RCA Beta – Chapter on Capacity Effects

Table of contents

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1. Introduction

1.1. Purpose of the document

The publication of RCA Alpha has generated interest among railways and suppliers. Direct feedback and feedback from several workshops have provided insight, where clarifications or additional content would be helpful.
This document gives an overview of the capacity effects of an RCA-based system. This overview helps to understand which RCA mechanisms provide a contribution to capacity and should help interested parties to determine what capacity effects may be interesting in their own context.
This is the very first publication on this topic from RCA and its main purpose is to establish the topic and get discussions with stakeholders in the sector going.

1.2. Overview RCA mechanisms and capacity effects

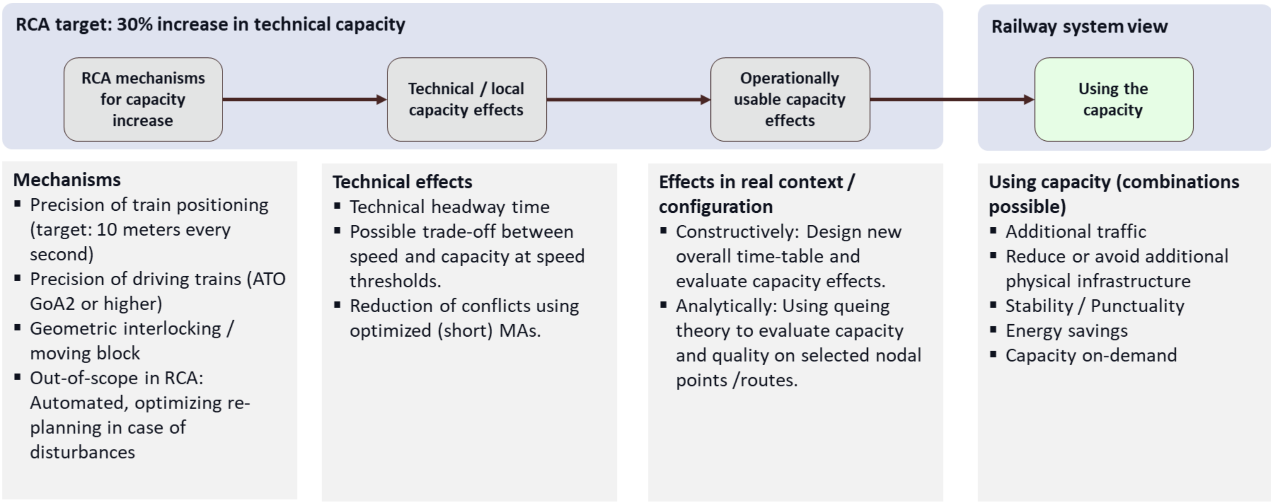
Increasing capacity is one of the main goals of RCA. A substantial increase in capacity can be used to provide more train services, to reduce or avoid investments in physical infrastructure or to increase the stability of the operations. Several mechanisms in RCA contribute to this increase in capacity. At the same time capacity is a notoriously difficult concept[1] in railways.
At the very least there is a need to distinguish between:

- technical capacity as a result of technical effects and for example expressed as “headway time” or “train-per-hours” on a single cross section of the network, and;
- realizable capacity as a result of effects in the context of train mix and timetable constraints on a given railway line.

[1] Difficulties include:

- No commonly agreed definition of capacity, and therefore no single way of measuring capacity.
- Capacity depends on many interrelated factors, making simple capacity statements (“increase by 30%”) mis-leading.

The following diagram gives an overview over the RCA mechanisms, the capacity effects and how they can be used at the business level.



