Quantitative Methods for Assessment of Railway Timetables - DTU Orbit (22/05/2019)

Quantitative Methods for Assessment of Railway Timetables

The aim of this PhD thesis is to improve the attractiveness of future railway timetables. To achieve this goal, the qualitative term “timetable attractiveness” needs to be made quantifiable. To establish what timetable attractiveness is, the thesis gives an introduction to railway timetables in the form of a timetable definition and an overview of commonly used timetable types and existing timetable classes. All major timetable stakeholders in a given railway sector must agree on the timetable aspects covered by the term “timetable attractiveness”. This research succeeded in creating such an agreement in the Danish railway sector, through a process that included individual stakeholder interviews followed by a joint timetabling criteria workshop. The agreement is a list of six prioritized timetable evaluation and optimization criteria. To make the evaluation criteria quantifiable, a set of key performance indicators (KPIs) was developed beforehand. A total of 13 KPIs are presented. Their practical applicability has been successfully tested on examples of real-life Danish timetables. The thesis recommends a revised timetabling process at railway infrastructure manager Rail Net Denmark (in Danish: Banedanmark) that will take the recommended KPIs into consideration. This new time-tabling process will create the necessary foundation for improving future railway timetable attractiveness in Denmark. The aim and the structure of this PhD thesis are described in Chapter 1. The thesis shows how railway traffic and the railway timetable have been interlocked almost from the opening of the first public railway line 1825. A timetable increases both the traffic safety and the attractiveness of railways. Timetables plan traffic, avoid train collisions, and announce train services to potential customers. Chapter 2 gives an introduction to railway timetables. The thesis identifies a need for an improved European definition of a railway timetable. A two-part definition is introduced, with one part covering a liberalized railway sector and the other covering a state-owned or completely privately owned railway monopoly. The former is an agreement between an infrastructure manager and one or more train operating companies. The latter is an internal company agreement. This is followed by the presentation of some basic facts that apply to all railway timetables. A railway timetable has a time period of validity. In the European Union, this has been harmonized to one year and the timetable changes take place on the Sunday following the second Saturday in December. The thesis distinguishes between timetables created as part of long or short-term planning. A short-term timetable tries to make the best of the available resources, such as railway infrastructure and rolling stock fleets, to accommodate as many railway customer preferences as possible. When preparing a long-term timetable, the starting point is to create an ideal timetable that fulfills the customer preferences on the assumption that the necessary infrastructure and rolling stock can be made available. Moreover, the thesis identifies eight basic line structures for train services found in a railway timetable. These basic train service line structures are:1. Point-to-point line (high speed trains)2. Circle line (suburban trains or metro)3. Centralized nodes (e.g., Paris or London)4. Corridor / tree structure (e.g., the Danish railway network)5. Star shape (e.g., the metro in Rome)6. Universal star shape (e.g., the metro in Athens)7. Railway network with a core route (suburban trains in Copenhagen and Munich)8. Meshed railway network (German Intercity-Express trains). Chapter 3 gives an overview of the six most commonly used timetable types in the railway sector. Thesetimetable types are:1. The public timetable (available to everybody, on paper and/or digitally)2. The working timetable (primarily used by train staff)3. The graphical timetable or train graph (used by timetable planners and traffic dispatchers)4. The track occupation diagram (used by timetable planners and traffic dispatchers)5. Rolling stock roster plan (used by employees of the train operating companies)6. Train staff roster plan (used by employees of the train operating companies). The thesis identifies seven existing basic railway timetable classes. At the beginning of Chapter 4, an extended timetable categorization model is presented. The categorization of timetables into classes is based on the level of structure in a given timetable. A set of basic structural characteristics determine the level of structure. These structural characteristics are: x Timetable periodicity/the timetable is systematic (repeating traffic patterns)x Timetable symmetry (same stopping pattern and travel times for both driving directions of a train service)x Train meetings at selected station hubs (optimal transfer options)x High frequency train services (train services run at least every 10 minutes). The seven basic timetable classes identified by this thesis are: x The periodic /systematic timetable - The symmetric periodic /systematic timetable - The non-periodic/non-systematic timetable - The symmetric non-periodic/non-systematic timetable - The integrated non-periodic/non-systematic timetable. Based on earlier British and Swiss approaches to measuring the level of structure in a railway timetable, the thesis proposes improvements to these existing methods and introduces two new timetable structure indexes based on the newly developed concept of timetable patterns. The two indexes are: x Systematic timetable index – using the most used timetable pattern timewise x Systematic timetable index – using the longest continuous timetable pattern timewise. Finally, the seven timetable classes are described and compared in detail with each other. This gives an overview of strengths and weaknesses based on selected, but generally accepted, timetable evaluation criteria. Identifying the basic railway timetable classes in a timetable that covers an entire network is difficult and labour-intensive work. Chapter 5 presents a series of examples of timetable analyses to illustrate the VI Summary complexity of the task. It starts with the example of one railway line section served by one train service running according to one timetable class; goes on to the more complicated example of one railway line section served by several train services with different timetable classes, and ends with the most complicated example of an entire railway network served by several timetable classes. The thesis recommends weighting the timetable classes identified with timetable statistical factors such as: the number of train runs, passenger numbers, freight tons, train-kilometres, and passenger or freight ton-kilometres. Chapter 6 starts with a brief historical overview of the liberalization process in the European railway sector and of the liberalization of the Danish railway sector in particular. This is followed by a presentation of the overall Danish railway timetabling process. The process is one of collaboration between the infrastructure manager Rail Net Denmark (in Danish: Banedanmark), the train operating companies, and the Danish Transport Authority (in Danish: Trafikstyrelsen), which is the buyer of public railway service traffic. Next comes a detailed description of the timetabling processes at the following railway timetable stakeholders: x The Danish Transport Authority – buyer of public railway service traffic x The train operating company DSB – the largest passenger train operator x The state-owned infrastructure manager Rail Net Denmark – prepares the annual timetable. There is no formal timetabling process at the Danish Transport Authority.
so the result of
the process initiated and conducted in thereferease for the thesis. It is the first version of a
community list of prioritized
railway timetable evaluation
and optimization criteria in
Denmark. Since the Danish
railway sector is highly affected
by the ever-changing
national political climate, this
list is not necessarily very stable.
The thesis therefore recommends
that a similar (and perhaps
improved)
process should be carried out
every two to five years to ensure
an up-to-date common
understanding of timetable
attractiveness in the Danish
railway sector.
A lack of focus on customer preferences was also
identified through the results of the
stakeholder interviews and the workshop.
None of the parties set aside enough
resources to perform large analyses within
this important subject.

