships because the main obstacle in RoRo vessels (as identified in D4.2) was the limited utilization of cargo space. The second benefit does not affect the VOs and/or COs, which are the main two actors for whom the financial economic perspective is examined in WP2. Thus, it is not incorporated in the transport model.

An additional key benefit of the NOVIMAR cargo handling vehicle is faster and cheaper cargo handling. The handling costs and time will be adjusted in the transport model respectively, when examining a case using this new improved cargo system. The aim of the development of these two new cargo systems is to shift traffic from road haulage to IWT by convincing cargo owners and freight forwarders of the benefits of IWT as a fast and cost-efficient system (RoRo handling benefits). Therefore, TLCs are expected to be further reduced, which will result in a modal split adjustment (see Figure 1) (Ramne and Fagerlund, 2019; see D4.3).

5.3 Update of the NOVIMAR transport model (T.2.4.2)

The model has been changed after incorporating the main modifications which originated from task 2.4.1. These modifications or changes are made for the following sections: the calculations of the IWT cost, road transport cost, the determination of the total logistics cost and generalized cost, the Vessel Train builder and the VT segment analysis.

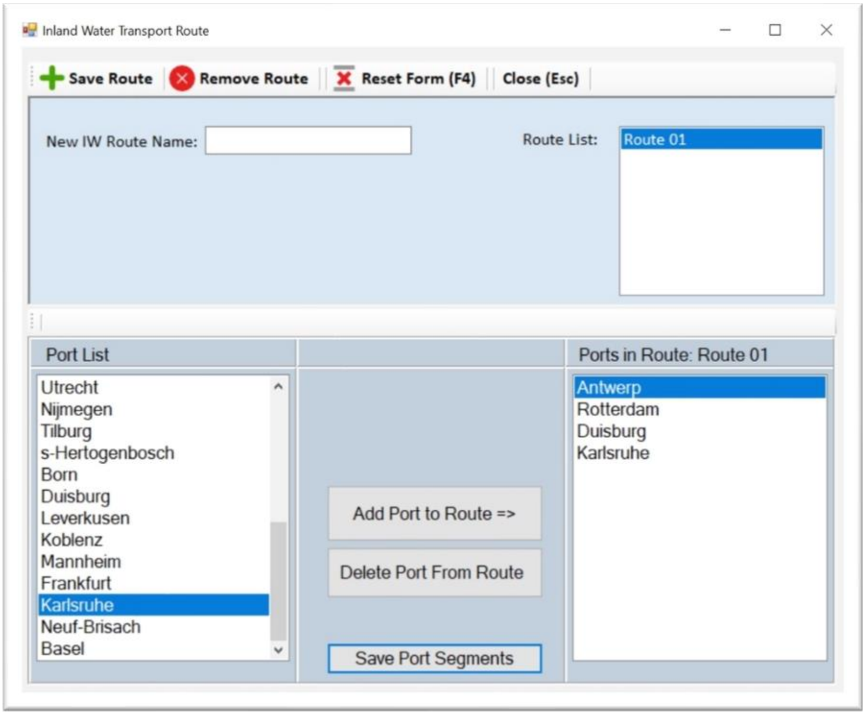
5.3.1 Inland waterway transport

In regard to the IWT calculations, the model currently allows to create a specific route on the IWT network. In the "Inland Water Transport Route" dialog box the user is now able to:

- Add new routes that can be analysed
- Add/ remove ports from a specific route.

This can be seen in Figure 2.

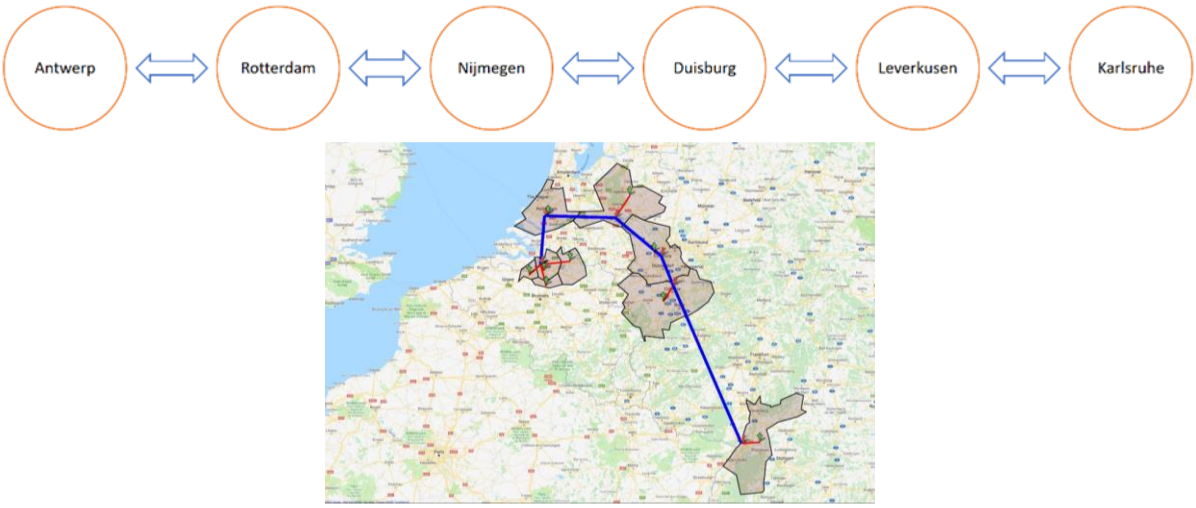
Figure 2: Inland Water Transport Route" dialog box



Source: Own creation

Each IWT Route can be built up from two or more consecutive ports. Figure 3 shows an example of an IWT route which consists of six consecutive ports which are linked to different regions from where cargo is transported.

Figure 3: IWT route between six consecutive ports (Antwerp- Karlsruhe)

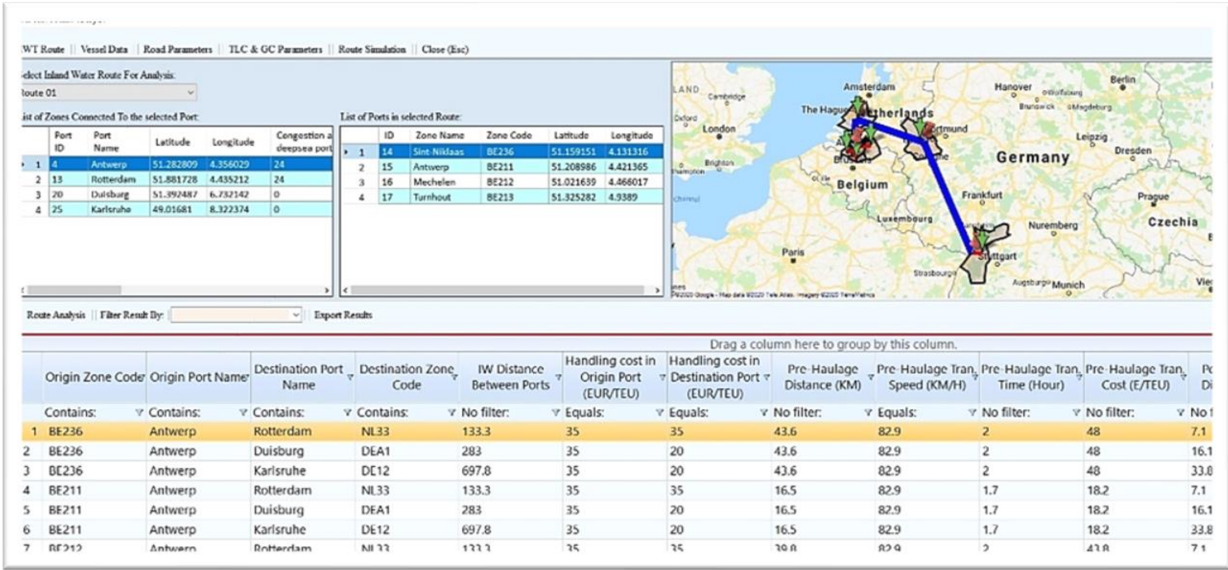


Source: Own creation

For this specific example there are 60 different directions of possible cargo flows between port zones. The complete list can be found in appendix B. For each direction there are 3 types of cargo included in the analysis (container, liquid bulk and dry bulk).

Inland waterway transport between port 1 and port 2 will be assessed according to a conventional vessel and the VT (which will be more elaborated in section 5.4.4). In the main user dialog box, the IWT route can now be selected for further analysis. When selecting the IWT route for analysis, a list of potential ports for the selected route shows up in a table. By clicking on a port, the regions that are linked to those ports also show up (Figure 4).

Figure 4: Possible ports and their hinterland in the IWT Route planner



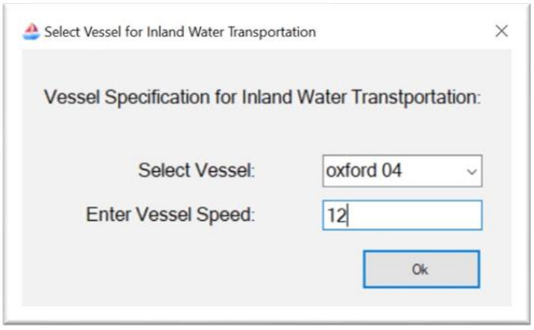
Source: Own creation

All ports and their related regions on the selected route can be seen by a built-in google map window. By double clicking the google map the IWT route is shown in a separate maximized window.

