

One Corridor – One Strategy

Joint Regional Development for the North-South Corridor



The need for investment on the 'Rheintalbahn' in the Upper Rhine Valley

– Results of a railway capacity analysis near the town of Lahr –

Hansjörg Drewello ▪ Stefan Gütle

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Contents

I. FIGURES	IV
II. TABLES	IV
1. INTRODUCTION	1
1.1 THE AIM OF CODE24 AND OF THIS STUDY	1
1.2 GENERAL ECONOMIC CONTEXT OF FREIGHT TRANSPORT IN THE UPPER RHINE VALLEY	2
2. THE RHEINTALBAHN	4
3. THEORETICAL BASES	6
3.1 DETERMINATION OF THE CAPACITY OF A RAILWAY LINE	6
3.2 BLOCKING TIME STAIRWAYS	7
3.3 MEAN MINIMUM HEADWAY	8
3.4 COMPOSITE OCCUPATION	10
3.5 BUFFER TIMES	11
3.5.1 ASSIGNMENT OF FIXED BUFFER TIMES	11
3.5.2 AGGREGATE BUFFER TIME WITHIN A PREDETERMINED PERIOD OF TIME	12
4. STUDY OF THE RHEINTALBAHN	13
4.1 CAPACITY OF THE RHEINTALBAHN	14
4.1.1 TIME BEFORE OCCUPATION	14
4.1.2 ACTUAL (PHYSICAL) OCCUPATION TIME	16
4.1.3 TIME AFTER OCCUPATION	16
4.1.4 BLOCKING TIME	17
4.1.5 BRAKING AND ACCELERATION TIMES	18
4.1.6 BLOCKING TIME STAIRWAYS ON THE RHEINTALBAHN	20
4.1.7 TRAINS PER DAY	23
4.2 PREPARATION OF THE CAMERA RECORDINGS	25
4.2.1 CHOICE OF CAMERA	25

4.2.2	CAMERA SETTINGS AND SOFTWARE	25
4.2.2.1	Measurement zone	27
4.2.2.2	Trigger temperature	27
4.2.2.3	Measurement accuracy	28
4.2.3	SETTING UP THE GREENHOUSE	28
4.2.4	SETTING UP THE CAMERA	29
5.	SURVEY AND RESULTS	30
5.1	LENGTH OF TRAINS	30
5.2	TRAIN NUMBERS	31
5.2.1	WEEKLY OVERVIEW OF TRAIN NUMBERS	32
5.2.2	NUMBER OF TRAINS ON MONDAY	33
5.2.3	NUMBER OF TRAINS FROM TUESDAY TO FRIDAY	34
5.2.4	NUMBERS OF TRAINS ON SATURDAY	35
5.2.5	NUMBERS OF TRAINS ON SUNDAY	36
5.2.6	PLAUSIBILITY ANALYSIS	37
5.3	POTENTIAL	38
5.3.1	CAPACITY RESERVES	38
5.3.2	OPTIMISATION POTENTIAL	38
6.	CONCLUSIONS	41
6.1	DIFFERENT RATES OF CAPACITY UTILISATION	41
6.2	THE RHEINTALBAHN AS A BOTTLENECK	42
7.	BIBLIOGRAPHY	45

I. Figures

Fig. 2-1 Rheintalbahn between Karlsruhe and Basel	5
Fig. 3-1 left: Blocking time stairway, right: Block section	8
Fig. 3-2 Blocking time stairway with a buffer train path	12
Fig. 4-1 Train stopping in Lahr station	13
Fig. 4-2 Recording made with the infrared camera showing two freight trains	26
Fig. 4-3 Greenhouse	28
Fig. 4-4 Infrared camera and laptop	29
Fig. 5-1 Weekly overview of train numbers	32
Fig. 5-2 Train numbers on Monday	33
Fig. 5-3 Mean train numbers from Tuesday to Friday	34
Fig. 5-4 Train numbers on Saturday	35
Fig. 5-4 Train numbers on Sunday	36
Fig. 6-1 Development of freight transport in the Upper Rhine Valley	44

II. Tabela

Table 4-1 Movement and blocking times	20
Table 4-2 Blocking-time overlap	21
Table 4-3 Frequency of train sequences	22
Table 4-4 Computation of the mean minimum headway	22
Table 5-1 Excerpt from the values measured for speed	30
Table 5-2 Excerpt of values measured for train length	31
Table 5-3 Frequency of the train sequences travelling from Offenburg to Freiburg	39
Table 5-4 Frequency of the train sequences travelling from Freiburg to Offenburg	39
Table 6-1 Development of freight transport volume in Germany from 2000 to 2008	42
Table 6-2 Development of daily HGV traffic at permanent counting points	43

1. Introduction

1.1 The aim of Code24 and of this study

For more than 30 years, there has been a national consensus in Germany that it was necessary to upgrade the railway line in the Upper Rhine Valley between Karlsruhe and Basel by adding two new tracks. This part of the European Transport Corridor Rotterdam-Genoa (TEN-T no. 24) is especially important for the success of the Swiss investment in transporting more freight on its New Railway Link through the Alps, namely through the Lötschberg and the Gotthard Base Tunnels. That was the intention stated in 1996 in a bi-national agreement between the Swiss Department of Transport and the German Federal Ministry of Transport. At the time of writing, only a quarter of the section that interests us here has been upgraded. Even if though freight transport is still growing rapidly in Europe, this investment at the heart of the Corridor 24 would not seem to be a matter of absolute priority to either Deutsche Bahn or the German government.

With a view to accelerating and jointly developing the transport capacity of the entire corridor, thereby ensuring optimum economic benefits and spatial integration while reducing negative impacts on the environment at local and regional levels, a trans-national initiative has been established within the framework of the European INTERREG CODE24 project. CODE24 stands for Corridor 24 development Rotterdam-Genoa and reflects the interconnection of economic development, spatial, transport and ecological planning along this relevant trans-European railway axis between Rotterdam and Genoa.

In order to analyse the need for appropriate investment, representatives of CODE24 asked the infrastructure manager, DB Netz, to provide data about the capacity and the current demand for and use of the German part of the Rotterdam-Genoa railway corridor. Data about freight transport in the Upper Rhine valley would have been of particular interest in order to test the hypothesis that there is a transport bottleneck in this part of the Rotterdam-Genoa corridor (Drewello, Günther 2012). This request was rejected (whether justified or not) by DB Netz, invoking the argument that the data concerned was confidential. Currently, representatives of Deutsche Bahn deny the existence of bottlenecks along the German part of the Rotterdam-Genoa corridor. They argue that DB Netz is able to satisfy all requests for new freight or passenger paths by rail (Jahncke 2008). In addition to that, the justification put forward for new infrastructure in years gone by was mainly that it was needed for high-speed trains.

Against this background, the Universities of Kehl and Offenburg organised a train count near the town of Lahr in February 2013. This reports sets out to present the results of the data collection and its interpretation. The first part consists of the calculation of a mean capacity for freight train paths per day for the two railway tracks near Lahr. This information is then used as a baseline for the real use of capacity, observed and counted day and night for two weeks. The second part explains the technical challenge in counting high-speed, regional and freight trains and differentiating between them using a high-tech infrared camera. The data collected is presented in the third part of the paper.

Finally, the results of the analysis need to be interpreted. The data provides insights as to whether or not there is a real bottleneck in freight transport on this part of the Rotterdam-Genoa freight corridor. If not, the next step is to reflect the approximate time until the existing infrastructure becomes saturated working on the basis of an estimate of future growth in freight transport. If there is a bottleneck to be considered, the question is, if we can observe an influence to road transport in the Upper Rhine Valley.

1.2 General economic context of freight transport in the Upper Rhine Valley

Despite the debt crisis, Germany's exports increased by 5.9% in 2011, reaching a new record figure of EUR 1.06 trillion (DIHK 2012: 3). Well over half of these exports remained within the European Union (EUR 627 billion). This growth in exports has also had an impact on rail transport. Its share of the market, based on transport performance, increased slightly between 2003 (15.7%) and 2012 (17.2%). (Allianz pro Schiene 2013)

In this, the Rheintalbahn has been taking a significant transport share away from road. It is one of the busiest railway lines in Germany for both passenger and freight operations (DB Projektbau GmbH 2012). Given the fact that it also carries cross-border traffic to Switzerland and France, it constitutes an important infrastructure component of the logistics of Germany's export sector.

The study presented in this report was carried out in a district or "kreis" known as Ortenau, which has a surface area of 1850.74 km² and is one of the key industrial and commercial locations in the Upper Rhine region. For many years, Ortenau has occupied one of the top regional positions in the sectors of services, the media and tourism. (Brennpunkt Ortenau, 2012)

The Rheintalbahn runs between Mannheim and Basel, two cities with marshalling yards that are amongst the biggest in Europe. Considering just the marshalling yard in Mannheim, its east-west gravity shunting facility has 42 sorting tracks, while 41 sorting tracks are available for the opposite direction, and the throughput capacity is approximately 5300 wagons per day (<http://www.deutschebahn.com>, 2012). The marshalling yard in Basel-Muttenz has 32 sorting tracks for north-south traffic and the same number for south-north traffic, and its daily throughput capacity is 5280 wagons. At the time of writing, the marshalling yard in Basel-Muttenz is undergoing modernisation. It is to be reckoned that this reorganisation work will result in higher throughputs in future. (SBB central customer service 2013)

One further factor that is going to have an appreciable influence on freight traffic in years to come is the entry into service of the two base tunnels through the Alps in Switzerland. The completion of the construction work on the Lötschberg Base Tunnel in 2007 and the probable completion of the Gotthard Base Tunnel in 2017 are creating a high-capacity route, which is going to make it possible to shift freight transport from road to rail on a large scale. It is thus going to be possible in the near future to transport more than twice the volume of freight by rail. (Deutschebahn.com, 2012). In order to be able to cope adequately with the growing demand for freight and passenger traffic, Deutsche Bahn and the German federal government have initiated a project to create a partly new, partly upgraded railway line between Karlsruhe and Basel.

Various studies have arrived at the conclusion that there is going to be a further significant increase in the growth of freight traffic. One such study, by BVU Beratergruppe, forecasts 65% growth in the freight carried by rail in Germany up until 2025, which would correspond to a mean annual growth rate of roughly 2.4%. This would include particularly strong growth in the volume of combined transport carried by rail, and cross-border traffic has a decisive share to play in this. It is forecast to grow by 78% over the same period of time, i.e. very considerably more than purely domestic traffic, for which the forecast growth is 50%. (BVU 2008: 32)

Even today, it is already a reasonable assumption that there will be shifts to road in freight transport. There is thus a risk that the metropolitan region of the Upper Rhine could lose its attractiveness for large businesses as a consequence of the investment backlog. (K+P Transport Consultants, 2008)

2. The Rheintalbahn

The Rheintalbahn (or “Rhine Valley Railway”) is a double-track, electrified mainline railway running through the German federal state of Baden-Württemberg. Its route takes it from Mannheim via Heidelberg, Karlsruhe, Rastatt, Baden-Baden, Offenburg and Freiburg im Breisgau to Basel. It was originally financed and built by the state railway of the Grand Duchy of Baden. The first section to be completed, between Mannheim and Heidelberg, was opened in 1840. By 1855, the line had been finished, a section at a time, as far as Basel. The line grew in importance for international traffic, particularly after the First World War. That explains why the Rheintalbahn was electrified back in the 1950s, with end-to-end electrical operation becoming possible halfway through 1958. Work on the radical modernisation of the signalling system began towards the end of the 1960s on the 120-km-long section between Offenburg and Basel, with only the station in Freiburg being left out. Before then, this section had been equipped with mechanical interlocking systems, which were replaced with relay-based ones. Even at the end of the 1960s, the line was already carrying well over a hundred trains per day in each direction.

The Rheintalbahn is one of the most important and most heavily trafficked railway lines in Germany as regards both passenger and freight trains. This is due not only to local passenger services, but also, inter alia, to international freight and passenger trains to and from Switzerland and France. All long-distance passenger trains have stops in Mannheim, Karlsruhe, Freiburg and Basel Badischer Bahnhof, and some of them also stop in Heidelberg, Wiesloch-Walldorf, Bruchsal, Rastatt, Baden-Baden and Offenburg. The regional trains serving the Schwarzwaldbahn run every hour between Karlsruhe and Offenburg, and since December 2009 this frequency has been increased to half-hourly, but not regularly. Regional expresses and regional stopping trains with a fixed headway operate alternately every half-hour on the line between Offenburg and Basel. The stations at the two ends of the Rheintalbahn are Mannheim and Basel. These both have marshalling yards, which are amongst the biggest in Europe. Both the marshalling yard in Mannheim (Mannheim Rangierbahnhof or Rbf.) and the Swiss Federal Railways’ one on the communal territory of Muttens (Switzerland) just east of Basel (Basel SBB RB) have been designed to function as two separate yards for the two directions. The other marshalling yards that used to exist along the Rheintalbahn have all been closed down. They used to be in Heidelberg, Karlsruhe, Offenburg, Freiburg im Breisgau and Basel Badischer Bahnhof.

