1. Motivation

The development of railway traffic in Germany has shown a significant increase over the recent years, especially in rail freight traffic. The total amount of goods transported on the German railway network has risen from 291 Mt of transported goods in 2001 to 374 Mt in 2013, which means a total increase by 29 % in 12 years or an average increase of 2.5 % per year during this time. The growth was expected to be yet higher, and without the effects of the economic crisis in 2009, the increase would probably have been even more considerable. This development is shown in Figure 1.1. Experts in the field speak of a mere “renaissance” of rail freight traffic, making the decline in earlier decades almost forgotten.

![Figure 1.1.: Development of rail freight traffic in Germany between 2001 and 2013 in megatonnes (Mt) of transported goods per year; Statistisches Bundesamt (2014)](image)

On the one hand, this development is explainable by an overall increase in freight traffic, which is due to the importance of Germany as an exporting country and also as a freight transit country. Furthermore, ecological considerations gave rise to political incentives aiming at the shift from road transport to rail transport. The latter plays a main role in concepts and blueprints of planning authorities for a freight traffic that is “compatible” with the protection of the environment, particularly in terms of pollution, energy consumption
and land use. In this respect, rail freight traffic is widely seen as a resource preserving means of transport. As a result, these incentives also led and still lead to remarkable growth in inland railway traffic.

A recent strategy paper by the Umweltbundesamt (2009), the German Federal Environment Agency, deems it possible to increase the modal share of rail freight traffic from 18% in 2008 to 26% in 2025. According to their figures, accomplishing this aim would require a growth in the capacity of rail freight transport by 80% over this period, aiming at a value of 213 Gtkm in 2025. This would translate into 710 Mt of transported goods on the railway network if we assume the mean transport distance of 300 km observed in recent years to remain constant—a figure twice as high as nowadays.

The target value of 213 Gtkm for the transport capacity has been taken up in a study commissioned by the Umweltbundesamt (2010) which investigates the expansion requirements of the German railway network to accommodate the resulting traffic. According to this study, the expansion of the railway network has dragged behind the demand development for a long time as only the most pressing capacity shortages have been attacked and only the most necessary investments in the sustainment of railway traffic operations have been undertaken. Furthermore, it diagnoses a bias in the previous investment strategy towards projects focused on passenger traffic, neglecting the much higher growth in freight traffic. As a consequence, the German railway network exhibits several shortcomings in capacity already in the status quo, which frequently causes disruptions in the operating schedule of the railway transport companies.

The cited study aims to identify the regions in the railway network which need to be extended most urgently within the next two decades. It takes the freight traffic flows of 2007 with 105 Gtkm as a basis and projects that the current network without expansion is able to accommodate between 10 to 15% more traffic (about 130 Gtkm). To predict the traffic flows under a scenario of 213 Gtkm per year, it uses the very simplified assumption that the volume of traffic doubles on each of the lines in the network compared to the values of 2007. Starting from these figures, it evaluates potentials for using the remaining capacities to reroute part of the traffic in order to identify the lines where bottlenecks are expected to become most pressing. Figure 1.2 is directly taken from Umweltbundesamt (2010) and gives a graphical representation of the bottleneck situations in their underlying scenario.

The left picture shows that under their assumptions, significant undercapacities in the railway network have to be expected along the two main north-south corridors of transportation in the west and in the centre of Germany as well as in other regions. On the right picture, we see that using the remaining capacities in the network to reroute part of the traffic is not sufficient to accommodate the complete demand without losses in operation quality. Furthermore, it has to be taken into account that routing the traffic along detours decreases the efficiency and thus the profitability of the railway system.

From these findings, the study comes to the conclusion that a determined expansion of the capacities in rail freight traffic is needed. They calculate with 11 billion Euros of required capital to provide the necessary capacities and make suggestions for specific expansion projects to enact.
1. Motivation

The high growth rates in rail freight traffic to be expected for the future together with the tight public infrastructure budgets were the motivation for our industry partner GSV to start a joint project with the FAU Erlangen-Nürnberg on optimal expansion strategies for the German railway network. The aim of our joint study was to find an optimal distribution of the available budget to realize the infrastructure projects which are most beneficial for increasing the capacities in rail freight traffic. This spacial distribution of the budget was to be complemented by an optimal schedule for the implementation of the capacity expansions. The ultimate goal was the development of a dedicated planning software to be used by planners at GSV to study the optimal expansion of the network under different demand scenarios.

Our partners at GSV provided us with the necessary data on the railway network, the expected demand development and the effects of the available measures to improve the infrastructure. Our study uses 2010 as its base year, for which we could use demand figures from the database of GSV. For the target year 2030, they put especially high efforts into realistic assessments of future demands, which are the foundation of any reliable investment strategy. This demand prediction for the year 2030 serves as the basis for the strategic planning of Deutsche Bahn AG as a whole.
The resulting mean annual growth rates of about 2% between 2010 and 2030 are not as progressive as those underlying the study by the Umweltbundesamt (2010) with about 4% over the same time horizon. Nevertheless, the GSV prediction results in a total increase of almost 50% in rail freight traffic over 20 years, which can only be accommodated if the throughput of the network is significantly improved.

The above task leads to a challenging optimization problem whose solution is the motivation and the starting point of this thesis.
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