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A Day in the life of a Vessel Train – Exploring the Concept

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Abstract

The Vessel Train (VT) is a waterborne transport concept that makes use of the platooning principle. This article aims to provide a picture of a possible practical application, as well as to convey the multifaceted complexity the VT concept development entails. It shadows a trip of a follower vessel that joins into a VT and describes a possible daily routine for the inland sector. The story-line allows to elaborate on changes in the operational tasks as a result of the implementation of a VT. These changes are then further commented upon to provide an awareness of the benefits and challenges that will need to be resolved, in order to allow the VT to be an economically viable transport solution.

Keywords: Vessel Train; Waterborne Platooning;

1. Nomenclature

SS	Short Sea	**IWT**	Inland Water Transport
VT	Vessel Train	**LV**	Lead Vessel
FV	Follower Vessel		

2. Introduction

This paper introduces the principle of platooning and explains its application in the Vessel Train (VT) concept. Due to its novelty, the concept's viability has not fully been determined, however a clear image of its possible application has been shaped. This paper aims to show a possible way in which the VT may be implemented in the future. Simultaneously, it emphasises the benefits but also the development challenges that have to be dealt with for a successful implementation of the VT concept to be achieved. It is intended to interest a general audience for the complexity of the development of such an innovative transport solution.

First, the concept and its differences to road-based platooning is described. Then, further aspects of the concept are elaborated upon by telling the story of a day in the life of a vessel that is part of a VT. The format of a story line has been chosen to introduce the concept, to allows a step-by-step description of the operational processes undergone in the daily routine of the VT operations and Vessel Train users. The story is split into sections; each section represents a different operational stage of the trip. It describes VT prospects in a specific and graspable manner. Furthermore, it allows the reader, to be directed into a situation that can be connected to topics which will later on reveal a discussion of the advantages and challenges of the concept.

Once the day has been described, the physical and economical potentials and challenges of the VT concept development will be discussed. These topics are addressed with connection to the happenings within the day described and are all directly related to properties of the VT. This section will expand on the differences in the operational techniques of current waterborne transportation versus the VT.

The diverse approaches for the VT concept, as well as the challenges presented, can be considered first stage results of the project developing the concept. Before diving into the description of a day in the life of a vessel in the VT, several caveats must be mentioned. The situations described are fictitious. These scenarios do not necessarily prove economic viability. They are, instead, only a means to paint a picture of a variety of solutions to address the underlying challenges.

3. Platooning

This section introduces the Vessel Train concept and the NOVIMAR project that works on its development. Other than emphasising on the waterborne application of platooning, a direct comparison to the road based platooning development is provided. Here the differences of the two applications are clarified. The goal of this section is to provide a clear view into the investigation of this new waterborne transportation system.

3.1. Waterborne Platooning

The original meaning of the word 'platoon' derives from the military and refers to a subdivision of soldiers that forms a tactical unit (English Oxford Living Dictionaries, 2018). The transport industry has adapted this definition to transport units, to help define and develop a more efficient transport system, leading to the reduction of operating costs for different modes of transport.

The NOVIMAR project (NOVIMAR, 2017) calls this form of cooperative vessel operations a Vessel Train. NOVIMAR is a consortium of 22 companies and research institutes, funded by the European commission to determine the technical and economic viability of such a new transport concept. The viability is going to be determined by identifying as well as quantifying VT properties. These are then integrated into a transport network and a cost model. The results from such models allows for comparisons to be drawn to other modes of transport, and thus the competitiveness of the VT to be determined.

Fig. 1: Edited Snapshot of VT Animation (Vessel Train, 2018)

Fig. 1 illustrates this concept, in which each vessel can join or leave the platoon on its own accord. The train is herded by a lead vessel (LV); it is fully manned and in charge of navigation. It has communication and situational awareness responsibilities for all the follower vessels (FV) in the train. A FV needs to implement technology that allows the LV to monitor and control its propulsion and manoeuvring systems. This technology on the FV enables the vessels to operate with a smaller crew, as the navigational tasks are eliminated during the time in which the vessel sails in the train. The level of automation in this transport system is a factor that should enable it to be more economically competitive, since it brings a reduction in operating cost. The VT is a means to combine the advantages of autonomous navigation with a solution for some of the major challenges. It is therefore a means without the liability issues that are associated with autonomous vessels. Humans are still physically in control of VTs and can handle situational awareness and communication with external parties. Another advantage in the reduction of operating cost is to achieve an increase in use of smaller vessels to further push the penetration of waterborne transportation into urban areas.