The upgrading and partial new building of the line is intended to increase its capacity very considerably and to shorten travel and transport times. Once all this work has been completed, there will be four tracks throughout, making it possible to improve the structuring of train movements. The slower freight and local passenger trains are to use the two traditional tracks, whereas the two new tracks, which permit top speeds, are to be used by long-distance passenger trains during the day and freight trains at night.

All these measures are going to shorten the travel time between Karlsruhe and Basel by approximately half an hour to 69 minutes. It is also going to be possible to improve the organisation of the timetables. The section of the line between Rastatt Süd and Offenburg was taken into service in December 2004. For the sections further south, between Offenburg and Auggen, the German Federal Railway Authority (Eisenbahn-Bundesamt, EBA) has initiated all the necessary planning assessment procedures.

The biggest tunnel project that had been running in Germany in the last years was brought to a successful conclusion in December 2012 with the opening of the Katzenberg Tunnel, which is just short of 9.4 km long. It is the largest single engineering feature on the partly upgraded, partly new line between Karlsruhe and Basel. It runs in a north-south direction through the western edge of the hills that characterise a district known as Markgräflerland. This direct and straight route through the hills is going to make it possible to shorten travel times quite considerably in the near future. (Deutschebahn.com, 2012)

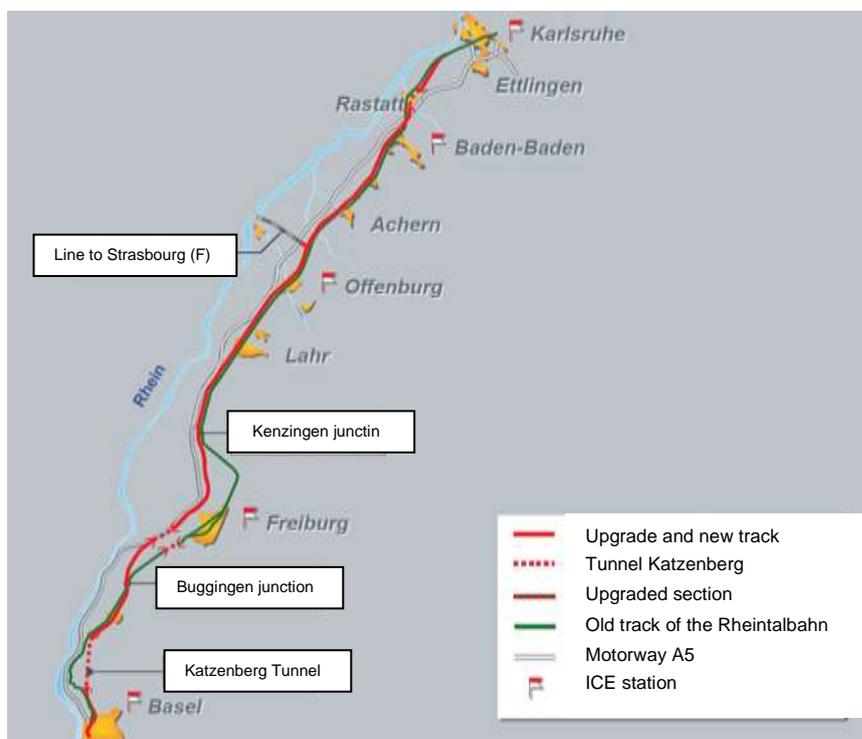


Fig. 2-1 Rheintalbahn between Karlsruhe and Basel (DB Projektbau GmbH 2012: 2)

3. Theoretical bases

3.1 Determination of the capacity of a railway line

Many different items of data are necessary for computing the capacity of a railway line. The most important of these are presented and described in the following sections of this report. Much of this data is only available to Deutsche Bahn, and that company has declared it to be a business secret. The computations presented in the rest of this analysis thus have to be based on the authors' own observations or on estimates.

One factor that is of major importance for determining the capacity of a railway line is the number of tracks available for running in a particular direction. It is in the nature of things that single-track systems have a very considerably lower capacity than double-track ones. The headways on each track are very much shorter on double-track systems than on single-track ones.

Another key aspect influencing capacity is the distance between the block signals. Railway lines are divided up into blocks of different lengths, and each one is marked off by means of a coloured-light signal. When a block is free for a train to proceed, this is indicated by a green light. The train is not permitted to enter the next block if the signal is showing red. The longer a block, the longer the time during which a train is going to occupy it. Longer blocks reduce the capacity of the line.

One further factor to be considered when appraising a line's capacity is the maximum speed permitted on it. As a general rule, local passenger trains and freight trains are able to run at their maximum permitted speed on most lines. By contrast to that, long-distance passenger trains have to date not been able to exploit their maximum permitted speed on most railway lines. In Germany, it is only on the new line between Frankfurt and Köln that trains can run up to the maximum speed of 300 km/h. Most of the other lines carrying long-distance passenger trains have design speeds of either 250 km/h or 160 km/h.

The faster a long-distance passenger train is permitted to travel, the shorter will be the time during which it occupies a block. However, higher speeds cause more path conflicts with trains ahead and for overtaking manoeuvres. Allowance can be made for that sort of situation in the operational plans, provided the operation is not otherwise disrupted. If disruptions do occur in the railway operation, it is the faster train that will have to adjust its speed to that of the slower train.

For a railway line to have a high capacity, it must offer opportunities for overtaking. These occur at stations and at special overtaking tracks. For a slower train to be overtaken it will turn out onto a holding track, where it will come to a standstill. It will have to wait there long enough for the overtaking manoeuvre to be completed by the faster train and for the block ahead of it to become free again. Passing tracks away from stations are mostly used by freight trains, since local passenger trains usually stop in stations during the overtaking manoeuvre and thus lose virtually no time.

The final important aspect for determining the capacity of a railway line is the sequence in which the various categories of train follow one another. Lines on which all the trains operating have the same speed have a higher capacity than lines with a mixed operation. The reason why capacity is lower on a line with a mixed operation is that the spacing between a fast train and a slow one must be chosen to be long enough for the slower train to reach a passing point before the faster train enters its block.

3.2 Blocking time stairways

A method known as “blocking time stairways” is used to determine the time interval at which the various categories of train ought to be allowed to follow one another on particular sections of a railway line (Fig. 3-1 - left). It is based on the blocking time model originally developed by Happel (Happel: 1959). The method can also be used to ascertain how much capacity is consumed by a single train movement. The blocking time stairway represents time during which the infrastructure is blocked on account of the train travelling through. It assigns a blocking time to each section of the line, which is the time during which that section is occupied by a train. The blocking time includes the actual occupation time (or physical occupation time), which is a statement of how long a train takes to travel through the block, to which must be added the time during which the section is necessarily blocked before and after the train’s physical presence in it. (Fig. 3-1 left; Pachl 2011: 143)

The blocking time before physical occupation by the train includes the time necessary for setting the train’s route, the signal visibility time and the approach time. The “time necessary for setting the train’s route” describes how much time is necessary for moving all the switches and crossings into the correct position and verifying that the route has been correctly set. (Jochim 2009: 208)

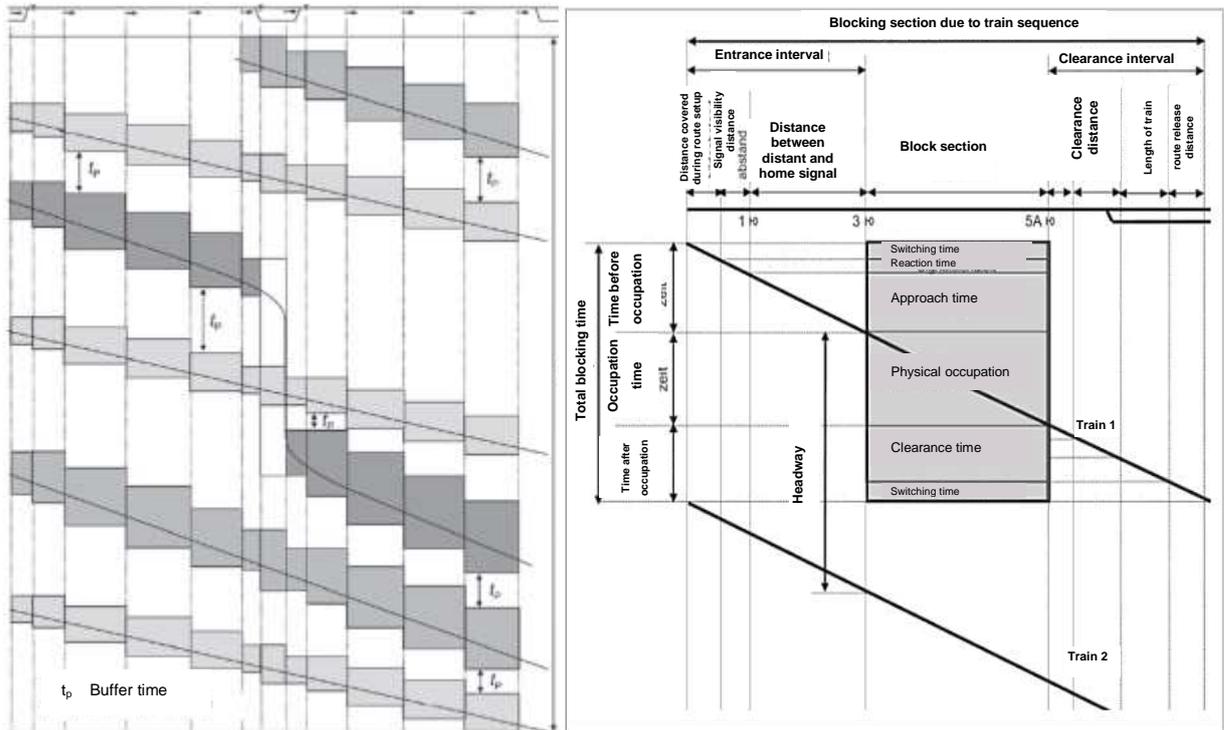


Fig. 3-1 left: Blocking time stairway (Pachl 2011), right: Block section (Heister 2009)

The “signal visibility time” is the time that elapses from when the driver first sees the signal until the train reaches the distant signal. The “approach time” is the time it takes the train to travel from the location of the distant signal to the location of the corresponding home signal. The blocking time after physical occupation by the train includes the necessary time for the train to clear the block and the time for cancelling the route set. The “clearance time” is the time it takes for the rear of the train to pass the home signal, the overshoot limit and the point the rear of the train must clear. The time taken to cancel the route set is the time that is needed for releasing the block that has been occupied. Once the train has left the block, a route-cancellation function resets the route. (Heister 2009: 298 ff.)

3.3 Mean minimum headway

The minimum headway is the minimum distance at which one train can follow another without either of them getting in the other’s way. It is possible to work out the headway by compressing the blocking time stairways until they just touch one another inside a block. The minimum headway is the maximum space between the beginning of the blocking time

of the first train and the beginning of the blocking time of the second train (Fengler 2008: 310).

Unintended waiting periods are not included in the calculation of minimum headways. In order, nonetheless, to be able to make allowance for such waiting times, small time windows or buffers are inserted between the individual blocking time stairways. A separate minimum headway needs to be calculated for every possible variation in the sequence of trains. For this purpose, the various categories of train are grouped together as models, such as long-distance passenger trains (LDPTs), local passenger trains (LPTs) and freight trains (FTs), and the results are entered in a matrix.

In order to obtain the mean value of these minimum headways, it is necessary to know the relative frequency of the different types of train sequence. If the timetable is known, it is possible to derive the relative frequency from it. If there is no published timetable, the value will have to be determined as an approximation for a random sequence of trains. In this case, the relative frequency is determined using the following formula (Pachl 2011: 241):

$$(1) \quad f_{ij} = \frac{c \cdot c_j}{c^2}$$

where f_{ij} : Relative frequency of a train belonging to category i being immediately ahead of a train belonging to category j

C_i : Number of trains belonging to category i

C_j : Number of trains belonging to category j

C : Total number of trains (all categories)

Using the matrix explained above and the relative frequency, it is possible to compute the mean value of the minimum headways. This reflects the structure of the train sequence on a given railway line in a comparable indicator. (Pachl 2011: 141)

$$(2) \quad t_{hw,min} = \sum(t_{hw,min,ij} * h_{ij})$$

Where $t_{hw,min}$: Mean minimum headway

$t_{hw,min,ij}$: Minimum headway for a sequence with a train belong to category i immediately ahead of train a train belonging to category j

The minimum headway is, however, not used for calculating the capacity of a railway line. The reason for that is that if a train were to run late, that would have direct impacts on the

following train and thus on the system as a whole. It would take a lot of time to make up for all the delays and for the trains to be able to run punctually again.

