VIA Consulting & Development GmbH

Nota Alternativen: Review of capacity benefits

13th February 2014

Version 1.01

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REVISIONS

Version	Author	Date	Remarks
0.90	Dr. Thorsten Büker Dr. Alexander Kuckelberg	2nd February 2014	
0.91	Dr. Thorsten Büker	3rd February 2014	Minor clarifications
0.99	Dr. Thorsten Büker	6th February 2014	Outcomes of meeting
1.00	Dr. Thorsten Büker	11th February 2014	Finalisation
1.01	Dr. Thorsten Büker	13th February 2014	Update of summary

1 Summary

The document "Railmap ERTMS, Capaciteitseffecten Level 2" was reviewed by VIA Consulting & Development GmbH with emphasis on the reliability of the applied methodology and the taken assumptions. The reviewers come to the following conclusion:

> The elaboration of potential reductions of minimum headway times and of travel times allow, as well as the general setup, is reasonable to determine network-wide benefits of an ETCS implementation. The underlying sample set size is comparatively small but allows deducting lower and upper bounds of the effects.

The major conclusions of the review are as follows:

- The overall setup of the study, in particular the strict separation between the incorporation of minimum headway time effects and travel time reductions, is of high reasonability.
- The elaboration of running time gains and minimum headway reductions per individual scenario seems precise and purposeful. The translation of running-time effects to travel-time effects is performed properly (with the restriction, that a dedicated timetable study would have been more reasonable).
- The underlying set of three infrastructures for the network-wide extrapolation is very small. It is only judged by experts, that they are representative for the network population. The size of the sample has to be seen with caution. Nonetheless, lower and upper bounds of the overall cost-benefit indicator can be deducted. For an average cost-benefit ratio of 0.92, they are as shown below:

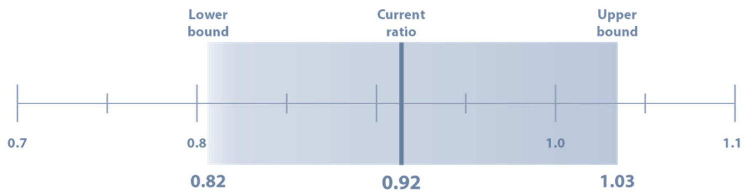

Figure 1 Lower and upper bound of cost-benefit ratio

- Assuming, that there is no considerable error due to the chosen simplifications given above, the benefits of ETCS are tendencially underestimated.
- The simplified handling of single-tracked regional lines does not reasonably falsify the overall indicators. (In specific local situations, an ETCS-related running-time reduction may indeed be one of various impacting summands, whose sum allows a modification of the operational concept. Nonetheless, such situations require specific analysis.)
- The magnitude of the elaborated impacts on capacity is within the range of former international studies and seams reasonable for the given purpose. For the magnitude of achieved running-time gains, there are only few references; anyway, they seem in a reasonable interval, too.

If an increase of the reliability is intended, this might be achieved by spending additional efforts on the application of the same methodology to further infrastructures (corridors) and on the elaboration of a dedicated timetable (at least for a subnetwork).

2 Task and input data

VIA Consulting & Development GmbH (VIA-Con) belongs to the leading consultants in the area of ERTMS, capacity and operations. Since 2002, together with RWTH Aachen University, a series of related studies was conducted on behalf of the International Union of Railways (UIC) as well as of various infrastructure managers. By the end of 2013, VIA-Con validated the plausibility of the *Nota Kansrijke Scenario's* (NKS) with focus on the benefits of increased capacity, decreased running times, and improved operational quality on behalf of the Ministerie van Infrastructuur en Milieu (MIenM). The quantifications and qualifications provided in the NKS were mostly based on an assembly of former studies and research work.

In the subsequent study, *Nota Alternativen* (NA), the analysis of potential socio-econimic advantages triggered by an introduction of ETCS on the Dutch network is deepened. For this purpose, MIenM asked ProRail to conduct a series of studies on the impact of ETCS on the capacity, on running times and related travel times and on the impact on operational quality. Furthermore, it was requested to scale the isolated effects to network-wide effects.