The VT concept can be applied to different waterborne transport sectors such as the Short Sea (SS) Shipping and the Inland Waterway Transport (IWT) sector. The focus of this paper is on inland navigation, but short comparisons of applications in the SS sector will be provided.

3.2. Road Based versus Waterborne Platooning

The application of the platooning principle has different advantages depending on which mode of transport the principle is integrated into. The VT is a recent concept, in which research has only just begun. Truck platooning on the other hand, is already several steps ahead in development and has undergone some physical road trials (Aarts & Feddes, 2016). The main benefit for road platooning is the reduced fuel consumption as a result of driving in close proximity of the vehicle ahead. The wind shadow of the truck ahead lowers the aerodynamic drag the follower truck experiences (Tsugawa, Jeschke, Member, & Shladovers, 2016). This feature is not directly applicable for vessels. Sailing at close proximity behind one another, as will be required for the VT, actually causes an increase in fuel consumption. This is caused by the FV sailing through the wake of the vessel(s) ahead (Borst, 2019; DST, 2017).

The second advantage of road platooning is the increased flow of traffic and the reduction of congestion caused by unnecessary breaking (Tsugawa et al., 2016). Waterways do not suffer congestions in the same manner as vehicles do on roads. Waterborne congestions are mainly located at docks, bridges and ports as opposed to waterways. The improvement of traffic flow on waterways is therefore not significantly affected by the implementation of VT.

Platooning can also help the productivity of the modes of transport since both the water and road-based applications require human workers. A higher level of productivity is achieved by allowing drivers/operators to rest while part of a platoon; therefore allowing for a longer overall operating time for each individual transport unit (Van De Hoef, Johansson, & Dimarogonas, 2016).

The description and comparison of the two platooning applications is to show that the same principles can be used in different ways to create different results. The main aim of the VT concept is to improve the competitiveness of the waterborne transport system compared to the other modes of transport. Waterborne transport is the cheapest but slowest mode. If other modes are able to reduce their cost per unit of cargo moved, though the implementation of new technology, then the waterborne transport are at risk of losing market shares. Improving comparativeness is achieved by cost minimization, and by the reduction of crew, but also an increase in the productivity of the vessels.

4. Being Part of a VT for a Day

This sections is split into different subchapters: each will focus on different aspects of travel within the VT. The first subchapter gives a brief geographical explanation of the story setting before starting to introduce the implications of choosing the VT. This will be followed by a description of the joining of the VT, as well as a section which will focus on special manoeuvres in VT formation. The final part of the day is formed by a description of the separation procedure of the FV.

4.1. Setting of the Day

The day in the life of a VT, follows a Class VI vessel named Commodore. The Commodore is a 80 m long vessel with a loading capacity of 1000 t. The vessel is owned by a small family business, in which the couple mans the vessel and lives on board. Between the two of them all necessary tasks on the journey can be performed, but they are operating under the A1 sailing regime, which only allows them to operate the vessel for 14 h a day. The route sailed in the story starts in near Oberhausen, Germany, and finishes in Waalwijk, Netherlands (Fig. 2). It is a trip of approximately 180 km.

Fig. 2: Route of a day in a VT

4.2. Choosing the right VT

In Duisburg Port, the Commodore is loading its cargo. During this procedure, the crew plans the route to Waalwijk. Problems in the loading of the cargo cause the originally planned departure time to be pushed back. This means that the Commodore will miss the VT liner service departure from the port of Duisburg. The crew reschedules the Commodore onto a Tramp service VT, led by Mama Duck 3, via the VT online platform that informs the crew of all other VT options in the area. It is a cargo carrying LV that originated in Cologne, with its final destination in Hollands Diep whilst passing via the Maas. The Commodore is to connect onto to the train at the Ruhr Estuary, at the outskirts of Duisburg.
The Commodore arrives at the connection point a quarter of an hour ahead of schedule. Mama Duck 3 radio calls in to instruct the Commodore to wait, in order to prevent an overtaking manoeuvre by the VT. The Commodore is to take its place after the third FV, as the final vessel of the train.