Despite that, trains do sometimes operate with only the minimum possible headway. That is usually the case when there is a threat of short-term bottlenecks and when a certain recovery period is available afterwards. At night, when the railway lines are free of passenger services, it is common practice to operate in this way. During the day, when there is a mixed operation, it makes sense to include buffer times in the timetables, since delays would otherwise have direct impacts on the whole of the railway operation. (Fengler 2008)

3.4 Composite occupation

The occupation rate is the proportion of time during which a section of a railway line is occupied by blocking times (Pachl 2011: 142). Given that trains travel at different speeds, additional gaps in time arise between the individual blocking times, but these are unsuitable for use by other trains. The total occupation time caused by trains could be considered as the composite blocking time of the line. Seen pictorially, this is like “compressing” the structure of the train sequence of a given operational programme until all the blocking time stairways just touch one another in at least one place.

If these elements in the train sequence are taken into consideration for calculating the occupation rate, the result is a composite occupation rate. It is possible to determine the composite occupation rate by dividing the composite blocking time of the line by the length of time considered.

$$(3) \quad o_c = \frac{N * t_{hw,min}}{t_{obs}}$$

where O_c : Composite occupation

N : Number of trains during the observation period

t_{obs} : Duration of the observation period

Working on the basis of empirical findings, Pachl recommends that for typical railway lines with a mixed operation the composite occupation rate should not rise significantly above 0.5 for any longish period of time (Pachl 2011: 175). This would result in cost-efficient

capacity utilisation of the line examined without operational difficulties being expected. The UIC (International Union of Railways) arrives at similar target figures. In its determination of capacity consumption, it includes additional elements in the occupation of the infrastructure as buffer times and maintenance times and, where appropriate, allowances for single-track sections too. According to UIC Code 406, a 60% occupation rate ought not to be exceeded taking the day as a whole, and a value of 75% ought not to be exceeded at peak periods (UIC 2004: 19 or Verkehrswissenschaftliches Institut der RWTH Aachen 2008: 14).

3.5 Buffer times

Buffer times are free periods of time between the blocking time stairways of two trains following one another. It is possible for buffer times to be used to reduce delays in the train sequence and to have a positive impact on the operational process. On the other hand, however, the use of buffer times reduces the number of train paths that can be timetabled. Pachl describes the dimensioning and distribution of buffer times as important tools in the hands of the operations planner for influencing performance and quality. (Pachl 2011: 174)

The length to be chosen for the buffer times depends on the reliability of the system. The more reliable the system is, the shorter the buffer times can be. That makes it possible to achieve a greater operational capacity. The sort of delays that can be expected can be established using statistical evaluations. On lines with a mixed operation, the guideline value for dimensioning buffer times is to take 0.5 for the composite occupation rate. What that means is that the mean buffer time ought to be roughly the same as the mean minimum headway (Pachl 2011: 175).

There are different ways in which the buffer times can be considered in a calculation. Firstly, there is the possibility of laying down fixed buffer times for particular train-sequence cases and, secondly, an aggregate buffer time can be provided within a particular period of time in the form of unallocated train paths.

3.5.1 Assignment of fixed buffer times

It makes sense to assign fixed buffer times to particular train-sequence cases if the train sequences laid down in the timetable are actually complied with in practice. That is the

case for passenger and high-grade freight services in particular. Longer buffer times are to be planned especially if a faster train is to keep moving without stopping. If the following trains are slower, it may be possible to do without a buffer altogether. (Pachl 2011: 177)

3.5.2 Aggregate buffer time within a predetermined period of time

A fixed buffer time for a planned sequence of trains loses its effect if the sequence is modified on account of disruptions and measures that rearrange the train sequence. That happens most frequently in the transport of freight, where very considerable deviations from the planned paths of trains can occur, for instance if a train is not loaded as planned in a container terminal. In practice, freight trains are often run in clusters. In such a case, no buffer time is inserted between the individual freight trains and they run with the minimum possible headway between them. That can only happen if one or more train paths are left free after a cluster of freight trains. These so-called buffer paths can be used to compensate for delays in the train sequence (Fig. 3-2).

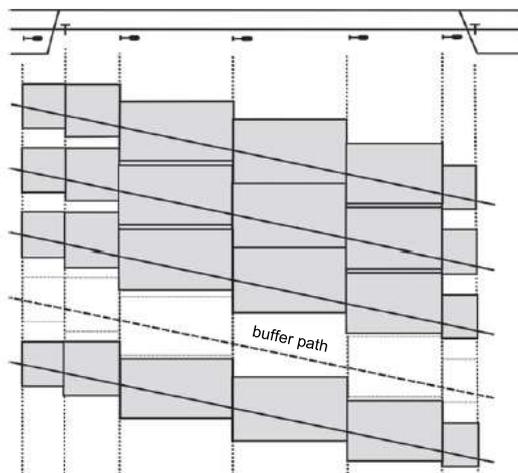


Fig. 3-2 - Blocking time stairway with a buffer train path (Pachl 2011)

4. Study of the Rheintalbahn

The Rheintalbahn between Offenburg and Lahr is a double-track system. On 18 February 2013, during the observation period covered by this study, one track was out of service between 23:00 and 04:00. So the whole traffic had to run on just one track.

Between Offenburg and Lahr the home signals are spaced out at roughly four to five kilometres. Two signals are located approximately 500 metres before the stations of Friesenheim and Lahr. The normal spacing between a distant signal and a home signal is around one kilometre. The section of track that is the object of this study is divided into four blocks. The first block is the departure one from Offenburg station as far as the next home signal, at a distance of some 3 km and still on Offenburg territory. The designations of the following blocks are Offenburg-Niederschopfheim, Niederschopfheim-Friesenheim and Friesenheim-Lahr. The village of Friesenheim and the town of Lahr each have a station served by local passenger trains, and the latter includes a track for freight trains to be overtaken.

Observations had already shown that the overtaking tracks were used frequently (Fig. 4-1) and that most of the overtaking was done by long-distance passenger trains. A number of manoeuvres were also observed with freight trains overtaking other freight trains. It is not known whether these overtaking manoeuvres had been timetabled or whether they were to make up for delays in the train sequence.

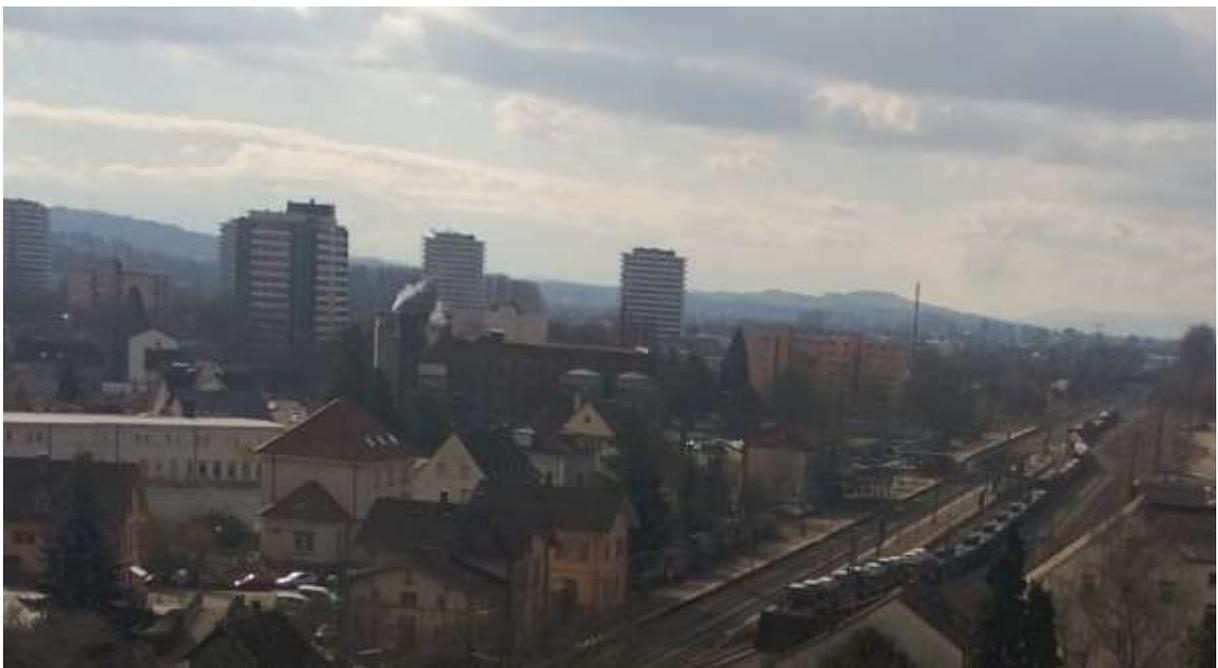


Fig. 4-1 – Train stopping in Lahr station

The maximum speed over this section of line is 160 km/h, which is only reached by long-distance passenger trains (ICEs and ICs). Local passenger trains run over it at 120 km/h, while freight trains build up speeds of between 80 and 100 km/h. Another observation was that faster trains have to adjust their speeds considerably to make allowance for slower trains and that ICE trains are particularly affected by this.

Virtually the whole of the Rheintalbahn is used for mixed traffic. It is only between midnight and approximately 05:30 that the line is reserved primarily for freight traffic. It was, however, also observed that empty passenger stock is also moved at night, and a few trains composed of a mixture of freight and passenger stock were also observed during the night. The purpose of trains with such a composition is not known, but it appears likely that the passenger coaches will be left at a station en route and used for passenger services operating from there.

4.1 Capacity of the Rheintalbahn

The first step in working out the capacity of the Rheintalbahn is to establish the blocking time by applying the model of blocking time stairways. The blocking time is made up of the following components: time before occupation, time of actual (physical) occupation and time after occupation.

4.1.1 Time before occupation

The time before occupation is comprised of the time necessary for setting the train's route, the time during which the driver is able to see the distant signal and the approach time. Given that this is another area in which Deutsche Bahn refuses to disclose any information, the first two items of data were estimated using the method proposed by Jochim et al (Jochim/Lademann 2009: 208):

Time for setting up the train's route t_{setup} : 12 s

Visibility time $t_{\text{visibility}}$: 6 s

The information that is needed for determining the approach time is the distance between the distant signal and the home signal. In the case of the Rheintalbahn, this distance is estimated at 1000 metres. How much time is needed to cover this distance can be calculated using the following formula:

$$(4) \quad d = v * t_{\text{approach}}$$

Rewriting this equation as a value of t_{approach} produces the following:

$$(5) \quad t_{\text{approach}} = \frac{d}{v}$$

where: d : Length of the line in metres

v : Speed in metres per second

t_{approach} : Time in seconds

This produces the time before occupation:

$$(6) \quad t_{\text{bO}} = t_{\text{setup}} + t_{\text{visibility}} + t_{\text{approach}}$$

where: t_{bO} : Time before occupation

t_{approach} : Approach time

t_{setup} : Time for setting up the train's route

$t_{\text{visibility}}$: Visibility time

Taking the various categories of train running on this section of the railway, the following approach times can then be calculated:

Long-distance passenger trains (speed: 160 km/h \approx 44.44 m/s):

$$t_{\text{approach,LDPT}} = \frac{1000 \text{ m}}{44.44 \frac{\text{m}}{\text{s}}} = 22.50 \text{ s}$$

$$t_{\text{visibility,LDPT}} = 22.50\text{s} + 12.00\text{s} + 6.00 \text{ s} = 40.50 \text{ s}$$

Local passenger trains (speed 120 km/h \approx 33.33 m/s):

$$t_{\text{approach,LPT}} = 30.03 \text{ s}$$

$$t_{\text{visibility,LPT}} = 48.03 \text{ s}$$

Freight trains (mean speed 90 km/h \approx 25 m/s):

$$t_{\text{approach,FT}} = 40.00 \text{ s}$$

$$t_{\text{visibility,FT}} = 58.00 \text{ s}$$

4.1.2 Actual (physical) occupation time

In the next step, it is possible to work out the actual occupation time, t_o . This, like the approach time, depends on the speed of the individual train categories (cf. equation 5). For an estimated mean block length of 4.5 km, the following actual occupation time can be computed:

Occupation time of long-distance passenger trains: $t_{o,LDPT} = 101.26 \text{ s}$

Occupation time of local passenger trains: $t_{o,LPT} = 135.01 \text{ s}$

Occupation time of freight trains: $t_{o,FT} = 180,00 \text{ s}$

4.1.3 Time after occupation

The final element to be computed is the time after the train has ceased to occupy the block (t_{ao}), which is comprised of the clearance time and the time for cancelling the route it has used. Jochim et al. estimate the mean time for cancelling a route (t_{can}) at 6 seconds (Jochim/Lademann 2009: 208).