By clicking on the route analysis a dialog box will appear and the user can now select a vessel type (class 1 to 6) and speed for the IWT (

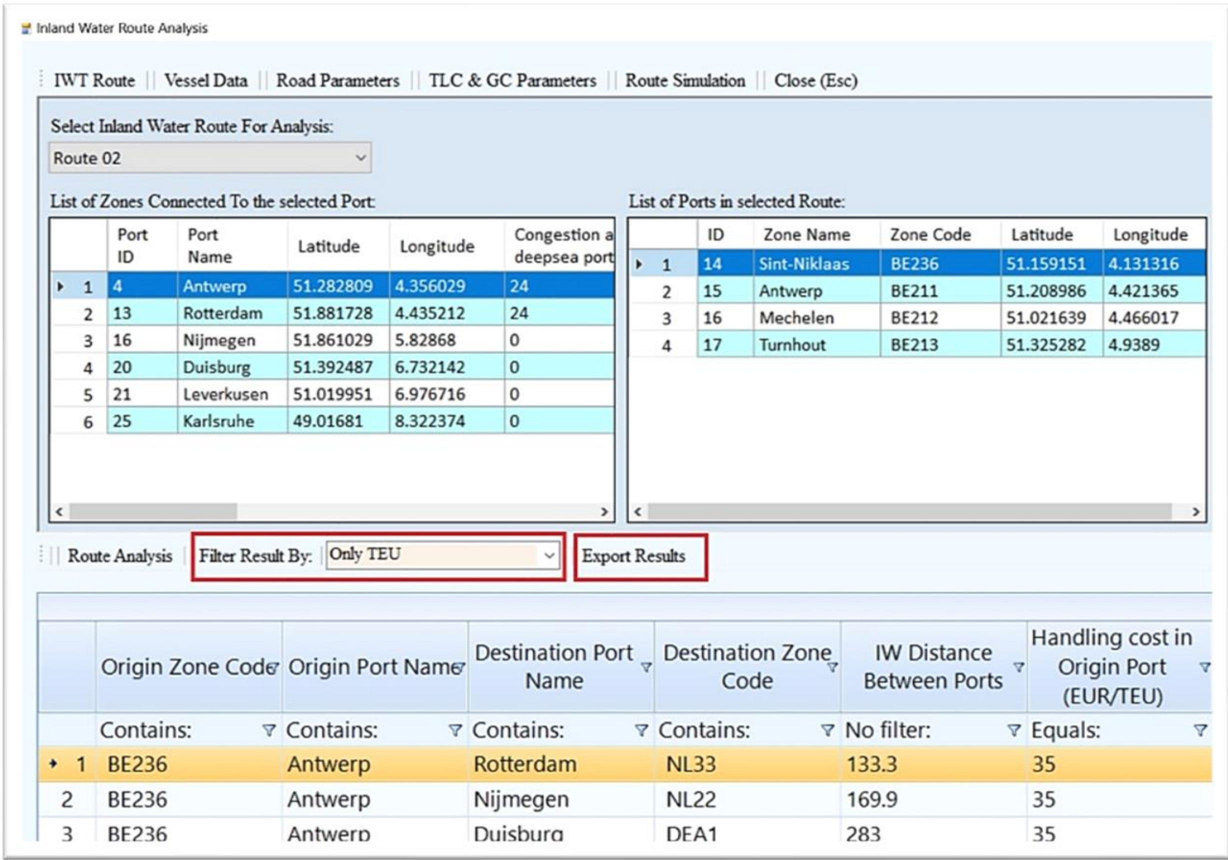
Figure 5). This selected vessel will be used as a reference for the conventional vessel and the VT between the ports.

Figure 5: Dialog box to select vessel type and speed



There are 62 columns in the results window, which can be found in appendix C. Results can be simplified and filtered by type of cargo. The user is also able to analyse and compare different types of cargo separately. Finally, the results can be exported in an excel file format by clicking 'export results' (Figure 6).

Figure 6: Exporting results of the IWT Route Analysis



5.3.2 Road transport

With the "Route Parameters" dialog box, the user is able to see and change all parameters related to the road transportation time, speed and cost calculation. These parameters will be used for main

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road transportation and pre and post haulage in combination with IWT. The details for the calculations can be found in deliverable 2.2 (page 72).

The calculated road transport options are based on the selected IWT ports. However, the main IWT analysis will also automatically trigger the calculation of the road transport cost.

Figure 7: Road parameters box

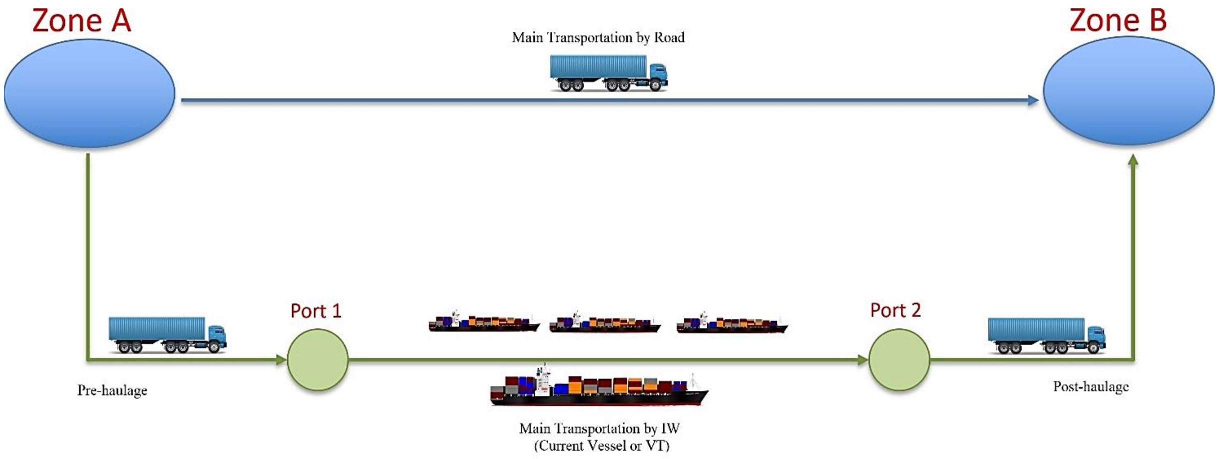
Source: Own creation

5.3.3 Total logistic cost and generalized cost

All different transport options from port zone to port zone are calculated according the selected network in the model. As stated earlier, two different modes of transportation will be evaluated and compared with each other (see also Figure 8).

- Road haulage: Direct transportation by truck from zone A to zone B
- IWT: including pre and post haulage by truck

Figure 8: Difference between road haulage and IWT with pre- and post-handling

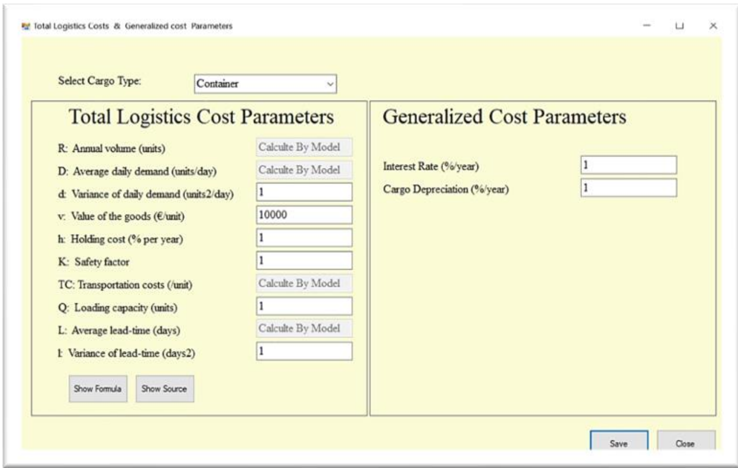


Source: Own creation

The user is able to set the parameters for the calculation of the total logistics cost and the generalized cost by filling in the blanc areas in the dialog box for different types of cargo (container, liquid bulk, dry bulk). The parameters and the dialog box within the program for the cost calculation is shown by

Figure 9. The details of these calculations can be found in D.2.2.

Figure 9: Total logistics costs and generalized cost parameters

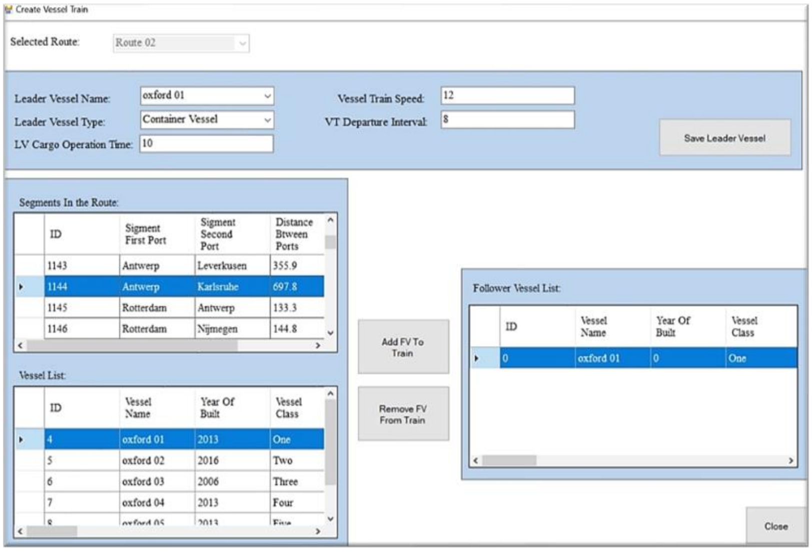


With this functionality in the model it is possible to calculate the cargo owner benefit, which is one of the main indicators that needs to be calculated.

5.3.4 Create Vessel Train

In the "Create Vessel Train" dialog box, the user is able to set more detailed parameters for the LV and VT in the selected route. These parameters consider the name, class, capacity, type and cargo operation time of the LV and the vessel speed and departure intervals of the VT (Figure 10). The inputs or parameter values of the LV can now be saved. They will be added to the segments automatically.

Figure 10: Creating the vessel train model



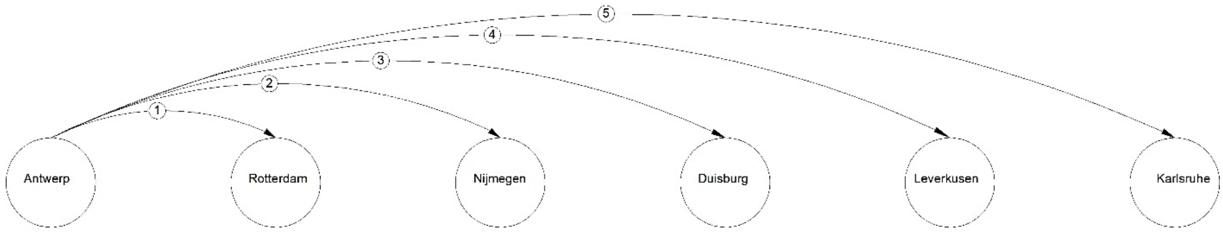
The transport route is now split into different segments for the analysis of the VT. A segment refers to a pair of ports in the predefined route. The first port is the port of origin and the second one is the port of destination. For example, when selecting a transport route between Antwerp and Karlsruhe, there are 30 segments. All of these segments have different volumes of cargo that will be transported.