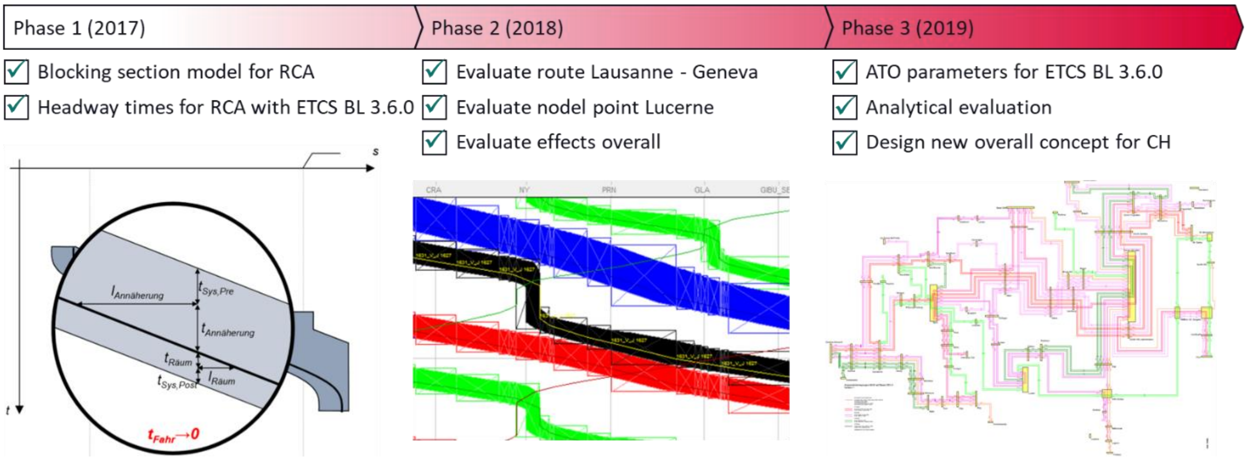
- Mechanisms: Since capacity effects depends on several contributing mechanisms in RCA, we want to explain the effect (and their interrelationship) of every mechanism: see chapter 2.
- Technical effects: see chapter 3.
- Realizable effects (effects in real context): see chapter 4.

Since the net capacity effects depend on factors specific for each network (average speed of trains, heterogeneity of traffic, required stability etc.) we cannot provide an absolute, universally valid number on the capacity increase of RCA, but we can provide concrete examples of the capacity increase in a concrete situation.
The results cited in this document are based on in-depth research on the network and traffic of SBB. For a future update of the document, results from DB and Network Rail will be included.

Note: The capacity effects come from the combination of known mechanisms such as ATO and moving block, not from some specific “RCA technology”. RCA puts the known mechanism into a coherent architecture and the results presented her show the possible effects when combining the known mechanisms.

1.3. Current state of capacity research regarding RCA

In the program smartrail 4.0 an in-depth investigation of capacity effects is being carried out. Based on the technical parameters of an RCA-based system, the following topics have been systematically researched:



Research on capacity effects will continue in the coming years. Most of the effects are not only calculated / modelled, but verified with test runs and pilot installations.

1.4. Scope and assumptions

For our purposes, the number of train paths that can be operated effectively in relation to a given service and quality objective (punctuality) is of interest. This capacity effectively adds value for rail customers.
As described in chapter 2, the signal sections are reduced to zero with RCA and enable headway time to be reduced. However, the capacity not only depends on the signal section length but is also a result of the interaction of various factors: timetable structure (service), rolling stock (ETCS braking curves, dynamics and stopping procedure), technical possibilities of the signalling installations (blocking sections), regulatory framework, railway network topology and operational precision when travelling and stopping. In order to make a statement about capacity, assumptions must be made about all these aspects. Unless otherwise stated, the following assumption applies: “It generally remains at least as good as it is.”

See section 3 of [1] in “Additional material” for more details on those factors.

1.5. Additional material

The following article has been an important source for this document and contains more details:

- [1] IRSA (International Railway Symposium Aachen) Article “A new offer concept for increasing capacity with smartrail 4.0”. To be published in November 2019.
- The next release of this document will include related studies from DB, NR and other IMs on capacity topics.