The clearance time (t_{cl}) depends on the train's speed and length and also on the overshoot length. The train speeds are generally known, but how much of an overshoot length is provided for each individual block signal is, on the other hand, not known. The standard overshoot length is at least 200 metres, but it can vary depending on the arrangement of switches, crossings and signals. (Jochim/Lademann 2009: 172)

Deutsche Bahn indicates that the maximum length of freight trains running on its network is 750 m and that that of passenger trains is 420 m. The mean length of local passenger trains is 125 m. (Jochim/Lademann 2009: 209)

The time taken to clear a block can be computed from the overshoot length, the length of the train and its particular speed. The formula for clearance time is thus:

$$(7) \quad t_{cl} = \frac{l_t + OL}{v}$$

where t_{cl} : Clearance time in seconds,

l_t : Length of the train in metres

L_{OL} : Overshoot length in metres

The time after occupation is calculated as:

$$(8) \quad t_{aO} = t_{can} + t_{cl}$$

Performing this calculation with the estimated data results in the following:

Time after occupation for long-distance passenger trains:

$$t_{cl,LDPT} = \frac{(420 \text{ m} + 200 \text{ m})}{44.44 \frac{\text{m}}{\text{s}}} = 13.95 \text{ s}$$

$$t_{aO,LDPT} = 6 \text{ s} + 13.95 \text{ s} = 19.95 \text{ s}$$

Time after occupation for local passenger trains:

$$t_{CL,LPT} = 9.75 \text{ s}; \quad t_{aO,LPT} = 15.75 \text{ s}$$

Time after occupation for freight trains:

$$t_{CL,FT} = 38.00 \text{ s}; \quad t_{aO,FT} = 44.00 \text{ s}$$

4.1.4 Blocking time

Finally, the total blocking time for a given block is worked out by adding together the time before occupation, the actual occupation time and the time after occupation:

$$(9) \quad t_{blocking} = t_{aO} + t_O + t_{bO}$$

Blocking time for long-distance passenger trains:

$$t_{blocking,LDPT} = 40.50 \text{ s} + 101.26 \text{ s} + 19.95 \text{ s} = 161.71 \text{ s}$$

Blocking time for local passenger trains:

$$t_{blocking,LPT} = 198.79 \text{ s}$$

Blocking time for freight trains:

$$t_{blocking,FT} = 282.00 \text{ s}$$

4.1.5 Braking and acceleration times

The blocking times presented above only apply for trains that run on the line between Offenburg and Lahr without stopping. Given that local passenger trains also call at smaller stations, such as Friesenheim, the additional times they need for braking and for accelerating from a standing start need to be considered for them as well.

In order not to treat passengers and cargoes too roughly, the negative acceleration during a braking manoeuvre is taken to be -1 m/s^2 . If greater acceleration values were to be practised, there would have to be a requirement for passengers to wear seatbelts. A simplified value of 1 m/s^2 is also assumed for accelerating from a standing start. Data is not available for locomotives and power cars, so it is not possible to calculate a value directly. There is thus no alternative to having recourse to this simplified value. (Jochim/Lademann 2009: 137)

The following paragraphs explain how the braking time, braking distance, acceleration time and acceleration distance are calculated for local passenger trains. In a similar way, it is also possible to calculate the braking and acceleration time for freight trains and long-distance passenger trains. The following equation applies for the braking or acceleration time:

$$(10) \quad v = a * t$$

where a : Acceleration value in m/s^2

Rewriting this equation: $t = \frac{v}{a}$

And the following equation applies for the braking or acceleration distance:

$$(11) \quad d = \frac{1}{2} * a * t^2$$

Braking or acceleration time (t_{braking}) for local passenger trains:

$$t_{\text{braking,LPT}} = \frac{33.33 \frac{\text{m}}{\text{s}}}{1 \frac{\text{m}}{\text{s}^2}} = 33.33 \text{ s}$$

Braking or acceleration distance ($d_{\text{braking, LPT}}$) for local passenger trains:

$$D_{\text{braking,LPT}} = \frac{1}{2} * 1 \frac{\text{m}}{\text{s}^2} * 33.33^2 \text{s} = 555.44 \text{ m}$$

A local passenger train needs a time of 33.33 s to come to a complete standstill at a platform, during which it travels through a braking distance of 555.44 m. For the sake of simplification, it is assumed that the same time and distance are necessary to accelerate from 0 to 120 km/h. This braking and accelerating manoeuvre very clearly lengthens the travel time and the blocking time. The result for the Niederschopfheim-Friesenheim block is that the braking and acceleration distances need to be subtracted from the block length. The distance over which the train can run at full speed is known. From that, finally, it is possible to work out the time during which the train can run at full speed.

$$t_{0,LPT\text{constant}} = 101.68 \text{ s}$$

Adding the braking and acceleration time for the block section results in the following expression:

$$t_{\text{braking,LPT}} = 101.68 \text{ s} + 33.33 \text{ s} + 33.33 \text{ s} = 168.34 \text{ s}$$

No consideration needs to be given to the train's stopping time at stations with the two-track system. If a train stops at a platform, the station's parallel tracks are free. So overtaking manoeuvres can be performed without disruptions.

One particularity concerns trains moving off again from a standing start and results from a divergent interpretation of the approach time and the visibility time. A train standing at a platform has a direct view of the departure signal. The approach time is thus the time it takes to travel between its stopping position and the departure signal. The visibility time loses its significance. Stopping places may be arranged differently resulting in approach times of different lengths. This point has not been taken into consideration for this study, given that there is no information available as regards precisely where trains stop and the positions of the departure signals.

For this reason, only the acceleration and braking times are considered for trains stopping in a station. That ought to lead to similar results. On the basis of the procedure described so far for determining the capacity of a line, it is possible to produce a blocking time stairway. This can then be used to determine the minimum headway and the buffer time.

4.1.6 Blocking time stairways on the Rheintalbahn

This next section shows how the blocking time stairways are computed mathematically for the railway line between Offenburg and Lahr. The first block is the departure block from Offenburg station. There is no need for visibility time, since the driver of the train standing in the station has an unimpeded view of the departure signal. Passing the departure signal is taken as the fictitious departure time of 0. The blocking time for the next block section is computed from immediately behind this departure signal.

For local passenger trains, which have to stop at a station inside the third block, the braking and acceleration times were calculated in addition. The stopping time was not taken into consideration, since it is assumed that it is possible for one train to overtake another in the station. In an extreme case, the local passenger train can be switched over to a different platform to permit a long-distance passenger train to pass it.

The following are the values computed for the line between Offenburg and Lahr:

Long-distance passenger traffic	Departure Block1	Block2	Block3	Block4
Start of blocking time	-0.20 min	0.96 min	2.64 min	4.25 min
Passing the signal	0.00 min	1.64 min	3.35 min	4.92 min
End of blocking time	1.98 min	3.68 min	5.25 min	7.24 min
Local passenger traffic	Departure Block1	Block2	Block3	Block4
Start of blocking time	-0.20 min	1.10 min	3.34 min	6.04 min
Passing the signal	0.00 min	1.91 min	4.18 min	6.83 min
End of blocking time	2.17 min	4.45 min	7.09 min	10.30 min
Freight traffic	Departure Block1	Block2	Block3	Block4
Start of blocking time	-0.20 min	1.33 min	4.33 min	7.18 min
Passing the signal	0.00 min	2.32 min	5.35 min	8.14 min
End of blocking time	3.05 min	6.08 min	8.87 min	12.41 min

Table 4-1 – Movement and blocking times

Before the minimum headway can be calculated, it is necessary to determine the resulting overlaps between blocking times for the individual train-sequence cases. The blocking-time overlap is the total duration of the time shifts of one blocking time stairway that is necessary to secure an uninterrupted movement within a particular block. The decisive value for determining the headway for the whole line is the biggest value resulting from the overlaps of the blocking times. The blocking-time overlap corresponds to the end of the blocking time minus its beginning.

The blocking-time overlap is illustrated in the following table. The maximum values are highlighted and represent the train headways.

	Departure Block1	Block2	Block3	Block4
LDPT ahead of LDPT	2.18	2.72	2.61	2.99
LDPT ahead of LPT	2.18	2.59	1.91	1.20
LDPT ahead of FT	2.18	2.35	0.92	0.06
LPT ahead of LDPT	2.37	3.49	4.45	6.05
LPT ahead of LPT	2.37	3.35	3.75	4.27
LPT ahead of FT	2.37	3.11	2.77	3.12
FT ahead of LDPT	3.25	5.12	6.23	8.16
FT ahead of LPT	3.25	4.99	5.53	6.37
FT ahead of FT	3.25	4.75	4.54	5.23

Table 4-2 – Blocking-time overlap

In order to establish the minimum headway, it is necessary to know the probability of the occurrence of each train-sequence case for the line between Offenburg and Lahr. It was one element of this study to work out the relative frequency of the occurrence of particular train sequences (cf. Tab. 4-3). Reading vertically shows which train passes first and horizontally which train follows it. The table is discussed in greater detail further on in this report.

The relative frequency of a particular train sequence is:

	2nd train	LDPT	LPT	FT	Other
1st train					
LDPT		7.78%	9.73%	8.58%	0.41%
LPT		5.12%	1.26%	12.55%	0.86%
FT		11.04%	10.35%	29.57%	0.70%
Other		0.49%	0.39%	0.96%	0.21%

Table 4-3 - Frequency of train sequences

All the data has now been established that is necessary for computing the mean value of the minimum headways. This is calculated using the following equation:

$$(12) \quad t_{hw,min} = \sum(t_{Mzij} * f_{ij})$$

Train-sequence case	Maximum values t_{Mzij}	Relative frequency f_{ij}	Result ($t_{Mzij} * f_{ij}$)
LDPT ahead of LDPT	2.99 min	7.78%	0.24 min
LDPT ahead of LPT	2.59 min	5.12%	0.13 min
LDPT ahead of FT	2.35 min	11.04%	0.26 min
LPT ahead of LDPT	6.05 min	9.73%	0.52 min
LPT ahead of LPT	4.27 min	1.26%	0.05 min
LPT ahead of FT	3.12 min	10.35%	0.33 min
FT ahead of LDPT	8.16 min	8.58%	0.71 min
FT ahead of LPT	6.37 min	12.55%	0.85 min
FT ahead of FT	5.23 min	29.57%	1.59 min
Mean minimum headway:			4.68 min

Table 4-4 – Computation of the mean minimum headway

This shows the mean minimum train headway to be 4.68 minutes or 4 minutes 41 seconds. The point must, however, be made, that only a small portion of the Rheintalbahn has been considered. ICE trains, in particular, are timetabled to travel non-stop over the whole section between Offenburg and Freiburg. If further blocks are added in the direction of Freiburg, the mean minimum headway increases, since the long-distance passenger trains have to adjust their speed to the slower local passenger and freight trains. It is true

that there are several other small stations on the line between Lahr and Freiburg, permitting overtaking manoeuvres. However, complete compensation for the increase in headway caused by overtaking manoeuvres is not possible given the braking and acceleration process, particularly of the freight trains. In order to obtain a more realistic result for the line's capacity, the mean minimum headway for the rest of the calculation has been rounded up to five minutes.

Taking the mean minimum headway and the numbers of trains established from studying this railway line, it is possible to determine the composite occupation rate. The figures produced by this study are examined in more detail in the following chapter. The results, however, are stated now, so that they can be used for the purpose of calculating the composite occupation rate. Taking the four-day period from Tuesday to Friday, the daily mean is 137 trains in one direction. This leads to the following composite occupation rate applying formula 3

$$O_{\text{composite}} = \frac{137 * 5 \text{ min}}{1440 \text{ min}} = 0.48$$

What this result means is that if an optimum operational quality is to be maintained, the line can, on average, only offer very minor additional capacities.

4.1.7 Trains per day

In order to be able to obtain a precise figure for the number of trains per day, it is necessary to add a certain buffer time to the minimum headway. On a line with mixed traffic, the composite occupation rate ought not to exceed 0.5 significantly for any lengthy period of time, since the operational quality would otherwise suffer. Working on the basis of the actual composite occupation rate, the buffer time and maintenance time ought to correspond to the mean minimum headway of roughly five minutes.

$$(12) \quad T = \frac{t}{t_{\text{buffer}} + t_{\text{hw,min}}}$$

where: t_{buffer} = Buffer time and maintenance time

That results in the following train numbers per day:

$$N = \frac{1440 \text{ min}}{5 \text{ min} + 5 \text{ min}} = 144$$

It is possible for 144 trains to run in one direction per day with a satisfactory operational quality. So 288 trains a day can run on the Rheintalbahn in both directions. These figures tally with those produced by a study carried out on behalf of the Deutsche Industrie- und Handelskammertag (German Association of Chambers of Commerce and Industrie) in 2008. (K+P Transport Consultants 2008: 17)

It is possible to increase capacity for a short period of time by reducing the buffer and maintenance times. Taking a longer period of time, however, the capacity of 288 trains per day ought not to be exceeded to avoid jeopardising a satisfactory operational quality.

