A study on the capacity of the Gotthard Base Tunnel

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Abstract

For the planned Gotthard Base Tunnel the capacities of a number of variants have been determined with the aid of operational simulations. Decisive for the system choice was found to be the outlay for maintenance of the installation. Maintenance of a double-track tunnel is more expensive than for a single-track tunnel, for two reasons: Reduction in the work that can be performed owing to the traffic on the adjacent track, and the large number of track changes. Together with aspects of production, maintenance, safety, construction and ventilation/ cooling, the results of the capacity study enabled a decision to be made in favour of a system with two single-track tunnels.

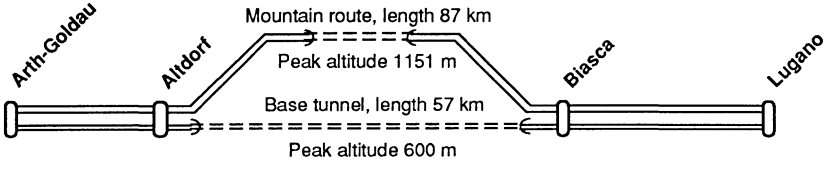
The Task

In the autumn of 1992 the Swiss electorate voted in favour of two new railway routes through the Alps at the Gotthard and the Lötschberg. Since then planning has been proceeding at full speed so that construction work will start in 1996. The Gotthard base tunnel with a length of 57 km represents the longest railway tunnel planned until now. To decide on the system, several variants regarding production, maintenance, safety, construction and ventilation/cooling were examined and compared with one another.

The aim of the study was to deal with the aspect of performance for the system comparison. The question was: Can the different tunnel systems assure a capacity of 300 trains a day, including maintenance needs? Two variants came up for discussion:

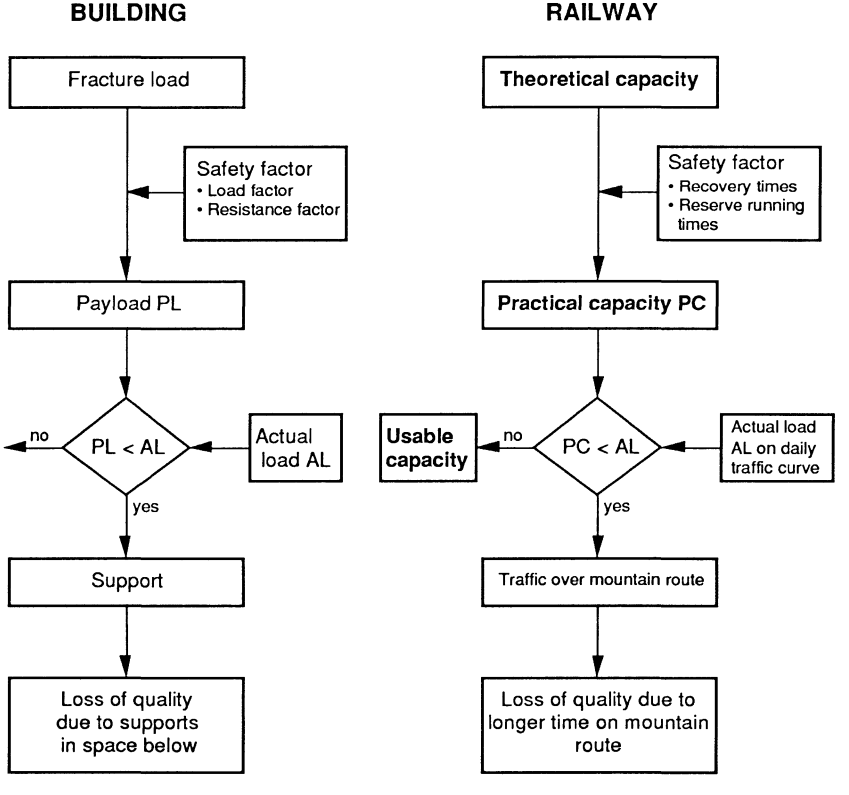
- Double-track tunnel with 11 track changes
- Two single-track tunnels with 3 or 5 track changes.