By this review, VIA-Con validates the plausibility of ProRail's study. The review took place in the period from 21st January 2014 until 7th February 2013. It was mainly conducted on the basis of the input data listed below:

[Pr105] Railmap ERTMS, Capaciteitseffecten Level 2
ProRail – VenD VaCo, EDMS# 3468930, v0.5, 17th January 2014

This preliminary version of the study served as input to the overall socio-economic cost-benefit analysis (MKBA). Later updates were performed by the authors but not used for the MKBA. For further reference, use was made of

[µ1] Maatschappelijke Kosten-batenanalyse ERTMS
Concept Eindrapport, version of 17th January 2014

[PP1] Presentation "Towards travel times and punctuality" provided by Arjen Lenten in meeting on 21st 2014 at Utrecht

[BCG0] Memorandum on the Favourable Scenarios for the introduction of ERTMS in the Netherlands, DRAFT – for the Steering Committee (translated version of report);
ertms-ConceptEindRapport-8Oct2013-TSt-Ams_v104_EN.docx

[µ0] Quick Scan Social Cost/Benefit Analysis for ERTMS, FINAL (translated version of report);
2013.10.02 IM032 qsMKBA ERTMS eindrapport definitief_EN.docx

To clarify questions on [Pr105] an interview with the authors was held at Utrecht on 23rd January 2014. During this interview, the following document was received:

[PrB6] Bijlage 6, related to [Pr105], but not yet included there

In addition, various sources listed in the annex were taken into account.

This document is setup as follows:

- Chapters 3 and 4 outline the initial questions related to [Pr105] and the received answers. This set of knowledge is the basis for executing the review.
- In chapter 4 the overall setup of the study is recapitulated by the reviewer. Furthermore, the propagation of errorneous technical figures on the overall cost-benefit ratios is briefly quantified, raising attention for potential consequences.
- Given this awareness, an appraisal of chosen assumption is provided in chapter 5. It becomes evident, how many assumptions most presumably have no impact on the overall outcomes, which share of assumptions may cause an over- or underestimation of the global indicators and which portion of assumption may trigger a falsification of the results (without knowing the "direction" of the error).
- Conclusions covered by [Pr105] are appraised in chapter 6.
- In chapter 7 the advantages and shortcoming identified in chapter 4 to 6 are summarized.
- To round up the picture, chapter 8 covers a rating of the achieved indicators with regard to former studies and to international studies. In a similar manner, chapter 0 compares the outcomes of [Pr105] to the results of the previous NKS phase.
- Finally, chapter 9 gives recommendations regarding the communication of the results at hand.
- For the sake of completeness, potential benefits thanks to ETML are summarized in chapter 12 and an overview of other capacity studies in given in chapter 12.

In general it is assumed, that the underlying computations by VACHE and DONS have been conducted according to the state of art. They are not reviewed explicitely.

3 Protocol of expert meeting on 23rd January 2014

On 23rd January 2014, an expert interview related to the preliminary version of the report, [Pr105], was held at Utrecht. Its authors were represented by:

- Kees van Gent, ProRail
- Birgit Heydenreich, ProRail
- Michiel Vromans, ProRail
- Sander de Pundert, ProRail

The questions listed in section 3.1 were addressed during the interview. The major outcomes are summarized in section 3.2.