4.2 Preparation of the camera recordings

The railway line between Offenburg and Lahr was examined with an infrared camera, which was made available by Offenburg University of Applied Sciences. It was installed on the roof of a nine-storey block of flats in Lahr, in a position that offers an unimpeded view of the Rheintalbahn (Fig. 4-1). After 2-3 days of experimenting before making the recordings, counting the trains began on 14 February 2013 and ended on 27 February 2013. The arrangement of the camera and the process of counting the trains are described in detail in the following sections.

4.2.1 Choice of camera

The advantage of an infrared camera is that it can take pictures equally well in daylight and in the dark. It is possible to differentiate between the various categories of train. The camera type chosen was a VarioCAM hr professional infrared camera. The individual video recordings need only little memory capacity. Moreover, the IRBIS 3 Plus program that goes with the camera offers various setting possibilities. One example is that recordings are only triggered once the temperature in the image reaches a value selected by the programmer.

It is not possible to recognise the lettering on the locomotives on the camera's images. So it is impossible to establish which train operating company is running a particular train. That is the only disadvantage worth mentioning as far as this camera is concerned.

4.2.2 Camera settings and software

The camera can be set so that it will only take pictures once a predetermined maximum temperature is exceeded in the subject area of the image. Recording is stopped when the temperature in the subject area falls below the maximum set. During the period when the measurements were made, outdoor temperatures were generally below 0°C. The warmest parts of the passing trains were their wheels and brakes, and their temperature was between 5 and 10°C. The camera was adjusted so that a passing train would trigger a film recording, and its temperature and a date and time stamp were to be added to the film data. The outlines of the trains are easy to recognise in the images, and there is no difficulty in differentiating between the three train categories: freight, local passenger and

long-distance passenger. The recorded images were evaluated after the end of the measurement period.

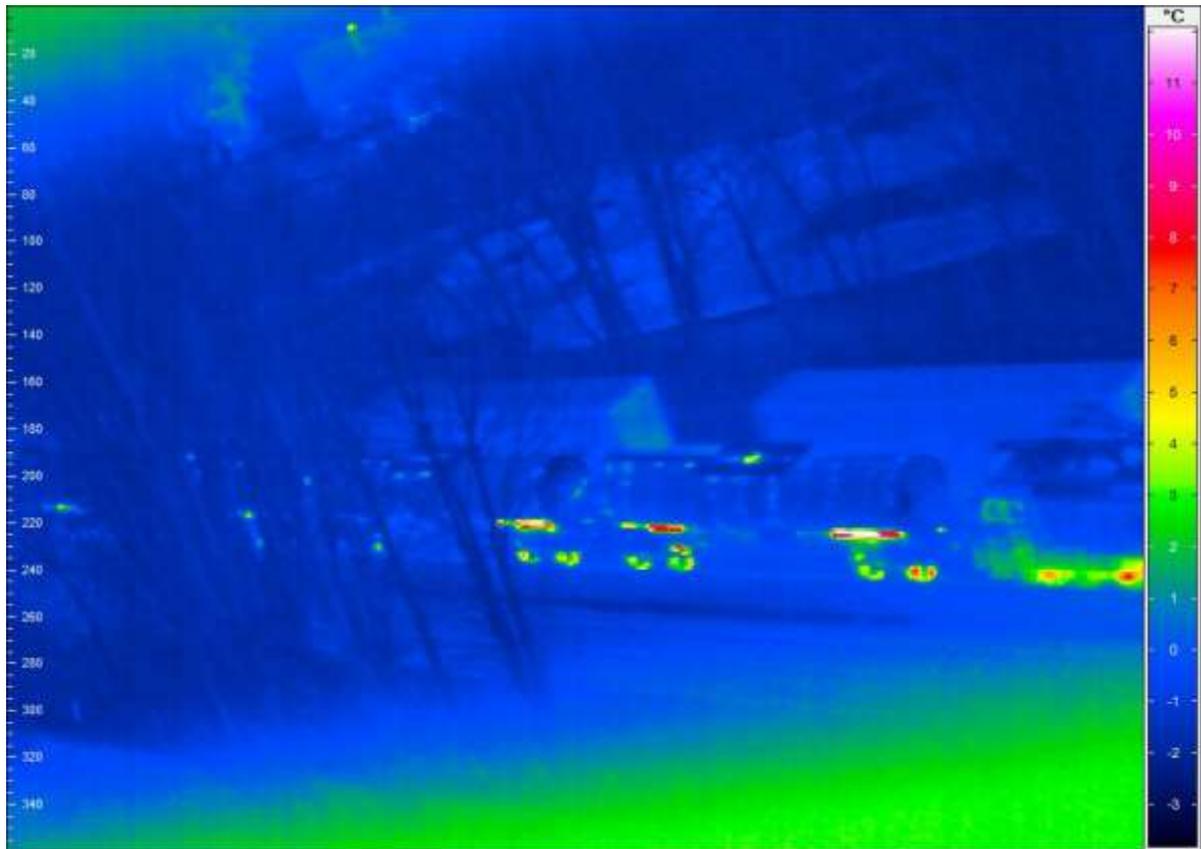


Fig. 4-2 – Recording made with the infrared camera showing two freight trains

The images recorded by the infrared camera are stored temporarily in the working memory of the accompanying laptop until the recording is stopped when the temperature falls below the maximum set. At the end of the recording, the images are transferred to the hard disk for storage there.

The laptop used for this project had only a limited working memory, and that was needed for use by other programs too. With the IRBIS 3 Plus program it is possible to set how many images are to be recorded per second. In that way, memory space can be saved. Despite putting a big effort into making adjustments, the laptop's small working memory caused recordings to be terminated prematurely particularly during the test phase but also on two days during the live recordings. If the maximum temperature in the subject area of the image was exceeded for a lengthy period of time (for example by a parked car), the recording kept on going. This overloaded the laptop's working memory and the recording was terminated.

4.2.2.1 Measurement zone

With the IRBIS 3 Plus program, it is possible to define a measurement zone inside the available subject area. The software thus focuses the temperature measurement on the measurement zone. It is also possible to indicate what temperature must be exceeded in the measurement zone for the recording to start.

4.2.2.2 Trigger temperature

Selecting the trigger temperature is problematic for recordings made outdoors. The temperature pattern throughout the day must be observed continuously. If the trigger temperature is set too low that may cause the camera to run continuously, which will forcefully terminate the recording. If, on the other hand, the trigger temperature is set too high, there is a risk that some trains might not be recorded at all.

Throughout the period from 14 to 27 February 2013, the temperature remained close to freezing point. The temperature of the freight trains' wheels and brakes rises to approximately 10°C for an outdoor temperature of around 0°C. Long-distance passenger trains, like the Inter City Express, reach temperatures of 5°C.

If the outdoor temperature goes up, recording long-distance passenger trains becomes more problematical, since the increase in the temperature of their wheels and brakes is not proportional to the outdoor temperature. In order to find a suitable temperature for starting the recording, it is recommended that the decision be based on the maximum temperature forecast for a given day. In winter, temperatures only change minimally in the course of the day, which generally guarantees that recordings of long-distance passenger trains will also succeed in the evening.

Problems do, however, arise if the sun shines for several minutes on the track and the ballast supporting it. A quick rise in the temperature of the ballast will trigger a continuous recording. During the measurement period, the sky was generally overcast, except for a few days, which made the recordings easier.

4.2.2.3 Measurement accuracy

In the course of a recording lasting several minutes, the temperature measurement may become imprecise. This gives rise to a fault in the measurement, which becomes visible in the laptop's software. The explanation for this is that there is a change in the temperature inside the camera. The consequence is that the measurement of the temperatures is too high or too low. Temperatures that are too high cause a continuous recording, which, again, will lead to forceful termination. Temperatures that are too low, on the other hand, lead to recordings that it is impossible to interpret, since the displayed image is close to black. (Infratec, 2013)

A solution to this problem was found during the test phase. The IRBIS 3 Plus software offers the possibility of shuttering. That means that the recording is interrupted for 1-2 seconds so that the thermogram can adapt to the changed temperature inside the camera. By determining an interval during which shuttering is to occur, it is possible to avoid measurement errors extending over long periods of time.

4.2.3 Setting up the greenhouse

In order to protect the expensive camera and the laptop accompanying it from the effects of the outdoor weather, a greenhouse was set up in cooperation with the physics centre of Offenburg University of Applied Sciences (Fig. 4-2). The greenhouse measures 2.5 x 2.5 metres and has plenty of space to house the camera and the laptop that goes with it.



Fig. 4-3 Greenhouse

4.2.4 Setting up the camera

The infrared camera was setup once the greenhouse was ready. It was fastened to a tripod permitting variable height settings and also forward/backward and sideways tilting. The camera was then connected to the laptop via a FireWire interface.

A frost-protection heater was also installed in the greenhouse to prevent temperatures from falling too low. The aim was to prevent the technical systems from failing on account of being too cold. The frost-protection heater switched on automatically as soon as the temperature fell below 0°C. It provided heat in the greenhouse without affecting the camera's recordings.



Fig. 4-4 – Infrared camera and laptop

5. Survey and results

5.1 Length of trains

The length of the freight trains was established through a random sample. The speed of the freight trains on the line between Offenburg and Lahr is known; it is between 80 and 100 km/h. In order to check this, the time a freight train takes to cover 200 metres was measured with a stopwatch. The following is an excerpt from the measured values.

Seconds	Distance	m/s	Km/h
7.49	200	26.70	96.10
7.95	200	25.17	90.61
7.15	200	27.98	100.74
8.6	200	23.26	83.72
7.17	200	27.89	100.42
8.73	200	22.91	82.47
7.78	200	25.71	92.54
7.77	200	25.74	92.66
6.94	200	28.82	103.75
7.8	200	25.64	92.31
7.87	200	25.41	91.49
8.02	200	24.94	89.78
7.4	200	27.03	97.30
7.36	200	27.17	97.83
	Mean	26.03	93.69

Table 5-1 – Excerpt from the values measured for speed

The mean speed was found to be approx. 94 km/h. A train moving at this speed needs 7.68 seconds to cover a distance of 200 metres. In order to establish the length of the freight trains, an additional value is needed, namely, the time from when its front enters the section to when its rear leaves it. Since this value includes the train length, the mean time for covering 200 m, i.e. 7.68 s, must be subtracted from it.

This results in the train length depending on the number of seconds. This value then has to be multiplied by the particular speed in m/s. The result is the train length in metres. Table 5-2 contains an excerpt of the values measured and the computations.

Time the train needs to cover a section 200 metres long (x)	Train length depending on the number of seconds x – 7.68 s	Length of the train with $(x - 7.68 \text{ s}) * \text{m/s}$
20.86 s	13.18 s	342.97 m
20.50 s	12.82 s	333.54 m
33.39 s	25.70 s	668.99 m
30.47 s	22.78 s	592.96 m
30.12 s	22.44 s	583.91 m
30.51 s	22.82 s	594.00 m
23.67 s	15.98 s	415.95 m
33.30 s	25.62 s	666.67 m
34.10 s	26.41 s	687.40 m
28.07 s	20.39 s	530.55 m
21.86 s	14.18 s	369.00 m
22.67 s	14.98 s	389.95 m
29.51 s	21.82 s	567.97 m
33.87 s	26.19 s	681.51 m
Mean length:		530.38 m

Table 5-2 – Excerpt of values measured for train length

The lengths computed here contain inaccuracies, since the times were measured by hand. A total of 66 trains were measured. This measurement resulted in a mean freight-train length of approx. 530 metres. It is clear from this that only very few trains exploit the maximum length they could have. Most trains still offer very considerable reserves. For a maximum train length of 740 metres, the mean unused length is 210 metres.

5.2 Train numbers

In the following section, the data collected is presented for each day of the week. The utilisation of the infrastructure capacity is also shown for the course of a day. For this purpose, the day is divided into three time slices, each eight hours long, and the mean train numbers are presented for these, as established over two weeks.