The Gotthard corridor between Arth-Goldau and Lugano consists of two through double tracks, the existing mountain route and the proposed new route:



Methodical Procedure

The capacity of a railway line depends on a number of factors which influence one another. The figures quoted in the literature are average values. They should be regarded as a rule of thumb. For the present study a distinction is made between three capacity definitions: theoretical, practical, usable. An analogy to the static calculation of a warehouse ceiling explains the difference between these definitions:

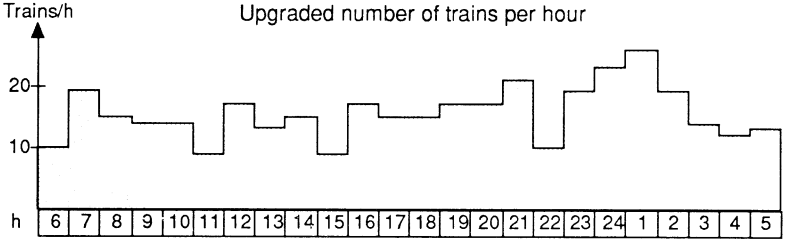


Of the factors which influence the practical capacity, two are of particular significance: The extent of maintenance and the arrangement of the timetable. The usable capacity is that part of the practical capacity that meets the demand. To calculate the capacities the following steps are necessary:

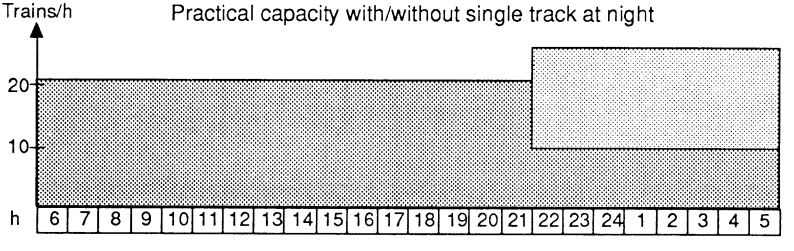
1. Preparation of the data models of all variants for an operational simulation with RWS [1].

2. Drawing up a draft timetable for day and night.

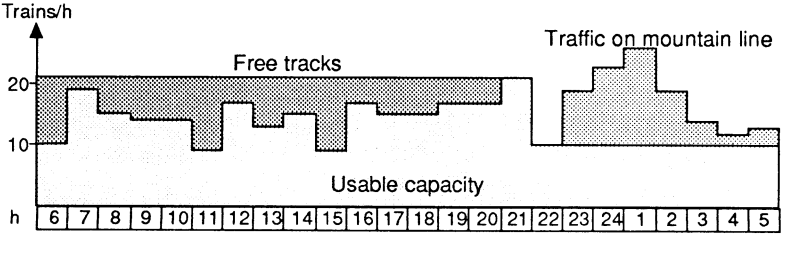
3. Determining the demand by upgrading the present daily traffic load to the target capacity for the Gotthard base tunnel.



4. Calculation of the practical capacities, separately for day and night traffic, with and without blocking tracks for maintenance.



5. Spreading the necessary maintenance shifts over the whole year with due allowance for the permissible single-track sections and a minimum capacity of 300 trains per workday. Determination of the effects of the maintenance concept per variant:



Categories of Trains and Draft Timetable

The examination involved the following categories of trains:

Train Type	Locomotive		Train		Max. Speed
	Number	Rating	Length	Load	
High Speed	1xBoBo	6100 kW	230 m	400 t	200 km/h
Intercity	1xBoBo	6100 kW	320 m	600 t	160 km/h
Fast Freight	2xBoBo	12200 kW	450 m	1200 t	160 km/h
Freight	2xBoBo	12200 kW	750 m	2000 t	120 km/h
Freight	2xBoBo	12200 kW	750 m	2000 t	100 km/h

Initial calculations of running times proved that there were relatively small differences between single and double-track tunnels. The generally lower speeds in the tunnel at the end of gradients are notable: a high speed train coming from the south has a speed of 172 km/h at the end of the gradient (0.1%), a freight train is slowing down to 86 km/h.

The capacity study is based on draft timetables. The entry times of passenger trains at the northern boundary of the system were stipulated by Swiss Federal Railways. Trains in the opposite direction run symmetrically. The minimum interval between trains is 3 minutes. A reserve of 7% is added to the trip times. The speed difference between slow and fast trains is 80 km/h (200 - 120 km/h) during the daytime, at night for reasons of capacity 60 km/h (160 - 100 km/h).

Transalpine Traffic at the Gotthard

The annual load of freight traffic is relatively well balanced. Only in August and at New Year may a certain drop be observed. On the average 25 - 30 mio. gross tons were carried over the Gotthard route in recent years, the southbound share being around 60%.

The weekly load shows much greater fluctuation. Two distinct blocks may be observed: Tuesday to Saturday and Sunday plus Monday. Freight traffic on Sundays and Mondays amounts to barely 40% of the weekday traffic. With this weekly load, the capacity of 300 trains per day is only necessary on weekdays.