3.1 Questions addressed

3.1.1 Questions on 2.1 "Aanpak en gehanteerte uitgangspunten"

- The description of the lines considered merely focues on the lines. To which extent are effects in the adjacent switching zones of the nodes taken into account, too?
- Is the mix of trains (IC, Sprinter, Goederen) on these lines representative for the overall network? How does the mix of services differ on the three lines?
- Is the length of the lines (respectively the length of overtaking sectios which require a unique train order) representative for the overall network?
- The initial situations are all based on ATB-EG/NS'54. References used during the elaboration of the NKS showed, that ETCS L2 effects on lines equipped with ATB-NG are of different nature. Is there a chance to represent the share of ATB-NG lines in the overall indicators?
- The optimization of the static speed-profile is performed for the ETCS scenarios only, although there is also a potential for optimization on certain lines in the ATG-EG scenarios. Is it in line to the overall assumptions of the cost-benefit analysis, to compare opvolgtijden and rijtijden to a non-optimized initial scenario?

3.1.2 Questions on 2.2.1 "Rijtijden Alkmaar – Amsterdam"

- How do the running-time differences for freight services look like?
- What is the difference between the two lines starting with "IC (uit Ekz)"?
- Should "2.1 %" in the fifth line be "2.8 %"?
- According to the table in Bijlage 3, there are 6 IC and 4 Sprinter per hour, each one running twice. According to the table given here, there are 5 IC and 2 Sprinter. Are the average values given in the lowest line simple arithmetic averages or are they weighted average with respect to the probability of each service?
- Is there a chance to split/quantify the effects caused by smoother acceleration (no need to adhere to ATB-EG until the next signal) and caused by "uitgestellt remmen"?

3.1.3 Questions on 2.2.2 “Rijtijden Lelystad – Weesp”

- Same as for 2.2.1, how does averaging take place?

3.1.4 Questions on 2.2.4 “Saemvatting rijtijden alle baanvakken”

- Given the small “size” of the steekproef, a generalization of effects needs to be conducted with care. Approximating the effects on technical running times for IC by an interval bordered with integer numbers (2 % to 3 %) is most likely the highest confidence to give. Is it really reasonable, to define this interval for Sprinter services by floating point numbers of 2,3 % to 4,3 %?

3.1.5 Questions on 2.2.5 “Verklaring resultaten rijtijdeffecten”

- In certain situations, e. g. leaving Zaandam, the speed may be increased to 80 km/h in case of ETCS L2. Basically, ATB-EG offers a supervision of 80 km/h, too. What would be necessary to achieve the same benefit by means of the legacy ATP?

3.1.6 Questions on 2.3.1 “Scope en method”

- The analysis is done by DONS. What are the differences compared to the procedure chosen for section 2.2? Is there an impact on the comparability of the achievied quantifications?
- Are the achieved running-time drops related to a pure increase of the speed to 160 km/h or to a mixture of the speed increase and the introduction of ETCS?
- The differentiation by “theoretische winst”, “praktische winst” and “incasseerbaarheid” is of high relevance. Presumably it was performed by timetable studies. To ensure reliable figures, this differentiation should be carried out for the outcomes of section 2.2, too. Is this feasible?
- The table “incasseerbare rijtijdwinst door het rijden van 160 km/u” provides absolute gains of technical running-times. For the sake of comparability to section 2.2 (and vice versa), it is highly recommendable to provide relative differences to the initial technical running-time, too.
- Is there a chance to provide a “rule-of-thumb” on the ratio of “theoretische winst” and “incasseerbaarheid”? This might help to underpin the outcomes of section 2.2.
- What the benefit of the subsection “Toelichting rijtijdwinst: de snelheidsparadox” in the given context?

3.1.7 Questions on 2.4

- Is there a relationship between the absolute opvolgtijd and the relative drop of opvolgtijd? Is it possible to present a density function (or the variance) of the change of opvolgtijden?

3.1.8 Questions on 2.4.1 “Opvolgtijden Alkmaar – Amsterdam”

- Is there a chance to provide a description of the considered types of train sequences (in particular “perronopvolgingen” and “piektijd”)?
- How often does each train sequence happen, if trains are operated in regular order? This probability is of high importance to quantify the buffer time gain.

3.1.9 Questions on 2.4.3 “Opvolktijden Utrecht – s’Hertogenbosch”

- In section 2.2.3 also freight services are considered on this line. Have they been considered in the analysis of minimum headway times, too?