4.3. Joining the VT

Once Mama Duck has arrived, the Commodore gets into its position within the VT and the crew activates the track pilot. Immediately, the “assisted guidance system” adapts the vessel speed to adjust its distance to the FV ahead, but also its heading to lead it in the exact path the LV has been on. Once that is reached, the speed is set to meet the operating speed of the VT. At this point, one member of the crew goes down and rests after an early morning start. The other resumes a maintenance paint job. The trip is continued incident free. The crew is being informed via radio call that by Nijmegen another FV is joining the train behind the Commodore.

4.4. Special Manoeuvres with the VT

Throughout the trip, when needing to deal with encounters with other vessels, the LV relies on its switches on the “automatic guidance” system. These force the vessel to follow the LV in a direct line and offsets it accordingly, to help deal with dynamic obstacles.
In the early evening, the FVs are being informed that the VT is approaching Weurt Lock. All vessels need to get ready for the crew to take over control during lock passage. Control is relinquished a few minutes before reaching the entrance that allows mooring at quayside. The Commodore is to join the second lock passage cycle. The time estimations in the description of the procedure are taken from Molenaar (2011).
Lock passage procedure:

- 18:00 h Arrival at upstream entrance to Weurt Lock. The Commodore temporally moored at quayside.
- 18:55 h Undocking from quay wall, ready for lock entry.
- 19:00 h Entry and mooring in lock.
- 20:00 h Unmooring and exiting lock.
- 20:25 h The Commodore and the final FV of the train need to catch up to the part of the VT that was in the first lock cycle. They have been sailing reduced speed, in order to allow the vessels in the second cycle to catch up.
- 20:50 h The Commodore catches up with the VT and relinquishes navigational control back to the LV.

4.5. Leaving the VT

Towards the end of the trip, near Hertogenbosch, the Commodore follows the VT for another 25 km before parting ways to reach Waalwijk. At the point of takeover, the track pilot is switched off to relinquish control back the crew. With a partially rested crew, the Commodore has now theoretically close to completing 14 h of travel to reach its final destination. The way to Waalwijk lead the vessel though a bridge passage and increased sailing time by 30 minutes.
The remainder of the train continues on to its final destination, at which point all the remaining FVs take back control of their navigations. In this final stage they can either decide to finish their trip as a solo vessel, as the Commodore as done, or try and find a new VT to tag along with for a second stretch of their trip.

5. Challenges of the VT Concept

This section will discuss the physical and economic benefits, as well as the challenges the VT concept faces. If unresolved, these challenges turn into disadvantages. The topics addressed in this section are structured such that they refer to the individual trip phases of the story told in the last chapter. In addition, all topics that are being discussed are deduced as a logical consequence of the properties of the VT. The topics presented are research results from the NOVIMAR project, which will also serve to asses any possible avenues toward finding a viable solution for the VT concept.

5.1. Choosing the right VT

The first part of the story, concerned with choosing the right VT, touches upon the fact that there may be different services the VT can offer. It also brings up the issue of waiting times created due to this concept. This section thus discusses different business models and services the VT could provide. This leads to a discussion of the challenges that waiting time and trust issues bring.

5.1.1. Type of Service

The description in the story refers to a VT liner service and a tramp service. When looking at the business model two main questions arise which are surrounding the type of vessel and the type of service that can be provided.

5.1.1.1. Type of LV

There are two applications of the LV service for the VT. These applications partake in the evolution of understanding the features of LV vessel types. The first is a dedicated LV, that has the sole purpose of providing a service to lead other vessels. This means that all costs created to operate this service need to be covered by the FV dues. The alternative application is using a cargo vessel that generates a standard income by moving cargo and an additional income by leading the train. This means that the contribution fee for the FV could end up decreasing, as the operating cost of the vessel is covered by the cargo transport income. The benefits and drawbacks of either of these LV services are listed in Table **1**.