Table 4: Model segments from origin to destination

1	Antwerp	Rotterdam	**16**	Duisburg	Antwerp
2	Antwerp	Nijmegen	**17**	Duisburg	Rotterdam
3	Antwerp	Duisburg	**18**	Duisburg	Nijmegen
4	Antwerp	Leverkusen	**19**	Duisburg	Leverkusen
5	Antwerp	Karlsruhe	**20**	Duisburg	Karlsruhe
6	Rotterdam	Antwerp	**21**	Leverkusen	Antwerp
7	Rotterdam	Nijmegen	**22**	Leverkusen	Rotterdam
8	Rotterdam	Duisburg	**23**	Leverkusen	Nijmegen
9	Rotterdam	Leverkusen	**24**	Leverkusen	Duisburg
10	Rotterdam	Karlsruhe	**25**	Leverkusen	Karlsruhe
11	Nijmegen	Antwerp	**26**	Karlsruhe	Antwerp
12	Nijmegen	Rotterdam	**27**	Karlsruhe	Rotterdam
13	Nijmegen	Duisburg	**28**	Karlsruhe	Nijmegen
14	Nijmegen	Leverkusen	**29**	Karlsruhe	Duisburg
15	Nijmegen	Karlsruhe	**30**	Karlsruhe	Leverkusen

To reduce complexity only five segments in the list are further explained. Each arrow in the following figure shows the total cargo flow from port origin to port destination.

Figure 11: Total cargo flow from origin to destination



For example, the first segment (Antwerp-Rotterdam) shows the total cargo volume which flows from Antwerp to Rotterdam regardless of the port zones.

The LV sails on all these segments and it will pass through all other ports with the same interval and speed as set as the parameter value (the departure interval of the VT is determined by the departure interval of the LV).

Based on the volume of cargo flow in each segment, the user is able to add different FVs to the segments. The annual capacity for the FVs which is added to the segment should not be more than the actual cargo flow.

In order to link the vessel capacity to the cargo volume a correction function is applied (CCCC). This correction factor is presented in the next formula.

$$\text{CCCC}= \frac{1}{A} * \frac{1}{1+(B-1)*\left(\frac{C}{100}\right)} * D \qquad \text{Eq. (1)}$$

Whereby, CCCC is the Cargo Capacity Correction Coefficient, A is the average Total / Full Ratio of the vessels, B is a factor that takes water levels into account, C is a factor that takes the duration of low water period per year into account and D is the occupancy rate of the vessel. Based data from WP5 the following main factors can be determined: A=1.6, B=1.4, C=20% year, D=0.8.

5.3.5 VT segment analysis

Segment analysis may take several minutes. There are 36 columns in the results window. The following table shows all column headers.

Table 5: Column headers of the segment analysis results

No.	Column Name		
1	Segment First Port	19	VT Capacity Liquid Bulk Tonne/ Year
2	Segment Second Port	20	Actual IWT Cargo Liquid Bulk Tonne/ Year
3	Max Vessel Class	21	Cargo Differential liquid bulk/ Year
4	Distance Between Ports	22	VT Capacity dry cargo tonne / Trip
5	VT Speed	23	VT Capacity Dry Cargo Tonne/ Year
6	VT Length	24	Actual IWT Dry Cargo Tonne/ Year
7	VT Sailing Time H	25	Cargo Differential Dry cargo/ Year
8	VT Maximum Waiting Time- Calculated (Hour)	26	VT Cost Eur/ Voyage
9	VT Maximum Departure Intervals- Calculated (Hour)	27	Current Vessels Cost Eur/ Voyage
10	VT Departure Intervals- User (Hour)	28	VT Gross Saving Eur/ Voyage
11	VT Departure Frequency (User) / Day	29	VT Cost during cargo Operation
12	VT Departure Frequency (User) / Year	30	Current Cost during Cargo Operation
13	VT Mean Waiting Time-User (Hour)	31	VT Cargo Operation Benefit
14	VT Capacity TEU/ Trip	32	Vessel Train Waiting Cost Eur/ Voyage
15	VT Capacity TEU/ Year	33	Vessel Train Net Saving Eur/ Voyage
16	Actual IWT Cargo TEU/ Year	34	Vessel Train Gross Saving Eur/ Year
17	Cargo Differential TEU/ Year	35	Vessel Train Waiting Cost Eur/ Year
18	VT Capacity liquid bulk tonne/ Trip	36	Vessel Train Net Saving Eur/ Year

Based on the outcomes of the calculations a VT design can now be created. This VT design will serve as the main IWT VT case for the Antwerp case. In section 5.5.1 the approach to design this IWT case is given in more detail.

5.4 Developing the main results for the Antwerp case (T.2.4.3)

The results for the Antwerp case are split in different sections. In the first sections the inland waterway case is explained and developed, while the last section deals with the short sea shipping case. For the development of the IWT case the following steps are taken:

1. A set of general calculations is performed to determine how the VT is functioning and how a VT in the Antwerp case can be designed (section 5.4.1).
2. Based on the insights of the first step, a baseline of the VT application is developed (section 5.4.2).
3. For the developed baseline the application of the MMMS and the WP4 developments will further be determined. (section 5.4.3)
4. Finally, the impact of the WP5 discussion on the number of persons on the FV on the baseline will be developed. (section 5.4.4)

Concerning the short sea case a separate analysis is made in section 5.5.5.

5.4.1 Designing the IWT VT case

In order to develop the main IWT Antwerp case a lot of different parameters need to be taken into account. This leads to a very large amount of different scenario calculations. In order to come to a suitable VT design a systematic research approach is used. This research approach can be summarized as follows:

1. During the first step, a VT is assumed with a LV of class 6 and one FV also of class 6. In all the calculations the FVs are manned with 1 crew member, as this is the main principal of the VT concept. This VT will sail between the ports of Antwerp, Rotterdam, Nijmegen, Duisburg, Mannheim and Karlsruhe, with a departure interval of 9 hours. All of the vessels will transport only containers. Based on insights obtained during the project, a cargo vessel is selected to be the LV within a BM where the VT organizer (or platform) and the vessel ownership belongs to the same company[9]. For this specific VT the main cost savings are checked together with potential cargo volumes that can be transported with the VT (cargo volume check).
2. The departure interval is now changed (16 and 14 hours). Similar checks as in step 1 are included.
3. Thirdly, the vessel sizes are changed (using class 5 and 2 for small waterways).
4. For the fourth step not only containers are taking into account but also bulk cargo volumes are added to the VT. There can be a VT which could have an increase in the number of FVs as there is more cargo to be transported (i.e. 2 FVs (1 TEU & 1 bulk) or 3 FVs (1 TEU & 2 bulk)). For all these calculations the same inputs are checked as mentioned in previous steps.
5. A small waterway will now be added to the developed network, where a class 2 vessel is used as a FV.
6. Finally, liquid bulk cargo vessels or tankers are added to the network and the results of the calculations are checked.

Based on this approach the following can be concluded:

- The VT net savings per voyage and per year decrease if the departure interval becomes too large. The more frequent the departures of the VT are, the higher the VT net savings are. Or in other words, long waiting times/long intervals between departures can diminish the VT net savings (per voyage and annual). Thus it is concluded, that a VT with vessels of classes 5 and 6 should have an departure interval[10] which is less than 24 hours.
- If the VT can be built up out of different cargo types than the VT becomes longer and the total net savings of the VT increase.
- The VT will not have a constant composition on the whole trajectory (from origin to final destination of the LV). This means that the VT needs to be able to exchange FVs in the port zones.
- The main area where there is enough cargo to setup a VT service lies between Antwerp, Rotterdam and Duisburg.

[9] In a later stage the results will be shown of another BM.
[10] The time between 2 scheduled departures.

Furthermore, the high frequency of departures is a significant factor to increase the VT net savings. The more frequent the VT departures, the higher the VT net savings (as shown in the analysis using an interval of 8.88 hours between departures). However, less frequent departures of the VT can be compensated by adding other types of cargo in the VT.

Within the analysis it is possible to design multiple VT constellations. The two extremes that can be determined are:

1. Turnhout, Antwerp, Rotterdam, Nijmegen and Duisburg. On this network the following VT is applied:
   a. 1 LV Antwerp – Duisburg, class 5, container, with a departure interval of 12 hours.
   b. 1 FV Antwerp – Duisburg, class 5, liquid bulk.
   c. 1 FV Antwerp – Rotterdam, class 5, containers.
   d. 1 FV Rotterdam – Duisburg, class 5, containers + 1 FV, class 5, bulk cargo.
   e. 1 FV Rotterdam –Nijmegen, class 4, containers.
   f. 1 FV Turnhout – Duisburg, class 2, containers.

This is a more complex VT system where it is possible to combine different vessel sizes and vessel types into one train.

2. Rotterdam - Duisburg.
   a. LV, Rotterdam – Duisburg, class 5, containers, with a departure interval of 16 hours.
   b. 2 FVs, Rotterdam – Duisburg, class 5, dry cargo.
   c. 1 FV, Rotterdam – Duisburg, class 5, liquid cargo.
   d. 1 FV, Rotterdam – Duisburg, class 4, liquid cargo.

This is a more simplified VT system which is only sailing between two ports, but it also has different cargo and vessel size types.

Both cases show positive cost savings and there is sufficient cargo available to setup a VT service.

5.4.2 Baseline VT application development.

In the second step the main case study is developed. This will be determined by the case which scores the best according to the results from step 1 of the analysis. From the first step two types of VTs were found that could work. The first case (Turnhout, Antwerp- Rotterdam, Nijmegen, Duisburg) will now be further elaborated. Despite being the most complex case, it shows the full capabilities of the VT. This case can be seen in Figure 12 and the main results are shown in Table 6.