3.1.10 Questions on 2.4.4 “Resultaten opvolgtijden alle baanvakken”

- According to the text, the given average values are weighted average. By which criterion did weighting take place?
- An interval is provided for the “gemiddelde opvolgtijdwinst”. How is averaging linked to giving an interval? Would be possible to provide boxplots for the achieved key figures?
- “De schattingen voor de (landelijke) gemiddelden laten dus geen uitspraak toe over andere individuele baanvakken”. What is the consequence for the network-wide extrapolation?

3.1.11 Questions on 3 “Reistijden”

- Are the results elaborated in chapter 3 based on “ETCS L2” or on “ETCS L2 + 160 km/h”?

3.1.12 Questions on 3.1 “Van rijtijdwinst naar reistijdwinst – methode”

- If I understand correctly, the actual feasibility of train paths based on reduced technical running-times was not checked in section 2.2 and was section in section 2.3. The assumption “Tussen knooppunten is de rijtijdwinst bijna één op één incasseerbaar als reistijdwinst.” has to be underpinned in detail, since it is of major importance for the general outcomes. Was the actual feasibility of “accelerated” train paths checked for the underlying lines?
- Since in average 0,5 minutes are added as indirect running-time supplement between two blokpunten, one may assume, that regular running-times (technical running-time plus 5 % rijtijdspeling) are distributed with 50 % in the interval of x:00 <= t < x:30 and 50 % in the interval of x:<=30 < t < x:60. Are these shares equally distributed so that one can derive that also after implementation of rijtijdwinsten thanks to ETCS L2, there is a split into equal halfs?
- Can the offset of 0,5 minutes be roughly translated to a relative approximation, enabling a better extrapolation in section 3.2?
- When is Bijlage 6 available? It is crucial to understand the conclusions.
- On enkelsporige baanvakken, rijtijdwinsten are not translated to reistijdwinsten. What is the amount of such lines and how is taken into consideration in the network-wide conclusion, that “de rijtijdwinst bij reizen over knooppunten heen gemiddeld één keer geincasseerd kan worden”?
- What the source of “…dat gemiddeld 6,4 % van de reistijd gevormd wordt door overstaptijd en 4,3 % van de reistijd op grote stations gehalteerd wordt”?
- Does the same ratio apply for journeys which mostly take place with either Sprinter services or with IC services?

3.1.13 Questions on 3.2 "Resultaten reistijdwinst"

- Is the 2.5 % of average winst for IC services corresponding to the indicator achieved in section 2.2.4? If yes, to which extent are rijtijdwinsten due to 160 km/h translated to reistijdwinsten?
- As well, is 3.3 % of average gain for Sprinter services assumed, is deducted in section 2.2.4?
- Are the scenarios "laag" and "hoog" derived from those intervals, which are introduced at the end of section 2.2.4?
- The improvement of 2.5 % is related to the technical running-times. Shouldn't the coefficients of 5 % (rijtijdspeling) and the offset of 30 seconds (integer times at blokpunten) at formally be taken into account, too?

3.1.14 Questions on 4 "Punctualiteit"

- Reduced technical running-times lead to additional running-time supplements, since not all running-time gains can be translated into train paths, cf. consideration by DONS in section 2.3. These additional running-time supplements allow recovering from delay and thus an improvement of operational quality, e. g. expressed in terms of punctuality. How is this relationship considered?

