# Velocity optimisation on waterways

# Impact paragraph

The transportation system as is not yet sustainable [44]. Oil is becoming a scarcer resource as it is sourced from uncertain supplies. Due to this growing uncertainty and price increase in oil, the economic security could be severely impacted due to its dependence on oil. Furthermore, the increasing demand for transport caused by globalization puts a high pressure on the existing transportation network. The congestion on the road network continues to increase and thus poses new challenges to the transportation sector and our society.

The EU proposed the Green Deal in order to define new environmental goals and strategies on achieving these [1]. Among others, they claim that their ambitious climate goals require a shift to more sustainable transport modes such as rail and inland waterways. In comparison to road transportation, the use of inland waterways is more environmentally friendly because of lower greenhouse gas emissions per volume or weight unit. It is also relatively cheap due to economies of scale and increased bundling opportunities. However, the inland waterway network is less dense than the road network.

Another strategy is the focus on multi-modal transport, i.e. combining rail and waterborne transport, including short-sea shipping in a supply chain. This may increase the coordination and administrative cost, but has a high potential to increase the use of more sustainable transport modes and thus to decrease overall emission.

Furthermore, the Green Deal calls for increased efficiency across the transportation sector. Digital technologies, smart applications and other new innovations will play an important role in increasing the capacity of current infrastructures and in reducing the cost of sustainable transportation.

In this research, we focus on problems that practitioners in inland-waterway transportation are currently facing. The real-world problems are reduced to mathematical formulation and solution concepts for the mathematical problems are proposed. For each of the solution concepts, we provide theoretical results or numerical experiments to give further insights.

Practitioners and regulators may use the designed algorithms and extend them to the specific real-life situation that they are facing. Thus, the results this thesis can be used to evaluate and design new business models that create profit and efficiency in inland-waterway transportation. Furthermore, the ideas may help regulators to evaluate the effectiveness of investments to digitalize and controlling measures.

The second chapter concerns a payment mechanism for an inland waterway system such that the total fuel consumption is minimized, without the opportunity for vessels to profit by deviating from the proposed solution. The applicability of these concepts is constrained by the computational complexity of the methodology used. Therefore, practitioners need to extend these ideas and provide computationally solvable solutions for real-life scenarios.

In the third chapter, we introduced and proposed different algorithms for the Periodic Lock Scheduling Problem. The enforcement of regular schedules could potentially be a management strategy for the locks. Vessels would then adapt their velocities according to this schedule and congestion would reduce drastically. The algorithms could be extended to scheduling tools for lock operators.

In the third chapter, we consider an entire fleet of vessels on a setup with multiple locks on river crossings. The algorithms are designed to provide a fast solution, which enhances the practicability. Additionally, they were designed for a general problem setting, and can be extended and adjusted to specific situations. Therefore, the proposed algorithms can be used by policy makers and practitioners to implement a central scheduling system on inland-waterways.

In the final chapter, strategies and algorithms for passing through a lock under uncertainty are presented. If the required data is accessible to a skipper, the algorithms can potentially be used in scheduling tool that helps skippers individual to save fuel while passing a lock. Therefore, the need for centralisation and cooperation is low, which then enhances attractiveness and acceptances by skippers.

There are many ways research on inland-waterway transportation can be extended even further. As claimed in the Green Deal, the success of the climate goals depends on multi-modal transportation. Much research on inland-waterway, harbor management and truck transportation has been conducted. Further research could focus on problems that occur if multiple modes of transportation are combined. Furthermore, there are many open question stated in this thesis that would lead to further refinement and extensions. All this together increases attractiveness, awareness and acceptance of practitioners.