Figure 12: Visual representation of the developed baseline

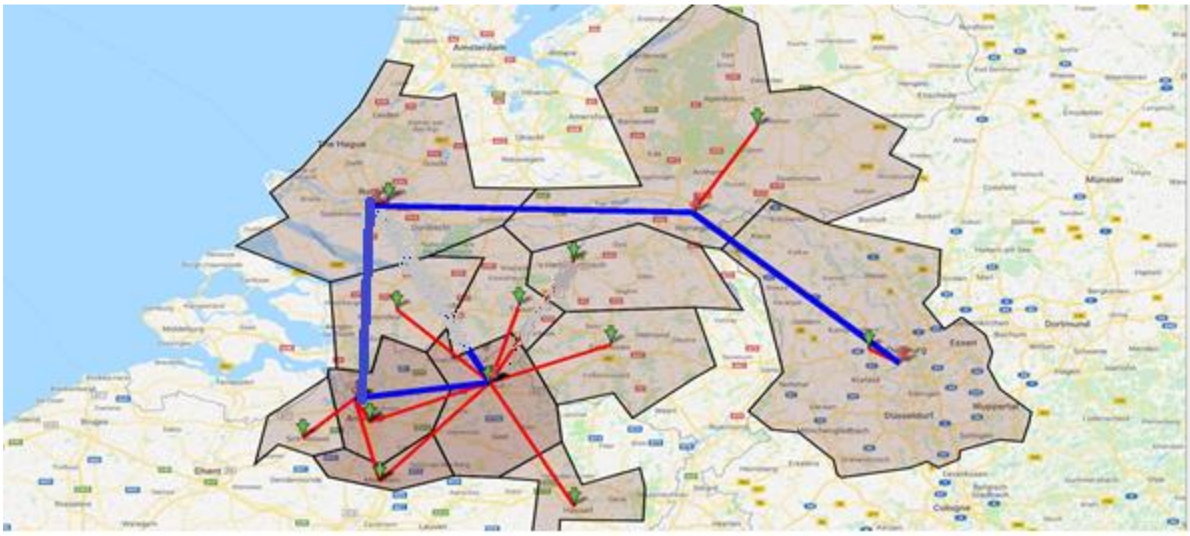


Table 6: Building the VT application (applying BM 2)

Segments of the VT							
Indicator		Turnhout – Duisburg	Antwerp – Duisburg	Antwerp – Rotterdam	Rotterdam - Nijmegen	Rotterdam – Duisburg	Average
Vessel Owner benefits per year	(€)	6,477	449,529	421,592	136,773	980,034	496,982
Vessel Owner benefits per voyage	(€)	10	616	577	188	1,343	681
VT organizer benefit	(€)	na	na	na	na	na	na
Cargo owner benefits	Container (€/TEU)	13.21	12.93	16.10	27.30	12.40	16.39
Business economics evaluation		positive	positive	positive	positive	positive	positive

For this case it can be observed that the benefits for the VO differ per segment. The segment Rotterdam – Duisburg has the largest benefits which are the result of the fact that there are 2 class 5 FVs deployed. The smallest benefits are observed for the class 2 vessel that sails from Turnhout to Duisburg. It can also be observed that the benefits increase with an increase of segment length. This can be explained by the fact that the main VO benefits are obtained by sailing. The increase in cost due to waiting for a LV also decreases, if the sailing distance increases. Each segment has an average benefit for the vessel owner of €681 per voyage, which accumulates to €500,000 per year, which equals an average of €83,000 per vessel per year.

It is also possible to link small waterway vessels to the VT configuration. These small vessels may benefit the most if they can sail a significant time as part of the VT and sail afterwards individually on the small inland waterways. A similar application and conclusion can be found in van Hassel (2011). Thus it is possible to use small existing inland ships to get a similar effect, not only in a local setting but also on a larger European scale.

The results for the cargo owner are also positive. This means that the cargo owner can save money if cargo is transported via the VT. These cargo owner benefits are only calculated for container cargo. Overall it can be concluded that this VT configuration can be applied and that there are benefits for all actors involved.

In the previous case a BM was considered in which the VTO and the LV & FV belong to one and the same company. In this case the investment costs for equipment for the VT are included in the calculations. The operational cost of the organisation is carried by the existing labour force of the shipping company. In this case, there are multiple vessel types in the same VT which means that the shipping company should be quite large and diverse. The NPRC[11] or CITBO[12] could be two examples of such a large cooperation / shipping company.

Most of the inland shipping companies are rather small-sized with barge operators that are usually owners with one or a few vessels. Therefore, a different BM has to be considered in which the VT organizer is separated. The fourth BM that was developed (digital platform) in D.2.3 fulfils this job and offers a platform that organizes and manages the VT configurations. The costs and the profit of such a platform is taken into account. The cost for such platform company is based on following parameters:

- A yearly fixed cost of €50,000 to cover the rental of a small office space plus overhead
- A variable cost of €240,000 per year to cover salaries (4 persons maintaining the platform with an average wage of €60,000 per year).
- A profit margin of 20% on the total cost (excluding the LV payments).
- A fee for the LV of €25,000 per year. This fee is required because the LVs, which are not part of the digital platform, are not compensated for their responsibility for the VT safety.
- The VT configuration has a total of 1 LV and 6 FVs, which depart every 12 hours. The average turnaround time of the LV is 1 week including one resting day. Therefore a total of 12 VTs are needed to set up this service. This means that a total of 12 LVs are needed, along with 72 FVs.

The VT configuration leads to an additional annual cost of €708,000. This cost needs to be recovered from the FVs. The is divided over the different FVs in the VT. This will be a yearly fee of €9,800 per year. If this cost is taken into account and also divided over the different segments, then the results are the following (Table 7):

[11] NPRC is a large Dutch inland shipping cooperation, https://nprc.eu/.
[12] Citbo is Flemish based CORPORATION of INLAND TANKER BARGE OWNERS, https://citbo.com/

Table 7: Building the VT application (applying BM 4)

		Segments in the VT					
Indicator		Turnhout – Duisburg	Antwerp – Duisburg	Antwerp – Rotterdam	Rotterdam - Nijmegen	Rotterdam – Duisburg	Average
Vessel Owner benefits per year	(€)	4,178	289,949	271,930	88,220	632,129	320,557
Vessel Owner benefits per voyage	(€)	6.5	397	372	121	866	439
VT organizer benefit	(€)	188	13,073	12,260	3,978	28,501	14,453
Cargo owner benefits	Container (€/TEU)	8.52	8.34	10.38	17.61	8.00	10.57
Business economics evaluation		positive	positive	positive	positive	positive	positive

From this case we can observe that the average benefits for the VO for all the considered segments are lower than when there is no platform that links the different FVs to the LV. The average savings per vessel per year are now equal to €320,000. The differences between the different segments are quite large. In Table 8 an overview of the cost savings per vessel per year can be observed.

Table 8: Yearly cost saving per vessel per segment

		Segments in the VT					
Indicator		Turnhout – Duisburg	Antwerp – Duisburg	Antwerp – Rotterdam	Rotterdam - Nijmegen	Rotterdam – Duisburg	Average
VO yearly benefits per vessel	(€)	4,178	289,949	271,930	88,220	316,064	194,000
Payback period	(year)	9.57	0.14	0.15	0.45	0.13	0.21

The VO benefits are the largest for the segments where the vessels are sailing between Antwerp, Rotterdam and Duisburg. These yearly cost savings outweigh the investments cost (assumed to be €40.000 per vessel and yearly subscription fee of €10.000) as can be seen in the payback period. For the segment Turnhout – Duisburg the payback period is quite long. Also here it need to be mentioned that the value of the small vessels are quite low (van Hassel, 2011), which makes that a new investment in these old, low valued vessel could be quite difficult. In order to add these small old vessels to the VT these vessels need additional support to invest in the VT technology.

Also for the segment Rotterdam – Nijmegen the benefits are lower than for the other segments. This is due to the fact that a smaller vessels is used here (due to the lower cargo volume on this segment) which makes that the cost savings per vessel are lower. However the payback ratio is half a year which makes that the investment in the VT technology[13] is justifiable.

[13] The VT technology is the technology needed to make a vessel a FV and a LV. This investment was estimated at €40.000 (based on the estimations of WP3 and WP4).

In this case the cargo owner benefits are also lower, although still positive. However, the VT organizer (platform) has a positive net benefit, which is equal to the profit margin.

For the cost estimation of setting up such a platform, a conservative approach is used (i.e. expensive subscription fee). It can be concluded that it is possible to also organize this VT constellation with a digital platform BM. This type of VT is also more applicable as there are many small inland shipping companies in the IWT sector. It would also be positive if the platform could offer a freight booking service. In this regard, there are already online applications available such as 4Shipping[14] which could offer this type of service.

5.4.3 Application of the MMMS and the WP4 developments of the baseline

Next to the development of the IWT VT baseline, the impact of two of the developments in the NOVIMAR project are also tested, which are:

- MIXMOVE Match solution developed by Marlo (see D.2.3)
- The new cross docking and cargo handling designs developed in WP4.

In regard to the first development and to measure the effect of the MMMS, a few input variables will be changed such as:

1) The waiting time for vessel in Antwerp and Rotterdam from 24 to 16 hrs. and 12 to 8 hrs.
2) The total / full ratio of inland vessels from 1.64 to 1.4 and 1.2 (see formula 1 for more details).

The selected input variables have an influence on both vessel waiting time in deepsea ports, which could be reduced if cargo is pre-sorted, and on the filling rate of the vessels[15], which should also be increased if more cargo is allocated to one specific vessel. Variations are used as the exact impact of the development is not known yet. The cargo owner benefits will increase if the waiting time in deepsea ports decreases. The largest benefits, however, are obtained on the segment Antwerp – Rotterdam. This is due to the fact that a double benefit can be obtained, which are caused by the fact that there are waiting time benefits in each port. The same is true for the VO benefits. Furthermore, the reduction in waiting time in deepsea ports due to pre-sorting has a positive impact on the operations of the VT and for the cargo owner.

From the calculations it can be concluded that if the waiting time in ports is reduced, the benefits for both the VO and cargo owner will increase. In this case an average of €150,000 per segment can be saved if the waiting time at deepsea ports is reduced with 25%.

The cargo owner benefits will increase if the waiting time in deepsea ports decreases. The largest benefits, however, are obtained on the segment Antwerp – Rotterdam. This is due to the fact that a double benefit can be obtained, which are caused by the fact that there are waiting time benefits in each port. The same is true for the VO benefits. Furthermore, the reduction in waiting time in

[14] https://www.4shipping.com/en/

[15] If the total to full ratio of vessels decreases, there are less empty vessels sailing due to the fact that ships will be loaded more optimal. This variation is applied to both the VT as for the conventional vessels.

deepsea ports due to pre-sorting has a positive impact on the operations of the VT and for the cargo owner.