2. RCA mechanisms with an effect on capacity

The following RCA mechanisms have a direct effect on capacity and have been used in the capacity research (see section 2.4. of [1]):

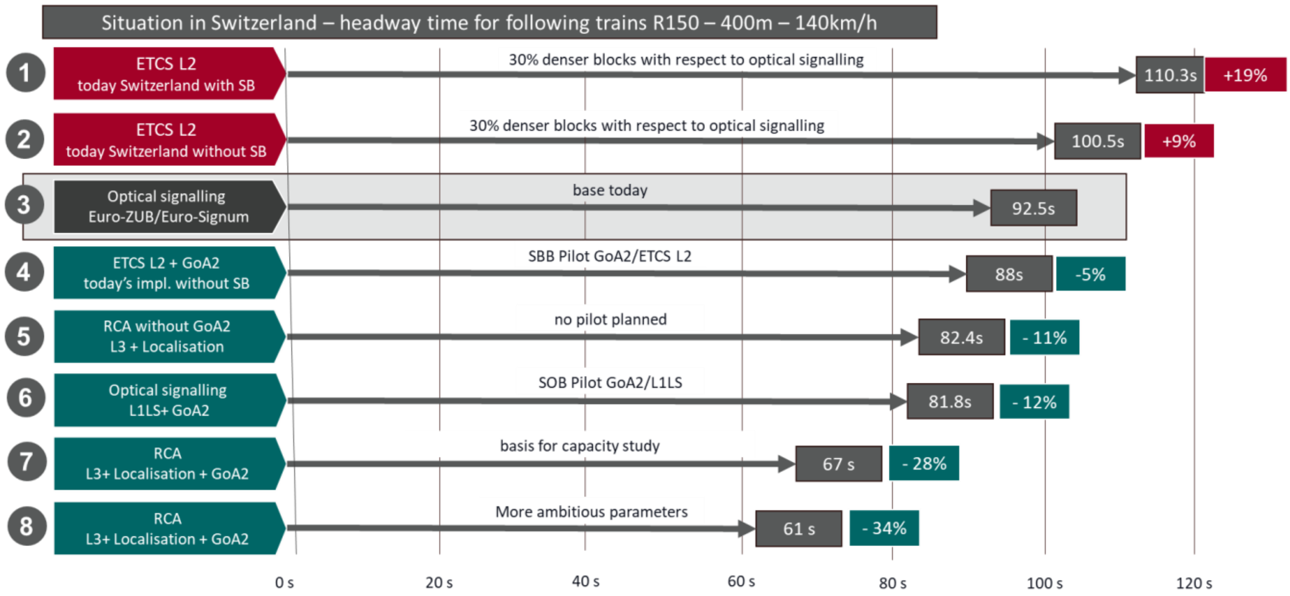
- ETCS Braking curves with advantages given by ATO GoA2 or higher.
- train-based, continuous localisation: localisation accuracy of +/-10 metres and a localization frequency of 1 second (TPR cycle).
- geometric APS (advanced protection system) for moving block with absolute braking distance.
- automated extension of the movement authority (MA) without waiting for a request from the vehicle (this includes the parameter: frequency of MA extension).

The calculations are based on:

- ETCS Baseline 3.6.0 braking curve model with no service brake in target speed monitoring.
- safety margins applied in Switzerland.
- trains travelling along $V_{Permitted}$.

3. Technical / local effects on capacity

The following diagram gives a comparison of different measured (1-3) and calculated (4-8) technical headway times in different configurations. It is very important to note, that comparisons are only possible with very specific assumptions i.e. this diagram does not say that ETCS L2 has lower capacity than optical signalling, but that a well optimized route with conventional signalling in Switzerland can have better headway times than the current ETCS L2 implementations[2] in Switzerland (which have for cost reasons not been fully optimized on headway times and which depend on stricter braking curves, than the case "Optical signalling").