The daily load of transalpine trains on weekdays and weekends during the summer timetable 1991 served as a basis for the upgrading. The target capacity on the Gotthard route is based on 300 transalpine freight trains (with 62 of them taking the mountain route) and 98 passenger trains (26 on mountain route). That results in a maximum of 310 trains through the base tunnel. To investigate the capacity the daily load of freight trains was upgraded from the present 115 to a future figure of 300 trains. Passenger trains will remain unchanged.

Accordingly, the potential traffic through the base tunnel amounts to 372 trains.

Trains	Weekdays Summer 91	Upgraded future daily load		
		Weekdays	Saturdays	Sundays
Freight	115	300	198	119
Passengers	72	72	72	72
Total	**187**	**372**	**270**	**191**

Line Capacity related to Service Offered

A draft timetable is based on a set concept for the passenger trains and contains only as many freight trains as possible with an interval of 3 minutes between trains. The capacity of the draft timetable is thus between the theoretical and the practical capacity. The minimum intervals between trains are only attained in exceptional cases. No statement is made as to whether the number of trains envisaged with the draft timetable is operationally admissible.

To determine a practical (i.e. operationally admissible) capacity with sufficient reserves and recovery times, a method known as "line capacity related to service offered" was adopted. With the introduction of regular interval timetables it was necessary to define the capacity of a railway line more clearly. The term "related to service offered" tends to indicate a procedure based on practice. On the section examined the number of trains running according to a timetable concept is counted. Then, as far as possible, additional trains are added to take increased demand into account. In this process attention is paid to stability of the timetable. The capacity limit of a double-track line is attained, if one train with a maximum delay of 10 minutes does not affect succeeding trains for longer than one hour.

In an initial phase the technically possible minimum interval between trains at the limits of the system was calculated with RWS. Based on these times, the draft timetable was thinned out in a second phase, with the aim of attaining at least 10 minutes buffer time per hour.

For the Gotthard base tunnel this resulted in the following practical capacity without maintenance (both directions):

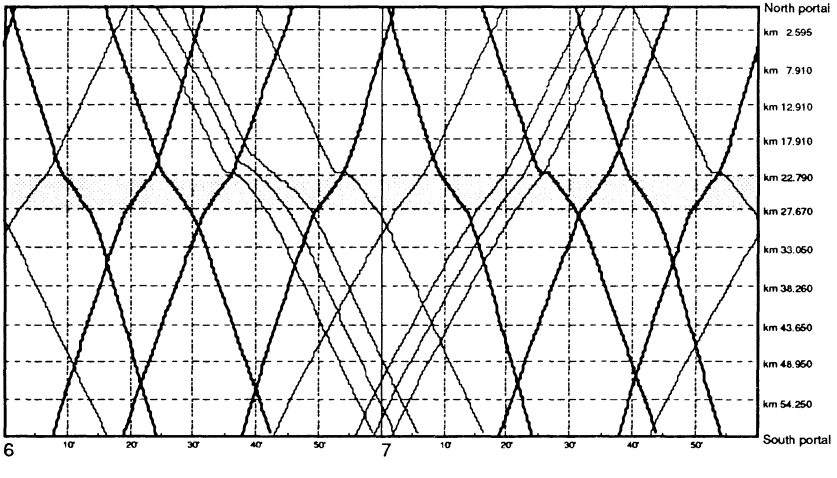
	Trains/h	Number of h	Total trains
Daytime timetable	21	16	336
Nighttime timetable	26	8	208
Total		**24**	**544**