Chapter 8 analyses each criterion from the common
Danish list of prioritized railway timetable evaluation
and optimization criteria with regard to the most important
influencing factors.
This includes the societal aspect in the form of political decision makers and railway customers.
Technical aspects are covered in the form of railway train operating companies and infrastructure managers. The most important
influencing factors are shown to be "Political requirements", "Customer requirements", "Train operating
company requirements" and "Infrastructure characteristics".
This thesis recommends eight new steps of analysis in a future
timetabling process to ensure an improved risk and attractiveness evaluation of a timetable.
It also presents a proposal for a
revised timetabling process at railway infrastructure manager Rail Net Denmark. The basic working steps remain
the same, since they are given by European Union legislation and Rail Net Europe guidelines.
The important changes are that
timetable planners will work with several timetable variants simultaneously and that a real iterative capacity allocation
process with the train operating companies will take place. This will require a much more intelligent and efficient timetable
planning system than is available today.
A set of 13 key performance indicators for the Danish railway system is presented in
Chapter 9. Seven of these are newly developed. Each key performance indicator is connected to one of the six
timetabling criteria. The key performance indicators are: 1. Systematic timetable index (Systematic timetable)-
Based on the total time of the most used timetable pattern 2. UIC 406 methodology (Capacity consumption on railway line sections)
VIII Summary- Compressed timetables based on the blocking time theory 3. Degree of deviation from timetable
planning rules (Robustness of the timetable)- Focus on agreed upon running times and timetable supplements 4.
Conflict Risk Index (Robustness of the timetable)- The number of potential train path conflicts at a station and their estimated risk levels 5.
Timetable train path fix points (Robustness of the timetable)- Geographical and temporal distribution of potential
train path conflicts 6. Proportion of train paths with shared rolling stock (Robustness of the timetable)- Number of train
paths with shared rolling stock compared to the total number 7. Proportion of train paths with shared train staff
(Robustness of the timetable)- Number of train paths with shared train staff compared to the total number 8. Proportion of
buffer time in turnaround time and hand-over time for rolling stock (Robustness of the timetable)- Level of time
supplements at terminus stations for rolling stock until next departure 9. Proportion of buffer time in turnaround time and
hand-over time for train staff (Robustness of the timetable)- Level of time supplements at terminus station for train staff
until next departure 10. Independent organization carrying out customer satisfaction surveys (Societal acceptance of
the timetable)- Inspired by the British organization “Passenger Focus” 11. Proportion of timetable transfer time prolongation (Attractive transfer options)- Timetabled extra transfer time compared to physical minimum possible transfer time 12.
Proportion of optimal transfer conditions (Attractive transfer options)- Number of transfers planned to take place on
the same platform out of the total number 13. Proportion of timetable travel time prolongation (Travel time)- Timetabled extra
travel time compared to travel time for theoretical non-stop train. These key performance indicators have proven
themselves in practical applications on examples of real-life Danish timetables. All calculations were done manually, but
they could be automated and integrated into future versions of timetabling software packages.

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