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Introduction

Who has never waited at a traffic light because all but one lanes of the road were closed for construction works? In this situation, the red light seems to stay for ages until a bunch of few cars from the other side arrive and the lane is finally free for the own passage. The reason is that after the last car from the other side entered the lane we have to wait the complete time the car needs to transit the stretch. The longer the distance the longer is the waiting time. This is a classical example of bidirectional traffic. It is characterized by the property that after one vehicle enters a tight lane, further vehicles moving in the *same* direction can do so with relatively little headway, while traffic in the *opposite* direction usually has to wait until the whole lane is empty again (cf. Figure 1 for a schematic illustration).

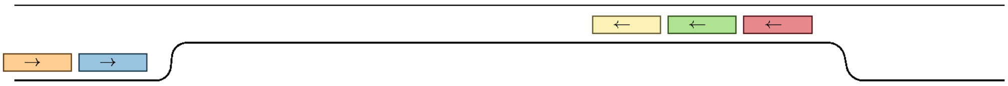

Figure 1: Traffic in two directions through a bottleneck. The three vehicles from the right can follow each other passing the tight lane relatively fast, while the two vehicles from the left have to wait a long time until the last vehicle from the right finished the transit of the complete stretch.

For examples like road works, tight mountain passes, or bridges traffic lights are a good solution to prevent collisions of vehicles entering a tight segment at its different ends. But when single-track infrastructures are controlled by some operators the planning process has to deal with the special character of bidirectional traffic, e.g., when coordinating trains on single-track railway lines.

In this thesis we investigate a further prominent example of that kind: the ship traffic at the Kiel Canal. Situated in the north of Germany the Kiel Canal links the North and Baltic Seas. Hence, the canal is operated bidirectionally. Since offshore vessels are not primarily designed for inland navigation, the passing of two ships with large dimensions is not possible at arbitrary positions. To deal with these problems, there are wider areas called sidings within the canal that allow for passing and waiting, cf. Figure 2. Hence, we actually deal with a sequence of bottleneck segments and decisions must be made about who is waiting for whom, where, and for how long. Responsible for these decisions is the Waterways and Shipping Board with a team of nautically experienced expert navigators. They try to distribute necessary waiting times in sidings fairly among all ships.

Since the Kiel Canal has seen a tremendous growth of traffic demand, which is expected to continue, an enlargement of the canal is planned. There are a bunch of possible construction options such as extending or creating sidings or to allow more flexible passing of ships by deepening and/or widening crucial parts of the canal. In order to assess the cost and benefit of these options their combined effects under predicted ship traffic needed to be reliably estimated. In this thesis we present the mathematical and algorithmic foundation