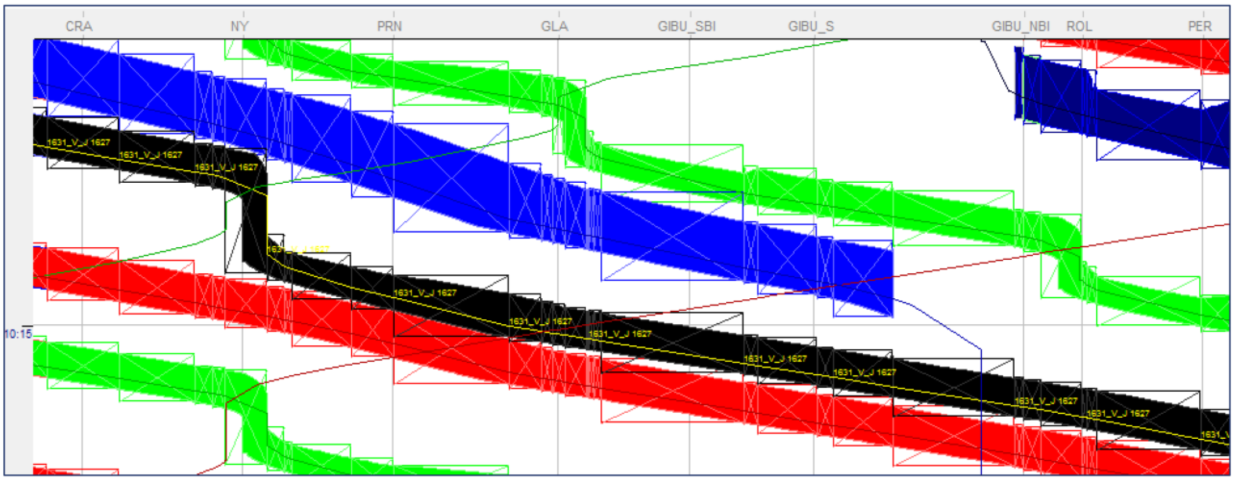
Braking curves

- The capacity evaluation in this document is based on the ETCS 3.6.0 braking curves.
- RCA as an initiative does not work on optimization of braking curves.
- Since the current braking curve model has some negative impacts on capacity, RCA welcomes efforts for optimization of braking curves ("game-changer braking curves model").

[2] The cases (1) and (2) correspond to 2 configurations of existing ETCS L2 lines in Switzerland. Both cases are pure L2 i.e. without an overlay of optical signalling. Target speed monitoring for the case (1).

Illustration of moving block / reduced headway

The well-known blocking section models have been recalculated based on the RCA mechanisms, leading to shorter headway times using RCA. The following diagram shows the model based on a real route. The diagram shows the additional capacity, comparing the blocking sections with RCA (moving block, bands) with the blocking sections of conventional external signalling (rectangles):



4. Capacity effects in real context / configuration

4.1. Analytical determination of the nominal performance

Several real configurations have been modelled using the STRELE and Potthoff methods. The methods are based on queuing theory and provide a relationship between capacity and the level of service (operational quality). Depending on the infrastructure characteristics and the stored operating program, the findings are that the nominal capacity with an RCA-based system increases between 5%-20% compared to optical signalling.

4.2. Constructive implementation in a new overall concept

Since the current time-table concept is based on the current technical capabilities, it became clear that to fully use the newly available capabilities, the construction of a new overall time-table concept would be necessary. This allows to compare the economic advantage (relative cost of obtaining a capacity effect in comparison to achieving the same effect with more physical infrastructure and/or more requirements on the rolling stock).

Section 6 in [1] (see “Additional material”) explains the methodology and process. A first concept has been constructed and has to be evaluated economically. First results include:

- More capacity (also) on heavily used routes (where the capacity need is strongest).
- Reduced travel times because of reduction of waiting times / reserves.
- More opportunities for freight traffic (more available slots, easier to overtake).

Detailed results are expected by the end of 2019.

5. Summary and outlook

The current studies have confirmed a substantial capacity benefit for an RCA-based system. Depending on chosen baseline and concrete situation (time-table, topology, rolling stock), the capacity effects are:

- 25%-30% headway time reduction (technical capacity) for two similar following trains.

- 5%-20% capacity increase (realizable capacity) in given areas according to analytical methods.

Notes:

- The capacity benefits can be used for improvement in different fields:
  - More train services
  - Reduce necessary infrastructure extensions
  - Improve operational quality
- How the capacity benefit is used will depend on individual railways, individual areas.

It is clear, that such substantial capacity increases strengthen the case for an RCA-based system considerably.

We will continue capacity studies in smartrail 4.0 and will continue to publish results in the context of RCA. For a future update of the document, results from DB and Network Rail will be included. The next results are planned for the end of 2019. We welcome feedback in any form and also links to related efforts & studies.