Table 9 shows the results of these variations on the average VTO and cargo owner benefits.

From the calculations it can be concluded that if the waiting time in ports is reduced, the benefits for both the VO and cargo owner will increase. In this case an average of €150,000 per segment can be saved if the waiting time at deepsea ports is reduced with 25%.

The cargo owner benefits will increase if the waiting time in deepsea ports decreases. The largest benefits, however, are obtained on the segment Antwerp – Rotterdam. This is due to the fact that a double benefit can be obtained, which are caused by the fact that there are waiting time benefits in each port. The same is true for the VO benefits. Furthermore, the reduction in waiting time in deepsea ports due to pre-sorting has a positive impact on the operations of the VT and for the cargo owner.

Table 9: Benefits of the MMMS

Indicator	Unit	Baseline	MMMS				
			Waiting Time = 16h	Waiting Time = 12h	Waiting Time = 8h	T/F = 1.4	T/F= 1.2
Vessel owner benefits	[EUR]	320,557	466,498	612,439	758,381	320,557	320,557
VT organizer benefit	[EUR]	14,453	14,453	14,453	14,453	14,453	14,453
Cargo owner benefits	[EUR/TEU]	10.57	21.79	27.15	32.64	9.61	8.22

What the calculations also show is that if vessels are better utilized (with a decreased T/F ratio), the benefits for the cargo owner when using the vessel train decrease. This is due to the fact that this approach of better utilizing cargo in inland vessels is applied to all vessels, including non - VT vessels. The cargo owner benefits (decrease in TLC) are larger for the conventional vessels then for the vessels that are part of the VT. These benefits increase, also in the VT, however, they are more significant for the cargo owner if the MMMS is applied to regular vessels. Finally, if vessels are used more efficiently, less vessels are needed, which makes it more difficult to make VTs[16].

To continue the WP4 application a third and fourth input variable is now changed:

3) Handling time in deepsea and inland ports is decreased with-25%, -50% and -75% compared to the baseline.
4) Handling cost in deepsea and inland ports is decreased with -25%, -50% and -75% compared to the baseline cost.

[16] From the calculations in 5.4.1 we could already observe that "enough" vessels are needed to developed VTs.

These variations are selected because the WP4 developments will impact both the handling cost and the handling time. These variations are used as the exact impact of the development is not known yet. The results of the calculations can be found in Table 10.

Table 10: Benefits of the WP4 applications

Indicator	Unit	Baseline	WP4		
			Time & Cost -25%	Time & Cost -50%	Time & Cost -75%
Vessel owner benefits	[EUR]	320,557	379,974	439,392	498,809
VT organizer benefit	[EUR]	14,453	14,453	14,453	14,453
Cargo owner benefits	[EUR/TEU]	10.57	28.16	45.59	68.84

The VO benefits due to the reduction in handling time are noticeable, but are relatively less significant than the reduction in waiting time. This is due to the fact that the waiting time in deepsea ports is much larger than the actual cargo operation time for inland vessels. The largest savings are obtained on the segments Antwerp – Rotterdam and Antwerp – Duisburg. The most significant benefits are observed at the side of the cargo owner who pays for the cargo handling. A reduction in the cargo handling cost will increase the cargo owner benefits to a large extent.

Next to the individual impacts also a combined scenario has been calculated where both the MMMS and the WP4 developments are taken into account. The results are shown in Table 11.

Table 11: Benefits of combined applications (MMMS+WP4)

Indicator	Unit	Baseline	Combined scenario
			(Waiting time 8h & T/F ratio 1.4) + (Handling Time & cost, -75% compared to baseline)
Vessel owner benefits	[EUR]	320,557	936,633
VT organizer benefit	[EUR]	14,453	14,453
Cargo owner benefits	[EUR/TEU]	10.57	84.31

From the results in Table 11 it can be concluded that the main business economic evaluation of the IWT VT will improve a lot if the full capabilities of both the MMMS and the WP4 designs are integrated. Using the FVs more efficiently (less waiting time) and reducing the handling time and cost will improve the benefits of the VO, while the reduction in handling cost will improve the benefits for the CO. By reducing these costs IWT, in general, will become more attractive compared to road transport[17].

5.4.4 Impact of WP5 discussions

The last variation considers the effect of having not one, but two crew members on each FV. From a safety point of view it could be necessary that one additional crew member needs to be on-board to monitor the FV[18]. The results of having 2 crew members on each FV are shown in Table 12 whereby two different options are taken into account. The first option considers the additional crew member to be integrated in the baseline. The second option is when this extra crew member is applied to the best case scenario in which the full applications of the MMMS and the cross docking platform are used.

Table 12: Benefits of the VT application with two crew men on the FV

Indicator	Unit	Baseline	2 crew members per FV	
			Baseline + 1 extra crew members on each FV	(Waiting time 8h & T/F ratio 1.4)+ (Handling Time & cost, -75% compared to base) + 2 crew members on each FV
Vessel Owner benefits	[EUR]	320,557	28,147	644,223
VT organizer benefit	[EUR]	14,453	14,453	14,453
Cargo owner benefits	[EUR/TEU]	10.57	0.77	84.88

It can be concluded that the vessel owner benefits will drop drastically from €320,000 per year to €28,000 (-91%), while also the cargo benefits decrease to less than 1 euro per TEU. This means that the economic feasibility of the VT is jeopardised if two crew members need to be present at each FV. The obtained benefits are too small to cover the risks involved to start up such a service.

If the full capabilities of both the MMMS as well as the WP4 developments are used, the benefits for both the VO and cargo owner increase which make the VT again an economic viable case. It can be concluded that, if an extra crew member is needed on each FV, then both the applications of MMMS and the designs made in WP4 are needed to overcome the extra cost of having 2 crew members on the FVs[19].

5.4.5 Short sea shipping case

The short sea shipping case study has been set up as a liner service operating between Le Havre and Hamburg at a predefined speed, in order to provide predictable departure and arrival times. The cargo LV departs when ready, so that no additional waiting times are created because of them.

[17] In WP1 this effect will be included when the external costs are calculated and taken into account.
[18] This option was discussed in the WP5 meeting in Paris 2020.
[19] The MMM-tool and WP4-developments also apply to non-VT vessels. The main VT-economic advantage is primarily the crew reduction on FV's to one crew member.

This section describes the main assumptions for the short sea case study as presented in Colling & Hekkenberg (2020) and also emphasises the main differences between the short sea case set-up and the previously described inland case. This is followed by a section that describes the approach to determine and assess the cost.

Assumptions

The VT transport system assessed in the short sea case study targets a LV that operates on a liner service between Hamburg and Le Havre. The conditions are set in such a way that the LV operates continuously and no waiting times are created. This does not only concerns the departure interval of the LV but also its service speed. No matter what kind of FV is set in the VT, the LV is adapted in such a way that the VT operating speed equals the design speed of the LV. Which means that all waiting times or increases in lead time incurred by the VT implementation are only affecting the FVs.

The waiting times are determined by assuming the FV arrival patterns to follow a Gaussian distribution. Thus, the average waiting time is set to be half the departure interval of the LVs.

The reduction in crew numbers has the effect that short sea vessels will no longer be able to operate safely for the same period of time outside the VT. Therefore, the decision to join the VT concept is a long-term decision for the vessel operator.

The contract between the VTO and the FVO operator is defined as a time-charter-like subscription. Such mobility subscriptions are also found in public transport services (Kamargianni et al., 2016).

Finally, another important assumption considers the productivity of a vessel which is reflected in the cargo volume moved per year, which means any additional waiting time results in lost cargo movement.

Approach

This section identifies the main formulas which are used in the cost model of the short sea case. In essence, just like for the inland case, the assessment approach compares the current state of operations of reference vessels to the VT conditions. The main difference between the inland and the short sea assessment presented in this document is that the short sea case sets a fixed crew reduction target of three crew members based on the results of Kooij and Hekkenberg (2019), which is the expected crew reduction caused by the implementation of the VT. Additionally, the set-up of the short sea case makes it possible to include waiting times created by the VT and deduces a maximum contribution fee that an individual FVO would pay to the VT transport system. This allows an indication of the required number of vessels to be calculated. This is assessed on a given route based with a long term contract. The inland case on the other hand, identified the savings created by the introduction of the concept for a variety of different destinations. It did not exclude short term decision making as being possible. The savings in the IWT case include the changes in productivity created by the VT implementation and can be further converted into external costs created by a modal shift of cargo to and from other less sustainable modes of transport.

The short sea case study approach is applied for a variety of different VT conditions and allows the identification of the most appropriate VT service conditions. The approach description is an extract taken from the preprint of Colling & Hekkenberg (2020).

Productivity

The productivity of both the reference vessel (P_R) and the follower vessel (P_{FV}), are expressed in the number of TEUs moved per year and can be determined using Equation (1). The main difference in calculations between the two productivities is that for the FVs productivity the VT waiting time is added to the voyage time, while for the current operations it is assumed to be zero. Waiting times that already exist are assumed to be part of the port time.

$$\boldsymbol{P_{R\ or\ FV}} = \frac{2(\frac{d}{v_R}+t_p+w)}{T}V \qquad \textbf{Eq. (1)}$$

Where: $P_{R\ or\ FV}$: productivity of reference or follower vessel (TEU/year)

v_R: service speed of reference follower vessel (kn)

t_p: time spent in port (h)

d: trip distance (nm)

T: operating hours (h/year)

V: cargo volume (TEU)

w: VT waiting time (h)

Once these two productivities are known, the productivity drop is the difference between these two values. In order to ensure that the new conditions created by the VT are equivalent or better than the current conditions, the constraint in Equation (2) is set. This constraint enables determination of the maximum follower vessel cost in order for the FV to benefit from the concept, as waiting times are created for the VT users.

$$\frac{C_{FV}}{C_R} \leq \frac{P_{FV}}{P_R} \qquad \textbf{Eq. (2)}$$

Where: C_{FV}: FV cost (€/year)

C_R: reference vessel cost (€/year)

The C_R elements are split into capital cost (depreciation, interest and insurance), voyage cost (fuel and waiting time) and general operating cost (crew, repair and maintenance and administration).

