Network analysis of delay propagation on Swedish railways

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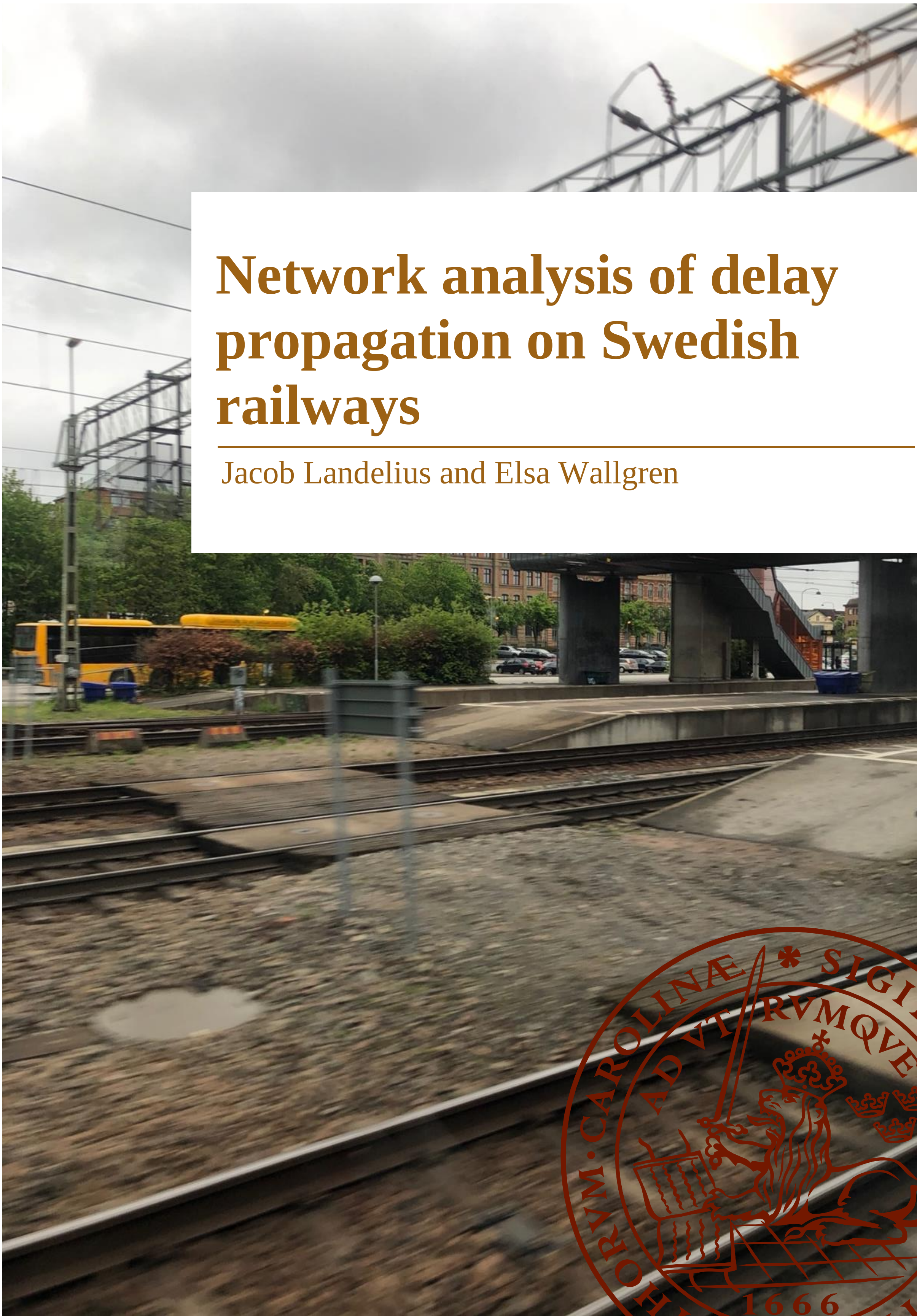

Where, and to what extent, delay arises in the Swedish railway system as well as how it spreads can be simulated by employing a network epidemic model, traditionally used to model infectious disease, with satisfying results.

Today, passengers travelling by train are twice as many as they were 30 years ago. The increasing awareness of environmental issues with other methods of transportation is likely to favor railway travel, and so the number of passengers is expected to continue to rise. As the number of passengers have increased, so have the requirements on keeping trains on time. Delayed trains are not only costly for train operators, but may also affect how likely people are to travel by train. Understanding where and why delays occur as well as how it might spread is therefore important both from an economic point of view as well as environmental one.

In the report A network analysis of delay propagation on Swedish Railway, it is shown how delay can be simulated and analyzed by using a modified version of a well-known network epidemic model, the SIS (Susceptible-Infected-Susceptible) model. In this model, a node typically changes state from Susceptible to Infected at an infection rate , and from Infected to Susceptible at a recovery rate . For the purposes of taking into account the possibility of trains being spontaneously delayed due to external factors (e.g. bad weather, power failures), the model is modified and includes a third parameter () to allow for nodal self-infection. In other words, a station can become infected without "catching" the infection from another station. Another modification is that, unlike the classic SIS-model, the model employed uses heterogeneous parameters, meaning that the rate of delay propagation (traditionally) is line-specific. Similarly, the rate of recovery (traditionally) as well as the rate of spontaneous delay, is station-specific.

By then optimizing the probability that a train carries with it infection (delay) from one infected station to another, susceptible one, the simulation is able to reproduce the level of delay over time as well as the geographic distribution of delay. In other words, the simulation reproduces both global as well as local delay behavior, thus showing that delay in the Swedish railway network may be simulated using the modified SIS model.

Three main uses of the resulting model are identified: the identification of critical points in the railway network, the simulation of the effect of delay preventive measures and the prediction of future delay. All of these may be valuable tools for stakeholders when prioritizing amongst projects and allocating resources. This can in turn impact the overall delay in the system and hence have an effect on the future demand of train travel in Sweden.