5.2.1 Weekly overview

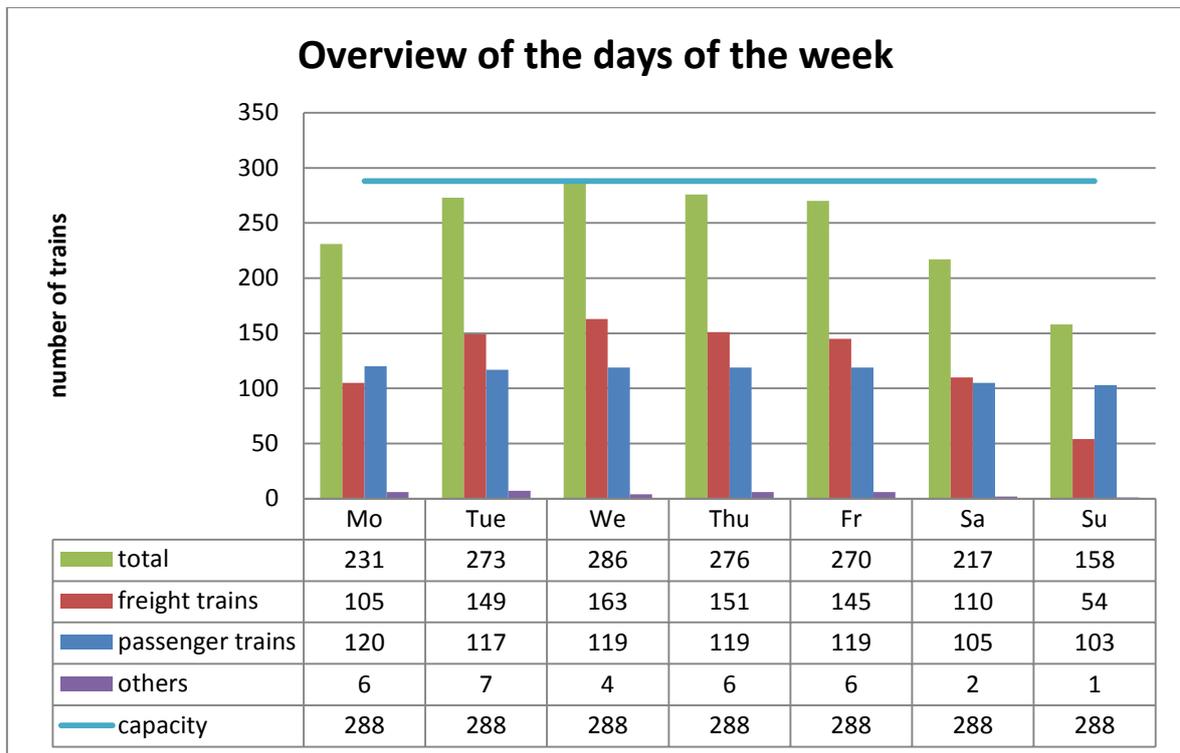


Fig. 5 1 – Weekly overview of train numbers

The weekly overview shows that, at the time the survey was carried out, the line's capacity of 288 trains per day was not really used to the full on any day. However, the measured capacity utilisation on the days from Tuesday to Friday comes very close to the estimated rate. This load is greatest on Wednesday with 286 trains. This corresponds to a capacity utilisation of 99.3%.

It is striking that the train numbers on Sundays are clearly lower than on other days of the week. The number of freight trains, in particular, reaches only one third of the train number on the very busy weekdays of Tuesday to Friday. The number of passenger trains is also 13% lower. On two days of the week, Saturday and Monday, the number of trains is also significantly lower than on the busiest days (-21% and -14% respectively).

5.2.2 Number of trains on Monday

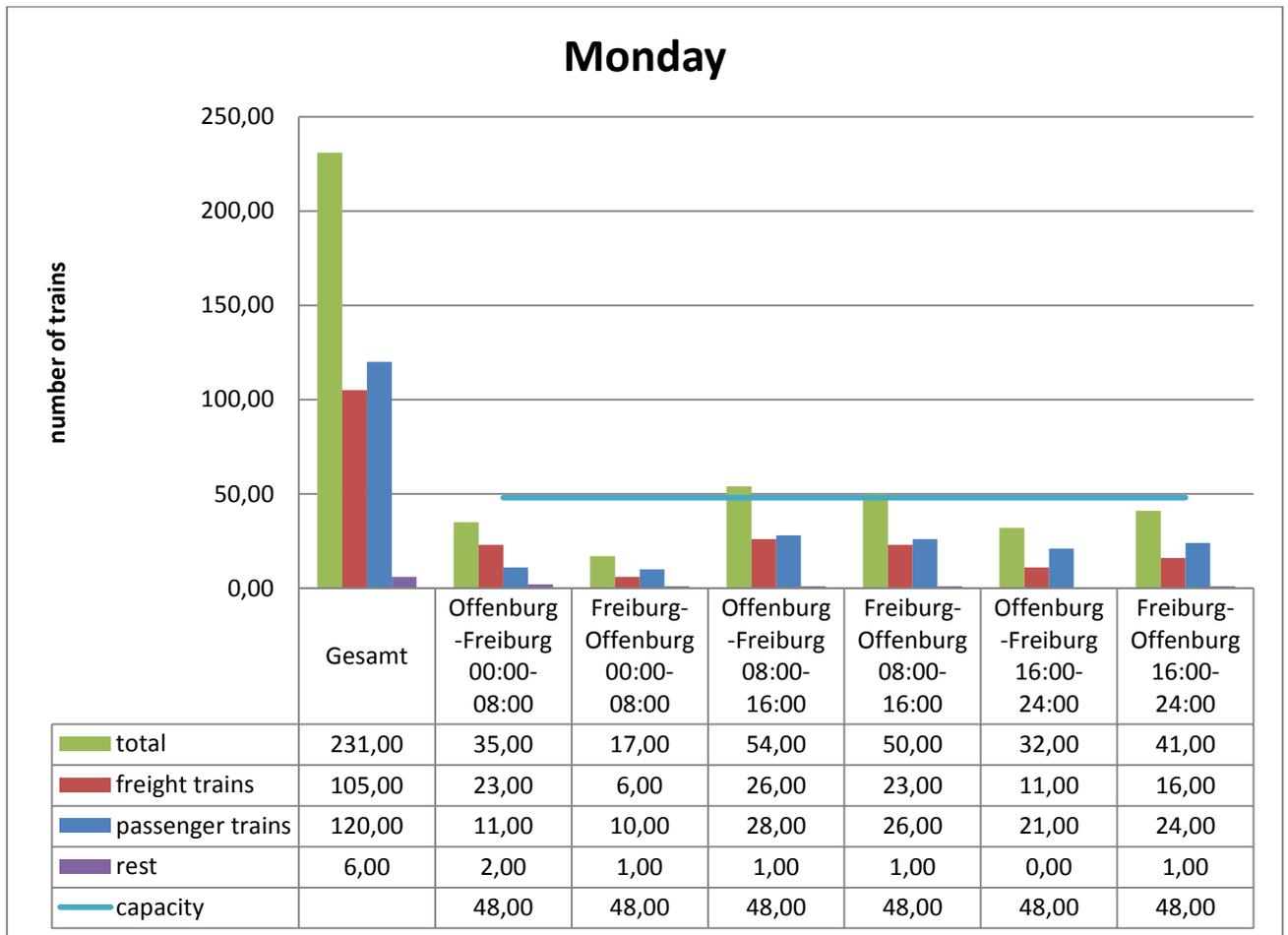


Fig. 5-2 – Train numbers on Monday

On Mondays, the capacity utilisation on this section of line is clearly at its highest during the time slice between 08:00 and 16:00. The computed capacity limit is exceeded in both directions (113% from Offenburg southwards towards Freiburg). This can result in deterioration in punctuality during this period. Capacity utilisation is markedly lower during the day's other two time slices. The explanation for that during the morning time slice from 00:00 to 08.00 is to be found especially in the lower number of passenger trains. During the evening time slice from 16:00 to 24:00, the number of freight trains is appreciably lower. It is striking that, during the morning time slice, twice as many freight trains travel in a southerly direction as in a northerly one.

5.2.3 Number of trains from Tuesday to Friday

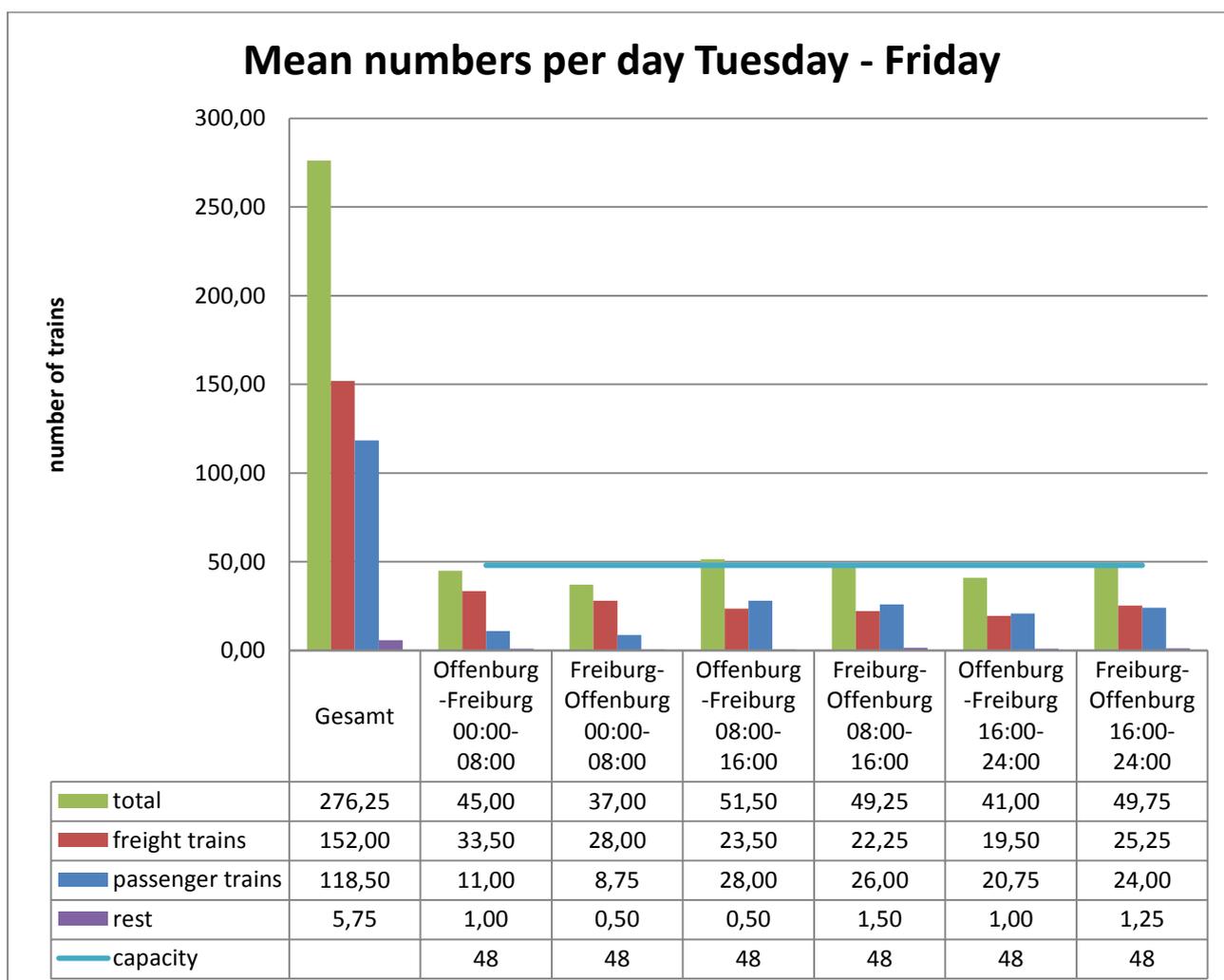


Fig. 5-3 – Mean train numbers from Tuesday to Friday

It is on the weekdays from Tuesday to Friday that the highest capacity utilisation is to be noted. During the observation period, a mean of 276 trains per days ran over this section of track. That corresponds to a capacity utilisation over the whole line of 95.8%. The number of freight trains increases by nearly 30% compared with Monday. During the middle time slice of the day, the number of trains in both directions exceeds the capacity limit. During the evening time slice, it is only in the northerly direction that the limit is exceeded.

Southbound traffic from Offenburg to Freiburg is heavier than in the opposite direction during the first time slice of the day, just like on Monday. Capacity utilisation is the other way round during the evening time slice.