The capital cost as well as administration cost are all calculated as a function of the newbuilding price of the vessel. The newly build cost as well as the maintenance cost are estimated from the generic formula established by Martinez Lopez et al. (2013). The former is estimated based on the gross tonnage of the vessels while the latter is determined based on the age of the vessel.

The fuel cost is calculated based on the resistance curves using the Holtrop and Mennen (1982) resistance prediction method. The specific fuel consumption of the vessel's engine and vessel operating speeds are taken as input data on a case-by-case basis. Finally, the crew cost is calculated based on crew size estimations from Kooij and Hekkenberg (2019) as well as salaries obtained from a Dutch industrial partner that operates its own vessels. The additional employment-related and indirect crew cost are determined by and based on Ghaderi (2019).

Contribution fee

Once the maximum FV cost is determined, the largest possible contribution fee per FV can be calculated using the following Equation (3). The contribution costs of the individual vessel are merged and have to compensate for the VT related costs of the LV. Only then the concept is beneficial for the VT operator and the VT user. Alongside the positive effects of the VT implementation, the VT also decrease in productivity of the short sea follower vessels as waiting times are induced and their individual sailing times outside of the VT are restricted. Under these conditions the contribution fee is equal to the net savings of the FVs.

$$\boldsymbol{C_{fee} = net\ savings = C_{FV} - C_R + \Delta_{crew} + \Delta_{fuel} - C_{VT}}$$ **Eq. (3)**

Where: Δ_{crew}: change in crew cost (€/year)

Δ_{fuel}: change in fuel cost (€/year)

C_{VT}: VT technology cost (€/year)

C_{fee}: VT contribution fee cost (€/year)

The change in crew cost (Δ_{crew}) are the same savings as previously described in the inland case. These savings are determined based on the crew analysis algorithm by Kooij and Hekkenberg (2019), which estimates the crew size reduction when automating the navigational tasks. The Kooij and Hekkenberg concludes the crew to shrink by the second officer and two deck boys.

$$\Delta_{fuel} = \boldsymbol{C_{fuel_R} - C_{fuel_{FV}}}$$ **Eq. (4)**

Where: $\boldsymbol{C_{fuel_R}}$: fuel cost of the reference vessel (€/year)

$\boldsymbol{C_{fuel_{FV}}}$: fuel cost of the follower vessel (€/year)

The change in fuel cost (Δ_{fuel}), expressed by Equation 4, occurs due to the difference in operating speed of the VT compared to the standard service speed of the reference vessel. This change is calculated in the same manner as the original fuel cost described in the C_R. However, instead of using the resistance of the vessel at its service speed, the difference to the resistance point at the VT operating speed, up or down of the resistance curve, is calculated.

The VT technology cost (C_{VT}) is the cost created by the VT technology installed on board. Capital cost elements as well as the maintenance and administration cost are assumed to be created by the implementation of the technology on board. Just like the inland case, the VT technology cost (i.e. depreciation, insurance, maintenance and administration cost) are determined as an annual percentage of the VT technology capital investment.

The last step is to compare the obtained maximum contribution fee value with the cost created on the LV in order to determine how many FVs would be needed to form an economically viable VT. The cost of the LV that has to be covered by the fee from the FVs is solely composed of the VT technology cost, which is assumed to be equivalent to that of the FVs. Depending on the case studies, an additional monitoring crew cost may be created in order to reflect the case where the VT system control is not fully autonomous yet.

Results

The results make it clear that the VT is most beneficial for VT users with fast vessels. However, operators of fast vessels need to be flexible to adapt to slower VT operating speeds (3-8kn slower). Smaller vessels that use the VT, do not need to be as flexible, as their vessels operate in their intended environment. Nevertheless, the benefits for slower vessels are significantly smaller, as no fuel savings are achieved on top of the crew savings.

Furthermore, the route lengths restrictions are larger for the slower vessels. It is most beneficial to use the VT services for longer routes because waiting times have a smaller impact on productivity. Even though the slower operating speeds may cause a productivity drop for the faster vessels, the fuel savings outweigh any other operating cost created while waiting for the VT. For this case study it was shown that, when no monitoring crew is needed, all assessed vessel types have viable conditions for a distance of 500 nautical mile.

The results suggest that mixing different vessel types in the same train is possible, but naturally poses more options for the faster vessels than the smaller slower ones. It can also be concluded that while the main initial focus of the concept was set on the reduction of the number of crew, a much larger benefit for this concept can be created by effectively adapting the slow-steaming principle in the VT service for the short sea shipping sector.

There are 48 vessels required to establish a viable VT service system between Hamburg and Le Havre. Hermans, M. I. (2017) shows an average number of 2773 ship passages (2187 Westwards, 3359 Eastwards) in the area of operations. Based on this information it can be concluded that the 48 vessels makes up less than 1% of the estimated European short sea vessel fleet.

5.5 Collecting stakeholders response (T.2.4.4)

The stakeholder responses are only based on the feedback given by the NOVIMAR partners. These results are presented in section 5.5.1. Next to this initial response also a separate online stakeholder meeting was held on 18 (intended for shippers) and 19 March 2021 (intended for barge owners)[20]. The key take-aways from these two meetings are presented in section 5.5.2.

5.5.1 Initial stakeholder responses of the developed case

The following NOVIMAR partners are asked to provide feedback: Plimsol, Touax, Van Moer and Duisburg Port.

Each partner was asked to provide feedback on the developed case. This feedback needed to be in the form of a SWOT analysis. The SWOT analysis includes two main levels: the internal factors (all elements directly linked to the developed case) and the external ones (all external elements impacting the developed case).

The internal factors are split in two other parameters: Strength and Weaknesses.

- <u>Strength:</u>

[20] See appendix D for the program of the meeting

These are the things that the developed case distinguishes itself from the main competition. Think about the advantages over other organizations. What is unique and what is so good about this developed case?

- Weaknesses:

What could be improved? What do others think that might be weaknesses of the developed case? What are possible pitfalls?

The external factors are also split in two other parameters: Opportunities and Threats.

- Opportunities

Opportunities are openings or chances for something positive to happen. They usually arise from situations outside the main developed case, and require an eye to what might happen in the future. They might arise as developments in the market or in the technology. Think about good opportunities you can spot immediately.

From what trends could the case benefit from? How could strengths be transformed into opportunity?

- Threats

Threats include anything that could negatively affect the developed case from the outside, such as supply chain problems, shifts in market requirements, or a shortage of crew members. It's vital to anticipate threats and to take action against them before you become a victim of them and your growth stalls. Think about the obstacles you face in getting the developed case to market.

What threats could harm the developed case? What is the competition doing? What treats do your weaknesses expose to you?

The main SWOT table, based on the responses of the project partners, can be seen in Table 13.

It can be concluded from the SWOT analysis that the developed concept has it benefits. It can solve the emerging issue of having not enough captains and it also has the opportunity to combine different cargo types and cargo flows.

On the downside there is the decrease in speed and a longer rotation time of a vessel which makes that the vessel is used less per year, which increases the fixed cost per transported TEU. Also a response team needs to be present in each port to support a FV if something goes wrong. Next to that also an extra cost might emerge if FVs (with one crew member) need to be handled at (inland) ports.

Table 13: SWOT analysis of stakeholder input

	Strengths	Weaknesses
Internal	1. Savings (especially for bigger vessels) by using less crews, 2. Less accidents 3. More efficiency in the logistic chain, improvement of delays for clients, 4. Cooperation like system 5. Mix of different cargo 6. Combination of different waterway 7. benefits for all in logistics chain	1. In case of problem, in order to react asap, we need dedicated teams at the ports, 2. In order to participate to the VT, each owner of FV needs to invest in a new technology, and this investment will reduce his profits, 3. Longer duration/lower speed 4. If water level drops, problems could occur with vessel draft 5. The benefit for class II vessels is relatively small and probably not convincing to participate 6. Reduced flexibility for route planning and additional short-term orders 7. Not for lower Danube (convoys)
External	1. The market has a lack of captains, the VT concept will need less captains for the same volumes transported (Vessels can be operated with less personnel in case the required staff is not available) 2. Increase in reliability because of less accidents 3. The VT system has the flexibility to include other FVs in the convoy at any time. 4. Improved modal split for IWT.	1. Some vulnerability to sanitary crisis as the current period, 2. In case the oil prices will collapse on long term, the road hauliers could become more profitable 3. Delays to get a new regulation for VT 4. Difficulties to insure the VT concept (sharing of responsibilities in case of damage). 5. Shipping companies do not want to cooperate and might be afraid to give too much information to competitors 6. Potential conflict of interest of owners
	Opportunities	**Threats**

Furthermore, all partners where asked to answer the following question:

Are you willing to invest in VT technology? If not, what does hinder the investment? What should be changed in the concept?

The main responses are given below:

- It might be difficult to start up the service due to the following issues:

  - The main benefits of the baseline, thus without the support of the MMMS and the WP4 designs, is in some segments quite small. This means that only a part of the developed VTs could be considered as a real investment.
  - The main hindrance of investing is the lack of adjusted regulation which makes it not yet possible to start with this service.
  - It might be difficult to start with the service as there is no insurance policy for the VT service. How is responsibility or liability shared between LV and FV companies? [21]
- If there were a demand for handling FVs, inland ports would think about offering a mooring / navigation service within the port to allow FVs to operate with reduced staff on-board.

Nevertheless, the model is able to provide the necessary outputs. One extra element needs to be included as an extra fixed cost which covers the cost of the supporting teams in the ports as well as the cost for handling FVs with only one crew member in inland ports.

5.5.2 Stake holder meeting

The stakeholder meeting was organized via the digital platform of MS Teams. The stakeholder meeting was split into two parts. In both meetings the following schedule was followed:

			Presenter
9:30	**9:40**	Introdcution	Erwin
9:40	**9:50**	Introduction of the main VT concept	Robin
9:50	**10:20**	Novimar developments + feedback from stakeholders Cargo reconstruction Cargo handling innovations New VT vessels	 Jan Tore Bengt Igor
10:20	**10:45**	Results IWT north Europe case + feedback from stakeholders 10 min pres 15 min feedback	Edwin
10 min break			
10:55	**11:20**	Results Short sea case + feedback from stakeholders 10 min pres 15 min feedback	Alina
11:20	**11:45**	Results IWT Danube case + feedback from stakeholders 10 min pres 15 min feedback	Edwin
11:45	**11:50**	Closing of the meeting	Erwin

[21] For this specific point a student of the university of Antwerp is looking into this aspect. Output from this Master thesis is expected in October 2020 and can be included in either an updated version of this deliverable or in D.2.5.