3.1.15 Questions on 4.2 "Toepassing van de method in deze studie"

- Do the three scenarios correspond to those scenarios introduced at the end of section 3.2?
- It is assumed, that ETCS L2 is deployed on the whole network. Effects for the PHS case shall be achieved by means of an expert judgement. Are there already first figures available?
- "Winsten op perronopvolgtijden zijn … conform de gemiddelde winst uit paragraaf 2.3, …" Shouldn't this be a reference to section 2.4?
- Is there a chance to summarize the chosen input parameters from sections 2.* at the beginning of section 4.2?
- The table "veroderstelde winst per scenario" notes 15 % of minimum headway time reduction for perron-opvolgtijden. How is this assumption setup?
- The table "veroderstelde winst per scenario" notes 3,5 % of (technical?) running-time gain gain on single-tracked lines. Where does this number come from?
- How does the approximation "80 % + …" for "instelwaarden buffer" look like for enkelsporige baanvakken?
- The ratio, that 80 % of the required minimum headway time represents the technical minimum headway time, is applied as well for train sequences on the line as for crossing movements. Is there a proof, that the ratio of 80 % is also valid for overkruistijden?
- Why are there five replicaties per BUP and then 150 replicaties per scenarios? Is it possible to clarify, how random variables (respectively sets of discretized random variables) are spread into the runs of the Monte-Carlo simulation?

3.1.16 Questions on 4.3 "Resultaten punctualiteit treindienst meersporige baanvaken"

- Punctuality is a relative figure, thus a change in punctuality shouldn't be represented as a relative notion on the relative basic figure. Is there a change to provide the effects in terms of percentage points alternatively?
- What's the basic niveau of punctuality in the ATB-EG scenarios?
- Can the change of average delay provided in relative terms, too?

3.2 Major outcomes

All major questions could be clarified during the interview, the answers were plausible. A summary of the answers is given below. An appraisal of assumptions is provided separately in chapter 4; references are made by means of roman numbers.

3.2.1 Answers on 2.1 "Aanpak en gehanteerte uitgangspunten"

- The investigation area per line embraces its adjacent nodes and line-related minimum headway times are computed with regard to acceleration and deceleration processes. Crossing traffic to and from other lines is taken into account, if it occurs in the timetabling. In the chosen set of corridors, this applies to the bifurcation of Uitgeest only. [i]
- There are no quantifications on the "standard" line length and train mix on the network. By expert judgement, the train mix on the considered line is representative for the overall main-line network. Also the length of the lines is representative for the national situation.
- The line Lelystad – Weesp is new infrastructure, where the possibilities of ATB-EG intensively exploitet. In contrast, Utrecht – s'Hertogenbosch represents a line of old infrastructure with a poor utilisation of the technical feasibilities.
- All lines show a comparable trend related to the introduction of ETCS.
- Lines equipped with ATB-NG were not covered by the assessment of effects on capacity. ATB-NG is to the largest extent used on single-tracked lines on the secondary network only. Since potential running-time gains on single-track lines are neglected according to the basic assumptions, ETCS solely causes benefits on operational quality but does not impact the overall effect on capacity. [ii]
- The basic scenario "0" does not cover any major investments to the network. Thus, an optimisation of the static speed-profile related to ATB-EG is not taken into account.

3.2.2 Answers on 2.2.1 "Rijtijden Alkmaar – Amsterdam"

- Freight services leave/enter in the middle of the line. The impact of ETCS on running times is negectable.
- Overall indicators are derived by weighted averaging with regard to the probability of each train pair in case of scheduled operation. [iii]
- Reduced running times are mainly caused by the improved brake supervision ("uitgestellt remmen").

3.2.3 Answers on 2.2.2 "Rijtijden Lelystad – Weesp"

- See above

3.2.4 Answers on 2.2.4 "Saemvatting rijtijden alle baanvakken"

- n/a

3.2.5 Answers on 2.2.5 "Verklaring resultaten rijtijdeffecten"

- See answer on basic scenario in 3.2.1

3.2.6 Answers on 2.3.1 "Scope en method"

- The study on raising speeds to 160 km/h was performed separately in an earlier phase. It covered a timetable compilation with account to new conflicts caused by the different speed profiles.
- The analysis was performed for isolated line sections, conflicts caused on adjacent line sections were not taken into account. [iv]
- The running-time reductions are derived by increasing the speed to 160 km/h only without incorporation of ETCS-related effects.
- While in the study cited in section 2.2 the whole train mix benefits from acceleration, only certain speed profiles were optimized thanks to 160 km/h. In particular sprinter may not be able to reach a speed of 160 km/h due to the distance between two stops. In consequence, no "rule-of-thumb" can be derived.