The quantitative cost implication of choosing either of these LV types in a VT, have been studied by Colling and Hekkenberg (2019) in a transport model. The results showed that the most important cost feature for both LVs is the crew cost. The investment cost and the cost caused by unavailability are also identified to be of influence. It is concluded from the study that the minimum VT length, that identifies the point of economic viability of the concept, can significantly change dependent on the services provided by the LV.

Table 1: Benefits and Drawbacks of Different LV Types (Colling & Hekkenberg, 2019)

LV	Benefits	Drawbacks
Dedicated	• A smaller vessel can be used, which lowers the operating costs of the overall vessel • High availability since it does not need to unload cargo • The destination of the VT is dependent on FVs • Flexibility in sector (IWT or SS) application • The VT is only restricted by the speed limits of the FVs, the LV is built to lead all size	• Costlier for the user, since the total LV operating cost has to be compensated for by the FVs • Slower implementation since higher capital cost is required to construct a complete new LV
Cargo	• Lower FV contribution cost since, the income from cargo partially covers operating cost of the LV • Faster implementation opportunities into the industry since refit vessels can be used • Two sources of income	• The availability of LV is restricted by (un) loading of the cargo • The destination of the VT is dependent on cargo destination • Less attractive to FV due to more restrictions in destination and departure • Space required on board for the VT monitoring personnel • VT speed is additionally restricted by the speed limitation of the LV

5.1.1.2. Service Types

Aside from the type of LV, it is also important to consider the way in which the VT operates. The commonly known service types are tramp and liner services. The tramp service is focused on the spot market and does not have a schedule. In contrast, the liner service operates on a predefined schedule. Each of these services bring unique situational benefits. For example, if the VT is operating as a liner service, timely departures are of high importance. It allows for more long term planning to be made but small wiggle room for delays. In ports the

IWT vessels are not given priority (Malchow, 2010), which causes long waiting times and makes it difficult to reliably schedule in liner services. Such an application would thus be more suitable for VT for SS vessels, which can be scheduled more reliably. Considering the two LV types, the dedicated LV is better suited for the liner service providers, since no cargo is loaded that could cause a delay. Operating a liner service also implies a requirement for a regular demand of cargo flow.
Less busy routes are more appropriate for the tramp service, which is based on the needs of the customer. This increased flexibility is advantageous but will likely come at a cost of longer waiting times and higher VT dues.

The most suitable business case is dependent upon the identification of the boundary conditions the VT requires to be viable. These boundary conditions may, for example, involve different sizes of FVs, operating speed, maximum and minimum length of the VT or even the number of locks passages the VT should not surpass on any given trip. Colling and Hekkenberg (2019) have been able to set an initial estimate of a minimum VT length, based on an economic analysis, to 6 FVs. This value may still vary with further research done into the VT assessment, however it provides an initial idea of the expected size magnitude.

5.1.2. Waiting Times

As seen from the first part of the story, waiting times are going to be increased by the VT service. This case describes an advantageous situation in which only one vessel has to wait. However, dependent on the departure requirements of a VT, situations may arise in which an entire VT may wait for multiple FV to join the train. The evaluation of waiting times aides in the understanding of how the productivity of the LV as well as the operations features of the FVs may be affected.

Waiting times at port, before the departure or even at locks as they are described later in the special manoeuvres section, can make the difference between a viable and unviable VT concept. How long can a VT wait for the arrival of an extra FV in the train? To answer this question one needs to directly compare the cost and benefits of using the VT. Two approaches allow for the anticipation of potential costs and benefits in different manners. For example, Benefits could be kept separate for each individual VT user. it would therefore be necessary for individuals to pay their fair share to the LV operator, making individual benefits from VT operations paramount. This approaches assumes VT users to be either individual businesses that operate their own vessels or to be agents who coordinate multiple VTs as a service. The latter would require information on all other operating VTs in order to advise on alternative VT solutions which may be needed.