At the stakeholder meeting the overall project was presented, along with the different Novimar developments. The overall concept and the Novimar innovations are combined in three different case studies. The first two case studies (Antwerp case and the short sea case) are part of this deliverable.

The comments of the stakeholders was in overall positive with respect to the robustness of the VT transport system concept and model. The comments are clustered per case studied:

1) Antwerp case
2) The Short Sea case

Rhine case comments

1. Novimove partner (Peter Shobayo): What is the minimum number of vessels in the VT?

   Reply Novimar team: The minimum is two FVs and one LV but the more vessels in the VT, the more the savings. However, from a safety point of view, the highest number of vessels in the VT can be four-five, depending on the length of the vessels.

Short Sea case comments

1. Coordinator of the European Inland Waterway Transport Platform (Nik Delmeire): I am not sure, if shippers will be willing to pay for the extra internal cost of slow steaming.

   Reply Novimar team: We took that into account. It is a challenge but from an environmental point of view is positive.

2. Coordinator of the European Inland Waterway Transport Platform (Nik Delmeire): But shippers never calculate external costs.
3. Novimar partner (Erwin van der linden): Thus the fuel savings are higher than the crew savings. Did you expect that?

   Reply Novimar team: Yes, we expected that because fuel costs are significant cost parameters of the total costs.

4. VO meeting attendant/Mr. Antoon Van Coillie (Blue line logistics): Slow steaming is interesting because it leads to low emissions.
5. VO meeting attendant/Sava (Guest): Could you please relate the VT advantage (crew reduction) with respect to pandemic health measures?

   Reply Novimar team: Indeed now that we have corona, it is ideal that there is only one crew member on board.

5.6 Modifying the VT transport model based on stakeholder meetings (T.2.4.5)

Based on the initial responses of the NOVIMAR partners there is no need to make major changes in the model. The main missing element is the extra fixed cost needed to cover the supporting teams in the ports. From the main stakeholder meeting no new extra needs to modify the model are identified.

6 ANALYSIS OF RESULTS

6.1 Summary of results

This deliverable benchmarks the VT concept with the transport model which is further finalized in task 2.4 in WP2 of the NOVIMAR project. The two BMs as presented in the previous deliverable (D.2.3) are adapted to additional capabilities and compared with the earlier developed Antwerp case study. The Antwerp case is defined with the transport model. The MMMS and the WP4 developments are tested and analysed. Next to that also a short sea shipping case is developed and analysed.

6.2 Analysis of results

IWT results

Based on the performed analysis, one main IWT VT application is developed: Turnhout, Antwerp, Rotterdam, Nijmegen and Duisburg. For this VT application two business models are investigated. The first BM considers that all the vessels are owned by one owner. This actor is also the one that is the VTO. The other BM that is investigated includes a platform that will organize and manage the compositions of the VT. In this BM the cost and profit of such a platform is taken into account. These extra costs are estimated to be €708,000. These costs need to be recovered from the FVs and will be divided over the different FVs in the VT. This will be an annual fee of €9,800.

From this case it can be observed that the average benefits for the VO for all the considered segments are lower than when there is no separate platform that links the different FVs to the LV. The average annual savings per vessel are now equal to €55,000. The cargo owner benefits are also lower, however, they are still positive. The VT organizer (platform) has a positive net benefit, which is equal to the profit margin.

In estimating the cost for setting up such a platform a conservative approach is used (i.e. expensive subscription fee). It can be concluded that it is possible to organize this VT constellation within a BM that includes a platform. This type of VT is more applicable as there are many small inland shipping companies in the IWT sector. Furthermore, it would be advisable if the platform could offer a freight booking service. There are already online applications available such as 4Shipping[22] and Bargelink[23] which could offer this type of service.

From the analysis of the developments of the MMMS, the WP4 developments with respect to new type of cargo handling and the impact of having two crew members on each FV, it can be concluded that the MMMSand the WP4 developments are contributing to a better economic performance of the VT. If it is needed that at least two crew members are present on-board of each FV then the MMMS in combination with the WP4 developments are necessary, otherwise the business economic evaluation of the VT becomes negative.

[22] https://www.4shipping.com/en/
[23] http://direct.bargelink.com/

Short sea shipping results

With respect to the short sea shipping case, it can be concluded that the VT is most beneficial for VT users with fast vessels. However, operators of fast vessels need to be flexible to adapt to slower VT operating speeds (3-8kn slower). Smaller vessels that use the VT, do not need to be as flexible, as their vessels operate in their intended environment. Nevertheless, the benefits for slower vessels are significantly smaller, as no fuel savings are achieved on top of the crew savings.

Furthermore, the route lengths restrictions are larger for the slower vessels. It is most beneficial to use the VT services for longer routes because waiting times have a smaller impact on productivity. Although the slower operating speeds may cause a drop in vessel productivity for the faster vessels, the fuel savings outweigh any other operating cost created while waiting for the VT. For this case study it was shown that, when no monitoring crew is needed, all assessed vessel types have viable conditions for a distance of 500 nm.

The results suggest that mixing different vessel types in the same train is possible, but naturally poses more options for the faster vessels than the smaller and slower ones. It can also be concluded that while the main initial focus of the concept was set on the reduction of the number of crew, a much larger benefit for this concept can be created by effectively adapting the slow-steaming principle in the VT service for the short sea shipping sector.

There are 48 vessels required to establish a viable VT service system between Hamburg and Le Havre. This number makes up less than 1% of the estimated European short sea vessel fleet.

6.3 Corrective measures

Due to the COVID-19 restrictions, it was not possible to have a physical meeting with stakeholders to check the validity of the results. This has been solved by having a digital check with the project partners that are active in the sector. On top of this also an online stakeholder meeting was organized to further validate the obtained results.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

This deliverable benchmarks the VT concept with the transport model which is further finalized in T.2.4 in WP2 of the NOVIMAR project. The two BMs as presented in the previous deliverable (D.2.3) are adapted to additional capabilities and compared with the earlier developed Antwerp case study. With the transport model the Antwerp case is defined, the MMMS and the WP4 developments are tested and analysed. Next to that also a short sea shipping case is analysed and developed.

Based on the performed analysis one main IWT VT application is developed: Turnhout, Antwerp, Rotterdam, Nijmegen, Duisburg. In this case the BM that is investigated is the one where there is a platform that will organize and manage the compositions of the VT, therefore we have to take the cost and a profit of such a platform into account. These extra cost are estimated to an extra cost of €708,000. These cost need to be recovered from the FVs. These cost will be split over the different FVs in the VT. This will be a yearly fee of €9,800 per year.

From this case we can observe that the average benefits for the VO for all the considered segments are lower than in the case there is no platform that will link the different FV to the LV. The average savings per vessel per year are now equal to €55,000. Also the cargo owner benefits are lower, but they are also still positive. Also the VT organizer (platform) has a positive net benefit, which is equal to the profit margin.

In estimating the cost for setting up such a platform a conservative approach is used (i.e. expensive subscription fee). So it can be concluded that it is possible to also organize this VT constellation with a platform BM. Also this type of VT is more applicable as there are many small inland shipping companies in the IWT sector. It would also be good if the platform could also offer a freight booking service. There are online application available such as 4Shipping[24] and Bargelink[25] which could offer this type of service.

From the analysis of the developments of the MMMS, the WP4 developments[26] with respect to new type of cargo handling and the impact of having two crew members on each FV it can be concluded that the MMMS and the WP4 developments are contributing to a better business economic VT performance. If it is needed that at least two crew members need to be present on each FV then the MMMS in combination with the WP4 developments are needed, otherwise the business economic evaluation of the VT is negative.

With respect to the short sea shipping case it can be concluded that the VT is most beneficial for VT users with fast vessels. However, operators of fast vessels need to be flexible to adapt to slower VT operating speeds (3-8kn slower). Smaller vessels that use the VT, do not need to be as flexible, as their vessels operate in their intended environment. Nevertheless, the benefits for slower vessels are significantly smaller, as no fuel savings are achieved on top of the crew savings.

[24] https://www.4shipping.com/en/

[25] http://direct.bargelink.com/

[26] The individual conclusions regarding the MMMS and the WP4 developments are given in D.2.3 (for MMMS) and in D.4.3. In this deliverable the focus is on the impact of these developments on the VT.

Furthermore, the route lengths restrictions are larger for the slower vessels. It is most beneficial to use the VT services for longer routes because waiting times have a smaller impact on productivity. Even though the slower operating speeds may cause a productivity drop for the faster vessels, the fuel savings outweigh any other operating cost created while waiting for the VT. For this case study it was shown that, when no monitoring crew is needed, all assessed vessel types have viable conditions for a distance of 500 nm.

The results suggest that mixing different vessel types in the same train is possible, but naturally poses more options for the faster vessels than the smaller ones. It can also be concluded that while the main initial focus of the concept was set on the reduction of the number of crew, a much larger benefit for this concept can be created by effectively adapting the slow-steaming principle in the VT service for the short sea shipping sector.

The required number of vessels needed to establish a viable VT service system between Hamburg and Le Havre are 48 vessels. This number makes up less than 1% of estimated European short sea vessel fleet.

7.2 Recommendations

With respect to this deliverable, there are no further recommendations, other than finalizing the work for task 2.4.5 when the COVID-19 restrictions are softened

Current logistics can be improved by the cross docking and cargo reconstruction and consolidation measures developments. These measures can be applied to independent vessels anyway, and these measures can't be the reason for justifying the investment in the VT-technology. Therefore the FV should only be manned by one crew member.

CEMT classes II and III were introduced as problem solvers for road congestion around urban areas. Even if the economic benefit is modest, classes II and III can ease road congestion and road transport emissions in urban areas. In WP1 the full social cost benefit analysis will be done and then also the full social impact of using small inland vessels can be determined.

Both WP 3 and 5 assume a VT consisting of one LV and two FV. In this deliverable the VT is composed out of 1 LV and 5 to 6 FVs. This means that from a business point of view the VT should be longer then what WP3 and 5 have used.