3.2.7 Answers on 2.4

- n/a

3.2.8 Answers on 2.4.1 "Opvolgtijden Alkmaar – Amsterdam"

- "Piektijd" is related to the minimum time span between an arrival of a train and the departure of a train in opposing direction, whereas the time is related to the arrival/departure time.
- Due to the high punctuality of more than 90 %, the impact of operating in reversed order on the key indicators is neglected. [v]

3.2.9 Answers on 2.4.3 "Opvolktijden Utrecht – s'Hertogenbosch"

- There was hardly any effect on the minimum headway times of freight services.
- With ATB-EG the block lengths are always designed to allow operation of poor braking freight services (braking from 80 km/h to standstill within 900 m). Introducing causes only a minor effect on minimum headway times between freight services but a considerable effect on minimum headway times between freight and passenger services. Thus, in general lines with a low to moderate share of freight services should cover an evaluation of freight-related minimum headway times. Nonetheless, for the case at hand, there was barely no effect on the freight-related minimum headway times. [vi]

3.2.10 Answers on 2.4.4 "Resultaten opvolgtijden alle baanvakken"

- The weighted average was derived with regard to the scheduled frequency of each train sequence. [iii]
- Given the available time and ressources, a capacity studies could only be conducted for two lines (plus the existing results for "Utrecht – s'Hertogenbosch"). The lines were chosen to the best knowledge to achieve reliable results for the national situation. Anyway, the achieved indicators do not allow drawing conclusions for individual situations.

3.2.11 Answers on 3 "Reistijden"

- The results are based on the application of ETCS L2 only. Effects caused by a potential speed increase to 160 km/h are not taken into account.

3.2.12 Answers on 3.1 "Van rijtijdwinst naar reistijdwinst – methode"

- A preliminary version of Bijlage 6 was handed over during the interview.
- Only the less frequented lines are enkelsporig, thus the error of errorneously incorporating travel-time gains on these network sections is assumed to be neglectable.
- In general, the travel time is split by 50 % to IC services, 40 % to Sprinter services and 10 % to regional services. The shares of travel time related to connections (6.4 %) and to stopping at stations (4.3) are averaged by passengers without particular consideration of travelling in IC/Sprinter/Regio.

3.2.13 Answers on 3.2 "Resultaten reistijdwinst"

- The rijtijdspeling and the integer-offset (rounding to full minutes) are not applied to the gain of technical running times, since they are of very minor impact. [vii]

3.2.14 Answers on 4 "Punctualiteit"

- On single-tracked lines, the additional running-time supplements resulting from the reduced technical running times are attributed to the train paths used in SIMONE. On multiple-tracked lines, this adaptation is skipped.

3.2.15 Answers on 4.2 "Toepassing van de method in deze studie"

- No expert judgement for the extrapolation of gifures on the PHS case is available yet.
- Basically, ETCS may cause a reduction of primary delays, since it is assumed, that the probability and extent of technical malfunctions drop. In consequence, also primary delays induced to SIMONE simulations should be adopted accordingly. This adaptation of the timetable was skipped. [viii]
- For each scenario, there were 150 simulation runs with different sets of primary delays. Each simulation run covered a time period of one starting hours plus five hours of the basisuurpatron. [ix]

3.2.16 Answers on 4.3 "Resultaten punctualiteit treindienst meersporige baanvaken"

- MIenM asked for the relative representation of punctuality with the initial indicator fixed to 100 %.
- The basic level of punctuality may not be published.

4 General setup and main drivers

After clarifying detailed issues of [Pr105], the general setup of the study is summarized in this chapter. As well, the very brief description between technical outcomes and the socio-economic impacts are given.