An alternative approach to the above would be to request all VT users to share the costs and benefits created by the VT. This approach assumes a larger organization is involved in the coordination of the VT, and is thus charged with the responsibility of cargo movements for the entire VT, therefore overlooking the overall profit. Knowing the maximum time a VT can wait for a FV can help determine feasible departure frequencies. These in turn would have to be crosschecked with the current demand requirements to see if such departure frequencies are viable.

5.1.3. Trust Issues

Considering shared benefit situations brings up a major challenge, which has to do with the trust issues that are present especially in the inland navigation sector. This issue needs to be addressed to provide a realistic view of the implementation of the VT.
Most vessels are operated by small family businesses, where the family lives on their vessel (Hekkenberg, 2013). Many of these are not willing to unionize and therefore cannot obtain leverage against bigger corporation's which they may have contracts with. So, if there are any contracts set up, these are frequently only for a short timeframe or are breached. This causes a large mistrust within the industry against large independent organizations. These are conclusions that have been drawn from interview with vessel operators, done as part of the consortium work (Van Hassel et al., 2018).

5.2. Joining the VT

The description on the joining of the VT, in section 4.3., mentions the technology required in order to join a VT. It also describes the most important feature which allows for a reduction in operating cost. This feature is the reduction of crew with an increase of productivity for vessels. Now that operating times and requirements of joining the VT have been considered, the next sections will focus on VT technology requirements, operating time changes and how the modernisation of tasks could work as advantageous assets.

5.2.1. VT Technology

The vessels that compose the VT are required to have appropriate technologies installed to allow following and leading, dependent on their role within the VT. Up to now, NOVIMAR has developed a technology in form of a software update that can be integrated into the existing navigational systems. It is thus expected that the activation and deactivation of the VT technologies will be as little as pressing a button. The supporting system that is found on the FVs is integrated through software into the navigational system of the vessels. In order to implement a successful use of VT, it would require the capacity to perform the following tasks (Friedhoff et al., 2018):

- Track keeping as defined by LV
- Distance keeping to LV, or the FV in front
- Initiation of stopping manoeuvre in case of emergencies

The way in which the FVs follow the LV can be done in different manners. These may be more or less appropriate dependent on the geographical und traffic conditions of specific scenario. The first presented operation mode, referred to as the “assisted guidance”, allows the vessels to follow in the LV’s path and can thus deal with static obstacles in a more predictable manner for other traffic observers. The operation mode of “automatic guidance”, on the other hand, allows all FV to directly follow in a line with the LV and simultaneously offsets its positions based on the LV’s movements. This makes it possible to deal with more dynamic situations, such as encounters with other vessels. Both of these modes are part of the Argonics track pilot that is being adapted for the application in the VT (Argonics Gmbh, 2017). Successful use of these pilot tools will however still require knowledgeable boat masters on the LV, that can guide all FVs through unconventional situations. Equipment-wise, the additional VT technology requirements are expected to be small. Most likely, these requirements will involve a form of a navigational software and communication equipment such as an antenna that allows data to be transmitted to the LV.

5.2.2. Operating Time Changes

The VT invokes different types of operational changes upon the vessels. The first is related to potentially negative physical restrictions of FVs, while the second allows to create the main advantage for the FVs, through operational cost reduction.

A VT can only go as fast as its slowest member. Which means careful consideration has to be placed on deciding which vessel can actually join a specific train. The operational features of a VT have to be adapted based on the vessels that form the train. The speed capabilities of a vessel are dependent on the installed power of the vessel size and the loading conditions of the vessels, which influences the draft of the vessel. If all but one vessel in the VT are forced to slow down over a long period of time, the benefit of sailing in the VT diminishes or may even disappear for the faster vessels. The same can be said for a slow vessel that would have to speed up to a higher speed than its design speed. This is in spite of the theoretical fact that vessels have the ability to increase their engine loads in emergency situations, therefore allowing them to speed up,. Operating at an emergency speed should not be done outside of emergency situations as the integrity of the engine may become compromised.

The positive changes in operating time caused by the VT are due to an increase in sailing time with less crew on board. This applies specifically to inland vessels, since they have the added restriction of different sailing regimes of 14 h, 18 h and some have a sailing regime of 24 h. These regimes depend on the number of crew members (CCNR, 2016). It is thus logical that this topic falls under the manning features but also under the operations features of the FVs.