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9 ANNEXES

9.1 Annex A: Public summary

This deliverable benchmarks the VT concept with the transport model which is further finalized in task .2.4 in WP2 of the NOVIMAR project. The two BMs as presented in the previous deliverable (D.2.3) are adapted to additional capabilities and compared with the earlier developed Antwerp case study. With the transport model the Antwerp case is defined and the MMM- tool and the WP4 developments are tested and analysed. Next to that also a short sea shipping case is analysed and developed.

Based on the performed analysis one main IWT VT application is developed: Turnhout, Antwerp, Rotterdam, Nijmegen, Duisburg. In this case the BM that is investigated is the one where there is a platform that will organize and manage the compositions of the VT, therefore we have to take the cost and a profit of such a platform into account. These extra cost are estimated to an extra cost of €708.000. These cost need to be recovered from the FVs. These cost will be split over the different FVs in the VT. This will be a yearly fee of €9.800 per year. From this case we can observe that the average savings per vessel per year are equal to €55.000. Also the cargo owner benefits are positive. Finally, the VT organizer (platform) also has a positive net benefit, which equals the profit margin.

From the analysis of the developments of the MMM-tool, the WP4 developments with respect to new type of cargo handling and the impact of having two crew members on each FV it can be concluded that the MMM application and the WP4 developments are contributing to a better business economic VT performance. If it is needed that at least two crew members need to be present on each FV then the MMM in combination with the WP4 developments are needed, otherwise the business economic evaluation of the VT is negative.

With respect to the short sea shipping case it can be concluded that the VT is most beneficial for VT users with fast vessels. However, operators of fast vessels need to be flexible to adapt to slower VT operating speeds (3-8kn slower). Nevertheless, the benefits for slower vessels are significantly smaller, as no fuel savings are achieved on top of the crew savings.

The results suggest that mixing different vessel types in the same train is possible, but naturally poses more options for the faster vessels than the smaller ones. It can also be concluded that while the main initial focus of the concept was set on the reduction of the number of crew, a much larger benefit for this concept can be created by effectively adapting the slow-steaming principle in the VT service for the short sea shipping sector.

The required number of vessels needed to establish a viable Short Sea Shipping VT service system between Hamburg and Le Havre are 48 vessels. This number makes up less than 1% of estimated European short sea vessel fleet, which makes that a Short Sea Shipping VT could be set up.

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9.2 Annex B: List of zones in the model

No	Origin Zone Code	Origin Port Name	Destination Port Name	Destination Zone Code	No	Origin Zone Code	Origin Port Name	Destination Port Name	Destination Zone Code
1	BE236	Antwerp	Rotterdam	NL33	31	NL22	Nijmegen	Antwerp	BE212
2	BE236	Antwerp	Nijmegen	NL22	32	NL22	Nijmegen	Antwerp	BE213
3	BE236	Antwerp	Duisburg	DEA1	33	NL22	Nijmegen	Rotterdam	NL33
4	BE236	Antwerp	Leverkusen	DEA2	34	NL22	Nijmegen	Duisburg	DEA1
5	BE236	Antwerp	Karlsruhe	DE12	35	NL22	Nijmegen	Leverkusen	DEA2
6	BE211	Antwerp	Rotterdam	NL33	36	NL22	Nijmegen	Karlsruhe	DE12
7	BE211	Antwerp	Nijmegen	NL22	37	DEA1	Duisburg	Antwerp	BE236
8	BE211	Antwerp	Duisburg	DEA1	38	DEA1	Duisburg	Antwerp	BE211
9	BE211	Antwerp	Leverkusen	DEA2	39	DEA1	Duisburg	Antwerp	BE212
10	BE211	Antwerp	Karlsruhe	DE12	40	DEA1	Duisburg	Antwerp	BE213
11	BE212	Antwerp	Rotterdam	NL33	41	DEA1	Duisburg	Rotterdam	NL33
12	BE212	Antwerp	Nijmegen	NL22	42	DEA1	Duisburg	Nijmegen	NL22
13	BE212	Antwerp	Duisburg	DEA1	43	DEA1	Duisburg	Leverkusen	DEA2
14	BE212	Antwerp	Leverkusen	DEA2	44	DEA1	Duisburg	Karlsruhe	DE12
15	BE212	Antwerp	Karlsruhe	DE12	45	DEA2	Leverkusen	Antwerp	BE236
16	BE213	Antwerp	Rotterdam	NL33	46	DEA2	Leverkusen	Antwerp	BE211
17	BE213	Antwerp	Nijmegen	NL22	47	DEA2	Leverkusen	Antwerp	BE212
18	BE213	Antwerp	Duisburg	DEA1	48	DEA2	Leverkusen	Antwerp	BE213
19	BE213	Antwerp	Leverkusen	DEA2	49	DEA2	Leverkusen	Rotterdam	NL33
20	BE213	Antwerp	Karlsruhe	DE12	50	DEA2	Leverkusen	Nijmegen	NL22
21	NL33	Rotterdam	Antwerp	BE236	51	DEA2	Leverkusen	Duisburg	DEA1
22	NL33	Rotterdam	Antwerp	BE211	52	DEA2	Leverkusen	Karlsruhe	DE12
23	NL33	Rotterdam	Antwerp	BE212	53	DE12	Karlsruhe	Antwerp	BE236
24	NL33	Rotterdam	Antwerp	BE213	54	DE12	Karlsruhe	Antwerp	BE211
25	NL33	Rotterdam	Nijmegen	NL22	55	DE12	Karlsruhe	Antwerp	BE212
26	NL33	Rotterdam	Duisburg	DEA1	56	DE12	Karlsruhe	Antwerp	BE213
27	NL33	Rotterdam	Leverkusen	DEA2	57	DE12	Karlsruhe	Rotterdam	NL33
28	NL33	Rotterdam	Karlsruhe	DE12	58	DE12	Karlsruhe	Nijmegen	NL22
29	NL22	Nijmegen	Antwerp	BE236	59	DE12	Karlsruhe	Duisburg	DEA1
30	NL22	Nijmegen	Antwerp	BE211	60	DE12	Karlsruhe	Leverkusen	DEA2

9.3 Annex C: Output list with details from the model

No.	Column Name	details
1	Origin Zone Code	
2	Origin Port Name	
3	Destination Port Name	
4	Destination Zone Code	
5	IW Distance Between Ports	
6	Handling cost in Origin Port (EUR/TEU)	
7	Handling cost in Destination Port (EUR/TEU)	
8	Pre-Haulage Distance (KM)	
9	Pre-Haulage Tran. Speed (KM/H)	
10	Pre-Haulage Tran. Time (Hour)	
11	Pre-Haulage Tran. Cost (E/TEU)	
12	Post-Haulage Distance (KM)	
13	Post-Haulage Tran. Speed (KM/H)	
14	Post-Haulage Tran. Time (Hour)	
15	Post-Haulage Tran. Cost (E/TEU)	
16	Vessel Class for Follower vessel	
17	IW Max Vessel Class (Between Ports)	
18	Vessel Capacity TEU	
19	Vessel Capacity Tone	
20	Vessel and VT Speed	
21	Sailing Time Between Ports	
22	IWT Total Time (H)	
23	IWT Yearly Cargo TEU	
24	IWT Yearly Cargo Liquid Bulk	
25	IWT Yearly Cargo Dry Bulk	
26	Rail Yearly Cargo TEU	
27	Rail Yearly Cargo Liquid Bulk	
28	Rail Yearly Cargo Dry Bulk	
29	Road Yearly Cargo TEU	
30	Road Yearly Cargo Liquid Bulk	
31	Road Yearly Cargo Dry Bulk	
32	Road Distance between Zones (KM)	
33	Road Transportation Speed (KM/H)	
34	Road Trans-Time between Zones (Hour)	
35	Road Transport Cost (E/TEU)	
36	IWT Transport Current Cost (E/TEU)	
37	IWT Transport VT Cost (E/TEU)	
38	IWT Transport VT Cost Saving (Euro/Voyage)	
39	Road-TLC TEU (E/TEU)	
40	Road-TLC Liquid Bulk (E/Tonne)	
41	Road-TLC Dry Bulk (E/Tonne)	
42	IWT-TLC TEU(Current) (E/TEU)	

43	IWT-TLC Liquid Bulk(Current) (E/Tonne)	
44	IWT-TLC Dry Bulk(Current) (E/Tonne)	
45	IWT-TLC TEU (VT) (E/TEU)	
46	IWT-TLC Liquid Bulk (E/TEU)	
47	IWT-TLC Dry Bulk(VT) (E/TEU)	
48	VoT TEU (E/H)	Value of time for TEU
49	VoT Liquid Bulk (E/H)	Value of time for liquid bulk
50	VoT Dry Bulk (E/H)	Value of time for dry bulk
51	Road-GC TEU (E/TEU)	
52	Road-GC Liquid Bulk (E/Tonne)	
53	Road-GC Dry Bulk (E/Tonne)	
54	IWT-GC TEU(Current) (E/TEU)	
55	IWT-GC Liquid Bulk(Current) (E/Tonne)	
56	IWT-GC Dry Bulk(Current) (E/Tonne)	
57	IWT-GC TEU (VT) (E/TEU)	
58	IWT-GC Liquid Bulk (E/TEU)	
59	IWT-GC Dry Bulk(VT) (E/TEU)	
60	P-Waterborne (TEU)	Model Split – Logit model TEU
61	P-Waterborne (Liquid-Bulk)	Model Split – Logit model Liquid bulk
62	P-Waterborne (Dry-Bulk)	Model Split – Logit model Dry bulk

9.4 Appendix D: Stakeholder meeting WP2

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VESSELTRAIN

The Vessel Train (VT) concept has been developed and applied to three different cases. For these three cases we would appreciate an external view and reflection from sector specialist. Because the VT concept is linked to different actors in the hinterland supply chains, we will be organizing two separate stakeholder meetings. The first one is dedicated to shippers (cargo owners) and the second one is dedicated to the operators (barge owners, terminal operators and ports (authorities)).

In these meetings we (the project partners) will present our main findings of the project with a special focus on economic viability. During these meetings, we want to learn from your insights and opinions about the results that we have obtained, and see if and how these developments could be implemented.

This document is intended to provide all participants with a common starting point.
Please follow this link to register for the meeting: ....

Edwin van Hassel,
University of Antwerp

Alina Colling,
Delft Technical University

Invitation stakeholder meeting www.novimar.eu