5.2.4 Numbers of trains on Saturday

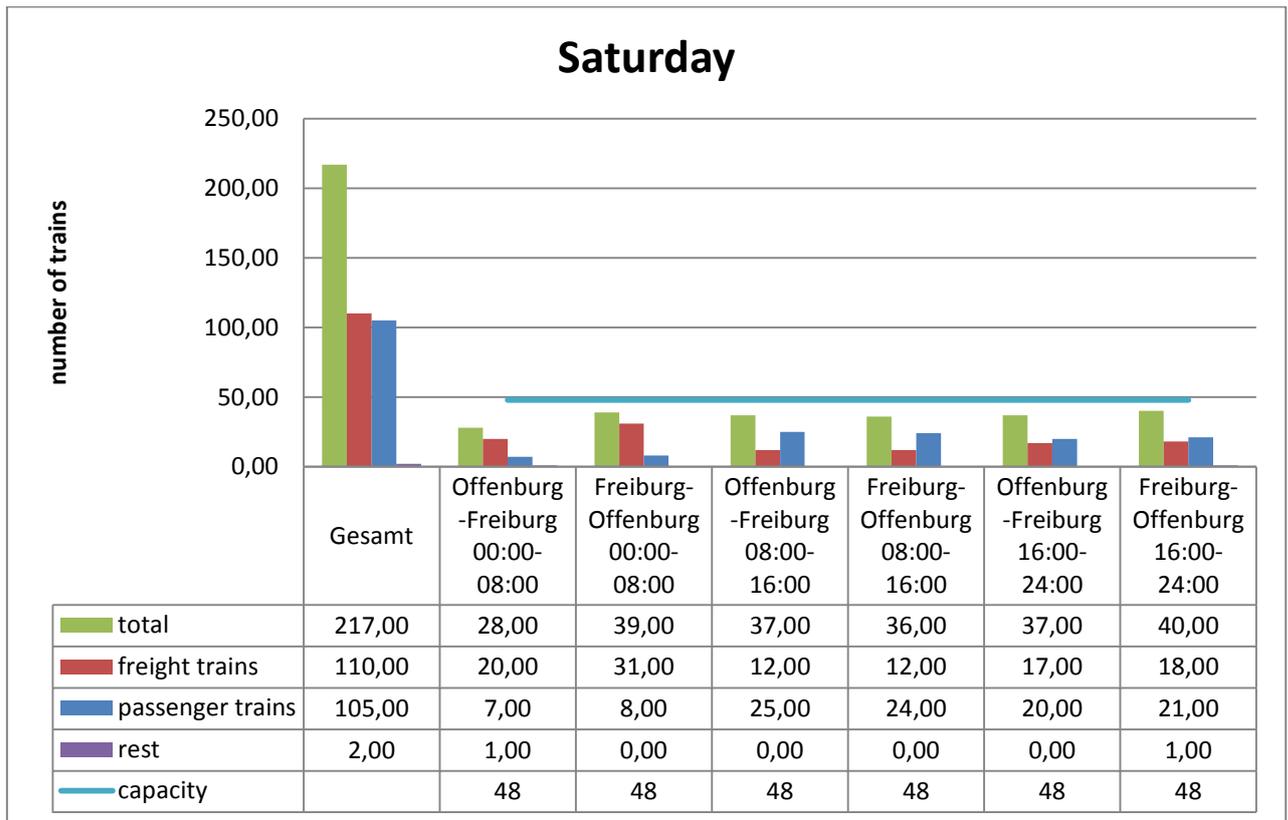


Fig. 5-4 – Train numbers on Saturday

The train numbers on Saturday are noticeably lower than those between Tuesday and Friday. Capacity utilisation is relatively balanced throughout all three time slices on Saturday. The only noticeable difference is that appreciably more trains move in a northerly direction than in a southerly one during the morning time slice. The mean total figure for trains using the line on Saturday during the observation period was 217. This corresponds to a capacity utilisation of 75.35%. So there is free capacity for additional trains to run on Saturdays.

5.2.5 Numbers of trains on Sunday

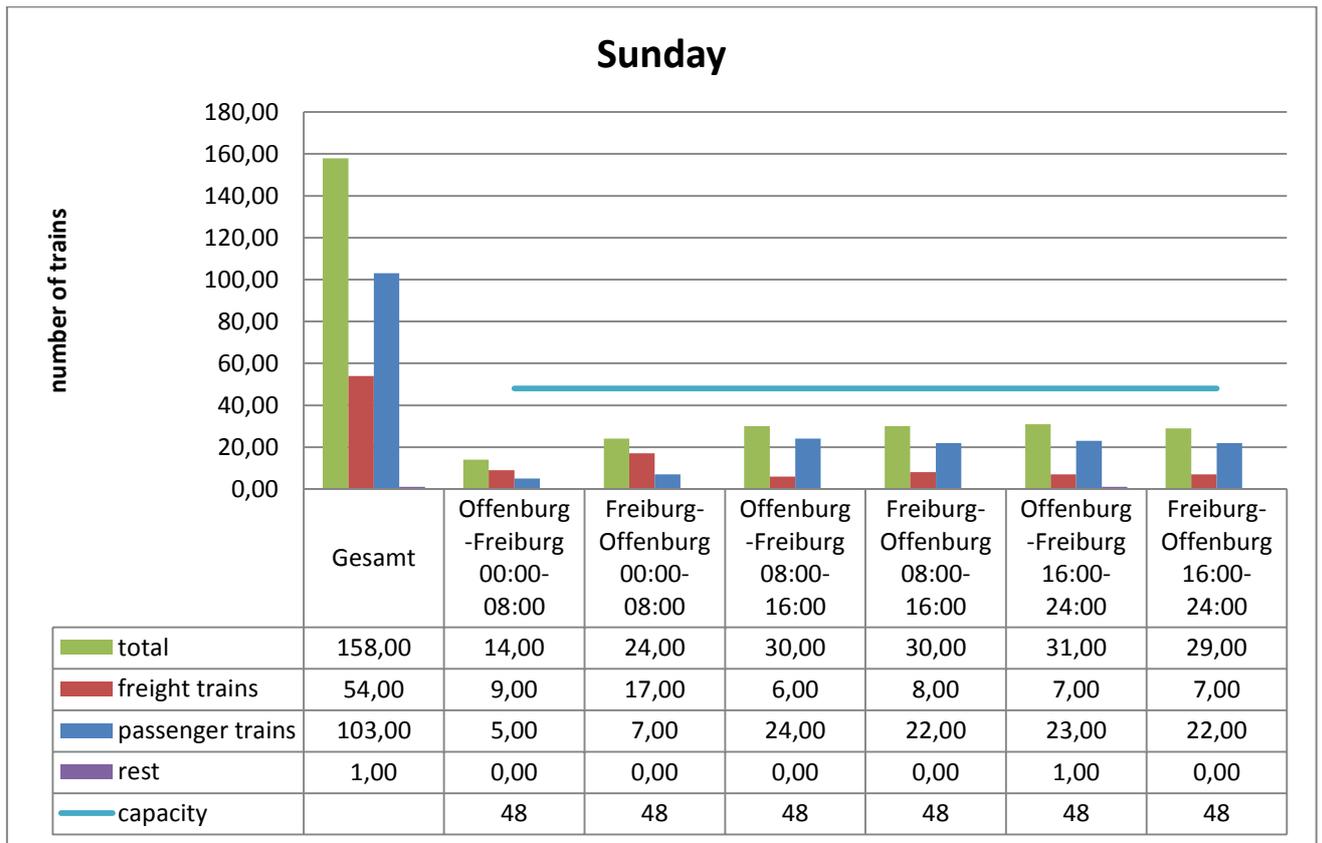


Fig. 5-5 – Train numbers on Sunday

With a mean number of 158 trains, the line's capacity utilisation on Sunday is 54.86%. This is the lowest figure for any time during the week. The volume of freight traffic is virtually halved compared with Saturday. This is a surprising finding. Given the Sunday ban on heavy goods vehicles (HGVs) in Germany, it would be a reasonable assumption that the transport companies would carry more by rail at the weekend. For Sunday, there is thus a potential of 130 additional trains that could run over this section of line.

In contrast to the days from Tuesday to Friday, it is to be observed that traffic running towards Offenburg is equal to or greater than traffic running towards Freiburg. The explanation for this might be that there is greater occupation of the Basel-Muttenz marshalling yard compared with the marshalling yards further to the north. The number of passenger trains is 11.39% lower than on Tuesday to Friday.

5.2.6 Plausibility analysis

The first plausibility test performed on these results was to compare them with Deutsche Bahn's passenger timetables. On some days, it was ascertained that the survey figures vary slightly from the timetable. One explanation for these deviations might be that the infrared camera triggered continuous recordings at certain times of day. It did not take very long for the image memory to become overloaded. Smaller deviations were also found to have been caused by erroneous counting of the trains. The data for the passenger traffic was compared with Deutsche Bahn's published timetable and that for the freight traffic was extrapolated.

A meeting was arranged with representatives of DB Netz in Karlsruhe on 19 April 2013.¹ In the course of the discussions, the network operator's experts stated that the measured distribution of the train numbers and also the absolute figures were in line with their experience. They did not, however, express any views on the detailed figures, putting forward the argument that these were classified as a business secret. The experts assume that the train numbers on the Rheintalbahn are also subject to seasonal fluctuations. The seasonal maximum in train numbers would thus be reached in the months of May and June and September to November.

¹ Rüdiger Scherer, head of client management, and Martin Sacher, head of infrastructure management

5.3 Potential

5.3.1 Capacity reserves

The analysis shows that utilisation of the capacity of the Rheintalbahn on the section between Offenburg and Lahr is subject to fluctuations during the observation period. Capacity utilisation is at its highest on the weekdays of Tuesday to Friday. The capacity limit is exceeded in particular, during the time slice between 08:00 and 16:00 and during the evening time slice in the direction of Offenburg. On the other days of the week, especially on Sunday, with a mean utilisation of 55%, there are still capacity reserves for additional trains.

A caveat must be issued, since it is not known with precision how much time is needed for maintenance work. During the observation period, it was noticed that one track was taken out of service some of the time. Both the northbound and the southbound traffic then had to use the same track. Deutsche Bahn regularly uses Saturdays and Sundays to perform longer jobs of maintenance and repairs. If a satisfactory operational quality is to be assured, gaps must be left in the timetable to allow this work to be done.

The statements by the DB Netz experts also indicate that the observation period occurred during a phase of below-average capacity utilisation. It follows from this that there is a further reduction in capacity reserves in the months with above-average capacity utilisation.

5.3.2 Optimisation potential

Possibilities for increasing capacity only exist in upgrading the railway infrastructure. The study presented here shows that the freight trains were not loaded to capacity during the observation period. The mean measured train length of 528 metres is 210 metres short of the maximum length of 740 metres. Improving capacity utilisation ought really to be in the interest of the network manager. Incentives could be given by modulating the scale of charges for train paths, by charging less for train paths for longer trains.

Other possibilities for expanding capacity can be achieved through operational and technical timetabling measures (Weigand 2009: 274). Examples that could be mentioned in this context are the supply-side structure of freight trains and the number and location

of the train-formation yards chosen by the train operating companies. Weigand also sees potential for optimisation in the simultaneous planning of train paths.

The section of railway line between Offenburg and Lahr might contain potential for optimisation in the planning of the train sequences. The two tables reproduced below show the relative frequency with which the various train sequences occur. Reading vertically shows the train running in front, and reading horizontally shows the train following it.

Offenburg-Freiburg	2nd train	LDPT	LPT	FT	Other
1st train					
LDPT		7.78%	9.73%	8.58%	0.41%
LPT		5.12%	1.26%	12.55%	0.86%
FT		11.04%	10.35%	29.57%	0.70%
Other		0.49%	0.39%	0.96%	0.21%

Tab. 5-3 - Frequency of the train sequences travelling from Offenburg to Freiburg

Freiburg-Offenburg	2nd train	LDPT	LPT	FT	Other
1st train					
LDPT		8.62%	7.77%	10.22%	0.22%
LPT		7.84%	3.58%	11.00%	0.53%
FT		9.20%	10.14%	27.52%	1.33%
Other		0.38%	0.64%	1.00%	0.00%

Table 5-4 - Frequency of the train sequences travelling from Freiburg to Offenburg

From these tables, it will be seen that a freight train travelling towards Freiburg has a probability of 11.04% of being followed by a long-distance passenger train. So the freight train would have to allow the faster long-distance passenger train to pass it. These overtaking manoeuvres cost time and possibly sacrifice important train paths. Trains travelling towards Offenburg have a similar distribution. In this direction, there is a 9.2% probability of a freight train being followed by a long-distance passenger train. The explanation for the high frequency of the freight train/freight train sequence is that no passenger trains run at night. That makes it possible for freight trains to run with very short headways at night. After a cluster of 4-5 trains with short headways, there is a longer pause, providing an opportunity for possible delays to be made up again.

A further increase in capacity can be brought about by reviewing and improving the technology. One possibility is continuous automatic train control (LZB or Linienzugbeeinflussung), which is already in use. This is based on an electric cable laid in the track and continuously monitoring the position and speed of a train. That makes it possible for trains to follow one another at braking distance. However, not all railway lines and trains are equipped with this system. It is only partly used on the Rheintalbahn. Furthermore, it is a technology that can only be used in Germany. (Jochim, 2009)

Another avenue worth pursuing might be implementation of the European Train Control System (ETCS), a concept developed in the framework of the European Union. It functions in a similar way to LZB, with the difference that positions and speeds are communicated by radio. In future, this system is intended to apply for the whole of Europe. (Pachl, 2011)

6. Conclusions

6.1 Different rates of capacity utilisation

The analysis presented in this report contrasts with other studies in that it shows how the capacity utilisation on one section of the Rotterdam-Genoa Corridor varies in the course of a week and on individual days of the week. Studies known previously have tried to present the capacity of a section of a railway line using just one single figure. In a report by the Infrastructure Managers' Group on "Development of the North-South Corridor" (2004: Annex 1), the assumption is made that the section of railway line between Offenburg and Freiburg has a capacity of 175 freight trains. Another study commissioned by the German Federal Environment Agency (Umweltbundesamt) arrives at the conclusion that the maximum capacity of the same section is 180 freight trains (Holzhey 2010: 57). The author diagnoses a bottleneck in 2006 and 2007. To be more precise, he finds a shortfall of ten freight-train paths per day over this section.

