Railway Track Capacity: Measuring and Managing

This thesis adopts a holistic approach towards railway track capacity to develop methodologies for different aspects of defining, measuring, analysing, improving and controlling track capacity utilisation. Chapter 1 presents an overview of the concept of capacity and the railway capacity challenge is explained. Chapter 2 focuses on past approaches to defining and analysing the concept of railway capacity. Existing methods for estimating capacity utilisation are studied in four categories: analytical methods, parametric models, optimisation and simulation. Chapter 3 examines various factors affecting capacity utilisation. Chapter 4 develops the systems engineering foundation toward railway capacity. From process improvement methods, Six Sigma and its Define, Measure, Analyse, Improve and Control (DMAIC) cycle is chosen as the underlying framework of the thesis. Chapter 5 defines lean, micro and macro capacity utilisation based on the discrete nature of railway capacity. Data Envelopment Analysis (DEA) is used to develop two novel methodologies to analyse lean capacity utilisation. A DEA model analyses relative efficiency of train operating companies based on their efficiency to transform allocated train paths (timetabled train kilometres) and franchise payments to passenger-kilometres while avoiding delays. A case study demonstrates its application to 16 train operating companies in the UK. The operational efficiency of stations is benchmarked from similar studies for ports and airports. Two models are developed for analysing technical efficiency and service effectiveness. 96 busiest stations in Great Britain are analysed by this method. For analysing capacity utilisation in the freight sector, the concept of ‘profit-generating capacity’ is introduced in chapter 6. It is applied in an American freight case study to choose between bulk and intermodal trains in a heterogeneous traffic. DEA is also used in another case study for identifying the most profitable commodities. Chapter 7 suggests using variation reduction and failure mode and effect analysis (FMEA) to control capacity utilisation. For improving railway capacity utilisation it is suggested to find and improve the weakest line section, the weakest trains and the weakest station. A real world case study of the South West Main Line in Great Britain, demonstrates applying these aspects. For finding the weakest line section two existing methods of the UIC 406 and the CUI method are compared with each other. For finding the weakest trains a meso index is suggested. It can identify which trains can be removed to free up some capacity in the busiest section of the line. Simulating delays and removing the highest delay causing trains is another method suggested. The weakest stations are identified by applying the DEA methodology developed in chapter 5. Target values for train stops at each station are suggested to be fed to the tactical timetabling. It is concluded that developing methodologies to analyse, improve and control railway capacity utilisation is needed and the methodologies proposed in this thesis can be a stepping stone towards them.

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