The VT will operate at a 24 h regime. The intention is to allow the FVs that are part of the train to operate at the LVs operating ability, while the FV keeps its crew level for a lower sailing regime. In essence, the vessel becomes more productive with the same crew cost. The time the vessel spends in the train will allow the crew to either rest or perform other tasks, such as maintenance tasks, in the meantime. To what extent this can be achieved, especially considering quick reaction time of emergency situations, is a point of close investigation within the NOVIMAR concept development.

VT services will provide increased benefit for long distances users. If emergency interventions of the crew are assumed to be exceptions during VT operations, the roles on board can shift task allocations, which in turn eliminates the need for certain crew members. The effects of automating the navigational tasks as it is done by the LV, has been shown by Kooij and Hekkenberg (2019) for the crew of a SS vessel, where up to three crew members (the second officer, and two ratings) can be taken off from current crew levels. A similar approach can be taken for the study of the effect of the VT on IWT crews.

5.2.3. Modernizing Vessels

Considering the changes the implementation of the VT will create for the roles on board, it is also important to acknowledge that modernization in tasks and reduction in crewmembers will make the sector more contemporary. A challenge the IWT sector is currently facing, which will unfortunately continue to become more severe as time passes, is the increasing average age of its crewmembers. Life on board is less popular for young people than it has been in the past. Youths would rather live in cities than be confined to living and moving around on a vessel (Van Hassel, 2011). An autonomous vessel may still need circumstantial human intervention, but such tasks should not require a person to live on board continuously. Although the increased level of automation on the VT will not make humans on board obsolete, it will change the nature of the work done and modernize certain tasks.

5.3. Special Manoeuvres in VT Formation

Special manoeuvres are key issues in the development and viability analysis of the VT concept. Some special manoeuvres, as described in the day sailing in a VT, can be performed in VT formation, others may require the VT to adapt procedures to be deal with these situations.

5.3.1. Encounters Manoeuvres

Encounters with vessels from opposite directions, overtaking or even crossings are to be taken into careful consideration with the VT. Overtaking procedures are already a lengthy manoeuvre for individual vessels in which the vessel that is being overtaken usually slows down to allow the overtaking vessel to pass. On top of that, the waterway needs to allow sufficient visibility of encountering traffic (Verheij, Stolker, & Groenveld, 2008). If an entire VT would have to be overtaken, such a lengthy process has to be carefully considered and fit into traffic procedures, to ensure it does not prevent other waterway users from surpassing the VT. Overtaking of dynamic objects in VT formation may theoretically be possible. A practical scenario would however have to be checked by regulatory entities to determine if such manoeuvres would safely be able to be achieved.

Special manoeuvres will affect not only the VT users but also surrounding traffic. One of the most predominant questions surrounding this issue, is whether the VT will be treated as a unit for security reasons, or if the individual links between FVS are flexible enough to allow for instance a ferry to pass in between the FVs. Otherwise, large waiting times may be created for the ferry if they have to allow the VT to pass unperturbed.

5.3.2. Lock Passage

The procedure described as part of the storyline, makes it clear that there are both similarities and differences between the current conventional procedures and the ones for FVs. The waiting times at the locks may be sporadically longer when VT arrives, but as such they are similar procedures to the current vessel.

The main difference to the current vessel operations can be seen after the lock has been passed. Part of the vessel train cannot continue the journey at the VT's normal operating speed, since it needs to allow the vessels of the later lock cycles to catch up with the platoon. Such a procedure has been assumed due to the confined space of rivers, that may not allow a large number of vessels to wait for the entire train to have passed though the lock, before continuing on the journey. Additionally, vessels are more easily controlled when they are moving, compared to when they are stationary, which is why a slow progression of the VT after the lock is favourable to a stationary waiting period.

Slowing down may be feasible for a few extra cycles, judging from the IWT lock time used for the log. However, there will come a point where the reduction in speed for a prolonged period of time, will erase any advantage the VT may bring to all FVs, just as it was described for the waiting times before joining the VT.