In the latest report from the North-South Corridor Infrastructure Managers, the number of freight trains running on the line between Offenburg and Basel on Thursday, 27 September 2012, is indicated as 177 (Corridor Rotterdam-Genoa 2013: 21). The authors are at pains to make the point that Thursday is one day of the week with above-average freight traffic and that September is a month with above-average freight traffic too. One criticism to be made of their study is that it completely ignores the quality of the transport services (susceptibility to delays) as described in section 3.4 above. The authors arrive at the conclusion that there is no bottleneck on this railway line.

What would be of interest in this connection would be to examine delays in passenger and freight traffic on days and in months with above-average and lower traffic volume. Realistically, however, that is not going to be possible, since Deutsche Bahn classifies that data as a business secret too.

Specific statements regarding unused capacities or optimisation potential are not possible with data that has had to be simplified in this way. Counting trains between Offenburg and Lahr shows that utilisation of the capacity of a section of a railway line varies greatly at different times of the day, on different days of the week and also in different months of the year. It also shows that the capacity of the Rheintalbahn is used to the full from Tuesday to Friday on that part of the line where there are still only two tracks and that no significant further increase in transport capacity is to be expected with this infrastructure. Decisions on necessary infrastructure enhancements to the German railway network must of necessity take this fact into account. Deutsche Bahn's practice of classifying this data as a

business secret constitutes an obstacle to an objective discussion on how meaningful it is for public **investments** to be made in the railway infrastructure.

6.2 The Rheintalbahn as a bottleneck

The data collected in February 2013 show that at this time of the year, at least at the weekend and more especially on Sunday, there are still capacity reserves for the transport of freight. On the weekdays of Thursday to Friday, this capacity reserve is, however, only marginal on the basis of the assumptions underlying the study. According to forecasts of how the volume of freight traffic is going to develop in the years to come, utilisation of the Rheintalbahn is going to be well over 100% of its capacity. This would lead to delays and longer waiting times along the whole corridor.

A further effect to be expected is that most of the growth in freight traffic is therefore going to take place on the road. Given that utilisation of the Rheintalbahn's capacity in the years before the world economic crisis of 2008 was already higher than measured in this study, this correlation was checked using the data from heavy goods vehicle (HGV) counts on the North-South motorways in the Upper Rhine Valley. The increase in the number of HGVs counted over the period 2000 to 2008 is compared with the increase in the tonnage transported by road in the federal state of Baden-Württemberg and in Germany.

Transport modes	Railways	Inland waterways	Roads	Total
2000	299 100	242 223	3 005 104	3 546 426
2001	291 100	236 101	2 884 479	3 411 681
2002	289 205	231 746	2 720 163	3 241 114
2003	303 757	219 999	2 743 858	3 267 614
2004	310 261	235 861	2 767 167	3 313 289
2005	317 294	236 765	2 764 983	3 319 042
2006	346 118	243 495	2 919 325	3 508 938
2007	361 116	248 974	3 027 941	3 638 030
2008	371 298	245 674	3 077 845	3 694 817
Percentage rise 2000 – 2008	24,1	1,4	2,4	4,2

Tab. 6-1: Development of freight transport volume in Germany from 2000 to 2008 in thousands of tonnes²

² Data source: destatis 2012

During the period considered, the tonnage of freight transported on the German railway network grew clearly by 24.1% whereas growth in the volume transported by road was relatively modest at 2.4%.

Permanent counting points	A35 Baldersheim	A5 Neuenburg am Rhein	Total
2000	5451	3.757	9.208
2008	7.235	4.186	11.421
Per cent rise 2000 - 2008	32,7	11,4	24,0
Permanent counting points	A35 Hoerdtd	A5 Achern	Total
2000	4.792	12.439	17.231
2008	6.654	14.518	21.172
Per cent rise 2000 - 2008	38,9	16,7	22,9

Tab. 6-2: Development of daily HGV traffic in numbers of HGVs (average number per day, seven days a week) at permanent counting points in the Upper Rhine Valley³

In both the southern and northern parts of the Upper Rhine Valley, there was a growth in the total volume of freight transported by road, with figures of 24% and 22.9% respectively, which is appreciably above average compared with the trend for Germany as a whole. The very much higher increase on the French A35 motorway is explained by the introduction of the motorway toll for HGVs in Germany in 2005. This led to approximately 200 HGVs being rerouted from the A5 motorway to the toll-free A35 motorway.

Within the time considered, utilisation of the capacity of the motorway parallel to the Rheintalbahn was already very high (cf. section 6.1), so it can be assumed that, contrary to the average situation for Germany, growth in the transport of freight in the Upper Rhine Valley took place almost entirely on the road. This effect can indeed be understood as a consequence of a bottleneck on the railway.

³ Data source: Bundesanstalt für Straßenwesen; Direction Régionale de l'Environnement, de l'Aménagement et du Logement Alsace

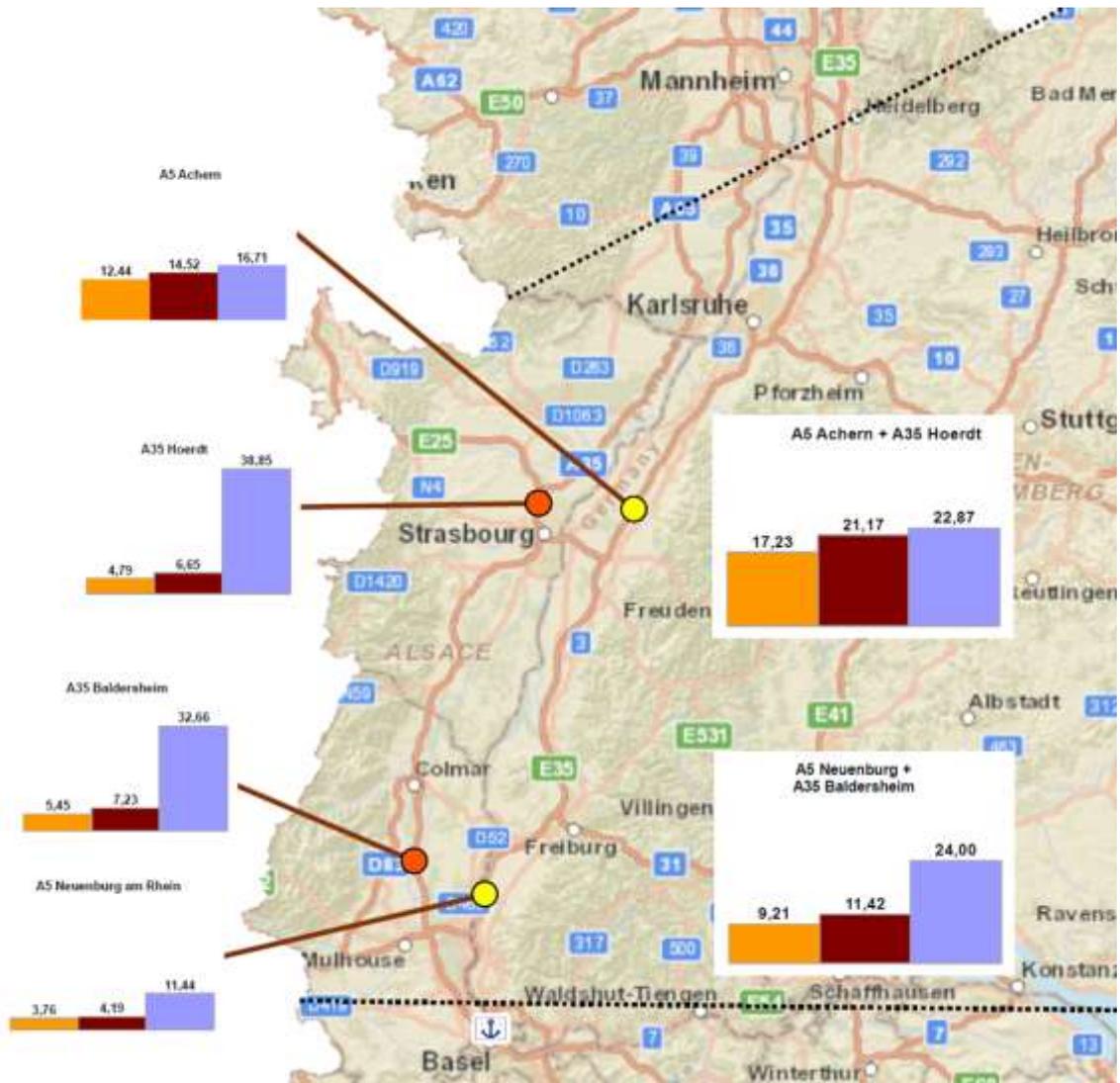


Fig. 6-1: Development of freight transport in the Upper Rhine Valley

7. Bibliography

Allianz pro Schiene (2013): Bund hinkt den eigenen Verlagerungszielen hinterher, Pressemitteilung vom 07.02.2013, Berlin

Brennpunkt Ortenau. (9. Januar 2012). Abgerufen am 11. November 2012 von <http://brennpunkt-ortenau.de/politik-und-wirtschaft/neues-jahr-bringt-neues-hoch/>

BVU Beratergruppe Verkehr + Umwelt GmbH. (2008). Prognose der Verkehrsnachfrage und der Zugzahlen auf der Oberrheinstrecke 2025. Freiburg.

Consultancy, H. T. (2009). Leistungsfähigkeit Infrastrukturen für den Seehafenhinterlandsverkehr.

Corridor Rotterdam-Genoa (2013): Implementation plan; Draft version 4.4.2013

DB Projektbau GmbH. (2012): Die Ausbau-und Neubaustrecke Karlsruhe - Basel - Verkehrsachse für Europa, Stand: Februar 2012, Frankfurt am Main

Deutschebahn.com. (27. Februar 2012). Abgerufen am Januar 2013 von http://www.deutschebahn.com/de/konzern/bauen_bahn/aus_und_neubauprojekte/karlsruhe_basel.html

Deutscher Industrie- und Handelskammertag DIHK (2012): Der Deutsche Außenhandel 2012/2013, Berlin

Drewello, H., Günther, H. (2012): Bottlenecks in Railway Infrastructure - Do they Really Exist? Proceedings of the European Transport Conference, Glasgow/London

Happel, O. (1959): Sperrzeitentreppe als Grundlage für die Fahrplankonstruktion, Eisenbahntechnische Rundschau 8, Heft 2, 1959, S. 79-90

Heister, G. (2009): Eisenbahnbetriebstechnologie. Bahn Fachverlag.

Holzhey, M. (2010). Schienennetz 2025/2030. Ausbaukonzeption für einen leistungsfähigen Schienengüterverkehr in Deutschland. Berlin

Infrastructure Managers' Group "Development of the North-South Corridor (2004): Progress Report 2004 for the IQ-C group, Utrecht, Frankfurt am Main, Roma, Bern

Infratec. (2013): Abgerufen am 23.04.2013 von <http://www.infratec.de/de/thermografie/anwendungsgebiete.html>

International Union of Railways UIC (2004): Capacity. UIC Code 406. Paris

Jahncke, R. (2008): Branchenspezifische Leistungsangebote im Schienengüterverkehr, Schriftenreihe Wirtschaft & Logistik der BVL e. V., Deutscher Verkehrs-Verlag, Hamburg.

Jochim, H., Lademann, Frank (2009): Planung von Bahnanlagen. München: Carl Hanser Verlag.

K+P Transport Consultants. (2008): Die Weichen auf Zukunft stellen. Stuttgart: Industrie- und Handelskammer Region Stuttgart.

Pachl, J. (2011): Systemtechnik des Schienenverkehrs. Wiesbaden

Verkehrswissenschaftliches Institut der RWTH Aachen (2008): Influence of ETCS on line capacity, Paris

Weigand, W. (2009): Mehr Kapazität für den Schienenverkehr - Reicht das bestehende Streckennetz aus? in: ETR, Dezember 2009, Nr. 12, S. 722-727

Wolfgang Fengler, W. M. (2008). Das System Bahn. DVV Media Group GmbH.

Zentraler Kundendienst SBB. (30. Januar 2013). Schweiz.