Capacity allowing for Maintenance

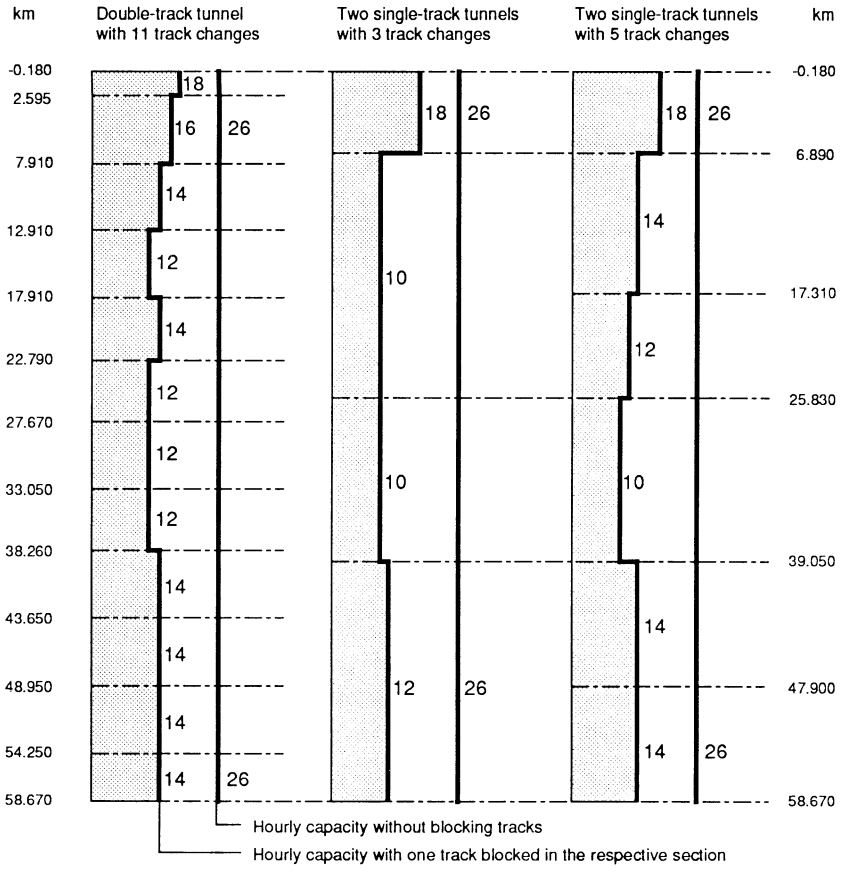
To determine the capacity allowing for maintenance (i.e. partially single-track operation) the following boundary conditions apply:

- During the daytime maintenance shall only be undertaken on those sections where no crossing of passenger trains occurs.
- Speeds for changing track: Double-track tunnel vdiv = 120 km/h, single-track tunnel: vdiv = 90 km/h.
- Maintenance in double-track tunnel: Speed limit on the adjacent track of 80 km/h on a section of about 5 to 6 km.

With these boundary conditions the hourly capacities of all variants were simulated for the possible single-track sections. Representative of all the cases examined is the following graphic timetable (RWS output) for the double-track tunnel with one single-track section between km 23 and 28:



In the diagram below the hourly capacities of the nighttime timetable are shown for the respective sections of the three variants investigated:



Although the average distance between track changes in the double-track tunnel is much shorter than that in the single-track tunnels, the hourly capacity of the variants at night is almost equal. Responsible for this result is the speed limit of 80 km/h for both directions in the double-track tunnel with the corresponding losses of running time.

For each variant, a different yearly number of maintenance intervals of 8 hours has to be taken into account:

Tunnel	Number of track changes	Number of shifts		Total shifts
		Points	Track	
Double-track	11	105	455	560
Two single-track	3	30	393	423
Two single-track	5	45	393	438

These maintenance shifts are spread over the year, regarding the calculated capacities while adhering to certain boundary conditions (e.g. maintenance of points only at weekends). Although the extent of maintenance work is quite considerable, the usable capacity does not drop below 300 trains/day for any of the variants. The greater demand for maintenance in the double-track tunnel results in two maintenance shifts on 200 days a year.

For the further variant comparison the following operational figures were determined. In addition, the increase in running time resulting from track changes and sections with speed limits in the double-track tunnel were worked out and extrapolated over a year, before being compared with the increased running time (+ 45 min) for trips over the mountain route.

	Double-track	Two single-tracks	
Track changes	11	3	5
Annual total transit trains	119'073	119'073	119'073
Through base tunnel [trains/a]	105'862	103'890	110'273
Over mountain line [trains/a]	13'211	15'183	8'800
Total free sections	41'658	45'121	44'215
Annual capacity base tunnel	**147'520**	**149'011**	**154'488**
Added running time mountain line [h/a]	9'908	11'387	6'600
Added running time base tunnel [h/a]	1'526	436	487
Total added running time [h/a]	**11'434**	**11'823**	**7'087**

These figures prove that the solution with two single-track tunnels, despite having only half as many track changes, is superior in the following points:

- Less traffic over the mountain line
- 90 days free from maintenance, fewer days with two maintenance shifts
- No sections with speed limit.

Jointly with aspects of production, maintenance, construction and ventilation/cooling, the results of this capacity study enabled a decision to be made in favour of two single-track tunnels.

To allow for the results of the capacity study changes had to be made to the project for the Gotthard base tunnel. The number of maintenance shifts was severely reduced. Moreover, the longitudinal profile was revised, the maximum gradient being reduced to 0.7%. Meanwhile operational simulation has been extended to cover the entire Gotthard corridor.

References

1. COMPRAIL 87, Computers in Railway Management: A Data Concept for Simulation of Railway Networks, P. Giger; Timetables for the Zurich S-Bahn, G. Rey.
2. Swiss Federal Railways: A procedure for determining line capacities relating to the services offered. Berne. October 1982 (published in German).