5.3.3. Bridge Passage

The procedure for bridge passage is a simplified version of the lock passage. The main difference is that it is not defined by the time it takes to move vessels from one side to the other of the obstacle, but rather by the amount of time the bridge can stay open. In the case of the bridge opening, the waiting time created affects both the vessel operator but also external parties. While the bridge stays open, the bridge cannot be crossed by pedestrians or vehicles, thus potentially creating traffic jams. The additional time the bridge stays open is wasted time for people. This example constitutes a societal cost created by the VT. In some areas, this may be a negligible issue but in other areas, there may be a maximum opening time for the bridge. For instance, bridges may only be allowed to stay open for 4 minutes at a time (Gemeente Haarlem, 2018). Such a limitation will cause longer VTs to pass the bridge in cycles. Both the societal and the direct costs must be considered when assessing the feasibility of the concept.

5.4. Separation from the VT

The piece describing the separation of the Commodore from the VT further emphasises the point made about the changes in operating time. Nonetheless, it is important to highlight the benefit of the solo features of FV, which allows them to reach the final destination. Prior to the conclusion , this section focuses on a topic that VT implementation will have an effect on, but that has not yet been directly addressed in the paper. This is the increasing use of small IWT vessels.

5.4.1. FV Capability to Sail on its Own

Using the VT services does not mean that the user is bound to the VT's destination. On the contrary, the VT is designed with the intention of only being a partial solution for the vessel operator. Each individual vessel is required to have the capabilities to sail to its final destination on its own. This means any work done on board while sailing in the VT will have to be done with careful consideration of the hours requires at the leaving stage of the VT.

5.4.2. Increasing the need for Smaller IWT Vessels

As stated in the introduction an aim of the VT concept is to deliver cargo closer to urban areas, to improve competitiveness of the waterborne transport with other modes of transport. This can only be done by small IWT vessels. However, the fleet of smaller vessels is continuously diminishing. Larger vessels make greater use of the economies of scale and can hence lower the price per unit of cargo transported compared to smaller size vessels (Van Hassel, 2011). Larger vessels can create more income, which is the most important element for banks willing to provide funding for vessels. The lack of financial support for smaller vessels makes them even less attractive for potential vessel owners.

The VT concept tries to work against this trend by lowering the operational costs through crew reduction and an increased productivity with the enhanced operating time. Doing so makes operating a smaller vessel more attractive and may help solve the financing problems that current inland vessel operators are facing.

6. Conclusions

The direct comparison of the water and truck platooning principles makes it clear that the advantage of fuel savings is not applicable to the waterborne alternative. However, this analysis has highlighted the need to identify an appropriate business model to allow vessels to benefit from the VT application.
This is further elaborated upon by the story that is being told in this paper. It conveys a vision of the application of a VT, by using the excising waterway infrastructure. Each travel phase addresses existing challenges of the transportation system and explains the way in which the VT intends to deal with and improve them. Simultaneously, each of these topics also elaborate on challenges that the development of the VT concept faces to be able to solve into a viable transport solution and thus emphasises the complexity of the development. The consideration of all these topics offers a glimpse into understanding the complexity behind the development of such a transport solution.
The description also demonstrates that both the physical and operational changes which allow the implementation of VTs, for existing vessels, are fairly small. Physical equipment requirements are in form of a navigation software and communication equipment with the LV. Operationally, it will be necessary to find a suitable train for each route. Additionally, it will also be necessary to add an appropriate waiting time to allow for the gathering of all vessels.
It has become clear that the following two main criteria will be pivotal in determining the viability of applying VT as a concept: 1) waiting times and special manoeuvres; 2) the selection of the appropriate vessels for the correct train, so as to avoid delays. Thorough analysis of these features is hence necessary. This will be completed in further research through the development of purpose built cost and network models, which allow for the identification of boundary conditions for the application of the VT concept. These conclusions could then be applied as guidelines for the successful implementation of this concept. Until 2021, the NOVIMAR project aims to consider all the mentioned topics above and more, to accurately identify if the Vessel Trains are a feasible and viable option for all transport actors involved as well as for society.

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