4.1 Summary of the general setup

A description of the chosen general setup, as understood by the reviewers, is provided below. Issues which are subject to a closer appraisal in Chapter 5 are marked with a reference.

- The different static-speed profiles (SSP) resulting from ETCS Full Supervision compared to ATB-EG allow a reduction of technical running times.
- This reduction of technical running times leads to a drop of minimum headway times, at least in general. (In the smaller share of cases, it may also trigger an increase of minimum headway times.)
- The reduction of minimum headway times is boosted, because ETCS Full Supervision allows an individual computation of approaching times as part of occupation times (cf. [3][4]), while ATB-EG requires comparatively long distances from the distant signal to the main signal due to its "worst braking train" principle.
- The reduction of technical running times is in first order exploited to reduce travel times, but only on multiple-tracked lines. On single-tracked lines, the running-time reduction is incorporated for an improvement of operational quality, only, because it cannot be implemented to the timetable due to crossing conflicts. [x]
- The reduction of minimum headway times is firstly used to avoid train paths bendings ("uitbuigingen"), allowing a further reduction of travel times.
- The potential drop of travel times, thanks to shorter running times, between nodes is assumed to equal the reduction of running times, since the same running-time supplements are applied. [xi]
- A considerable share of journeys is routed "over" nodes, which may cause a different relationship between running-time reductions and travel-time reductions. No dedicated timetable study (based on the different speed profiles) taking into account constraints from minimum headway times and passenger connections was performed. Instead, it is assumed that 87.1 % of the global travel time corresponds to running-time (cf. section 3.2.12), while the remaining portion is used for standing in stations and changing between trains. A differentiation, to which extent overall travel times are related to journeys "over" nores, is not given. As there is no dedicated knowledge, to which extent timetabling con-

straints might lower or increase the ratio between running-time reductions and travel-time reductions, a one-by-one relationship is supposed. Based on three different studies shown in [PrB6] the validity of this working assumption is validated. [xiii]

- Both impacts on travel times are socio-economically assessed separately.
- The impact on minimum headway times and on running times was assessed for two particular lines. In addition, results from one former study were taken into account. Due to time restrictions, no broader set of infrastructure could be evaluated. The three lines were declared to be representative for the overall network by means of expert judgement (cf. section 3.2.1 and section 3.2.10), but not by a quantitative comparison to the complete infrastructure population (e.g. regarding line length, train mix).
- The impact of ETCS on technical running times and on minimum headway times was evaluated for the same infrastructures. [xiv]
- While evaluating the effect on running times, no (re-)compilation of the timetable was performed but it was assumed, that all train paths benefit from reductions to a different extent. [xv]
- It is assumed, that there is no need to operate further seats kilometres / train kilometres in the ETCS scenarios, which means, there is no need for additional capacity. Thus, the reduction of minimum headway times is in second order applied to increase buffer times between train paths, improving the robustness of the timetable, leading to a higher operational quality (e. g. expressed in punctuality). [xvi]
- The translation of technical indicators (e.g. travel time reductions and punctuality gains) to socio-economic indicators is perfomed outside of [Pr105]. (Thus, it is also not subject of this review.)
- ERTMS does not only cover ETCS and GSM-R but also a Traffic Management Layer (TM). An introduction of TM is evaluated separately, accepting that potential benefits (cf. Chapter 11) are left out of scope. [xvii]

4.2 Most impacting parameters on cost-benefit ratio

The travel-time reduction, which is caused by the running-time reductions and by the avoidance of uitbuigingen has the by far highest impact on the socio-economic benefits. According to [PP1] it accounts for 1043 Million EUR NPV of the overall benefit of 1911 Million EUR NPV, related to the scenario "Hoofdrailnet implementation" ("HRN"). According to the same source, the cost-benefit value is 0.92. Based on separate information (discussion with Arjen Lenten on 23rd January 2014 and mail by Arjen Lenten of 31st January 2014), the mechanisms are as follows for the scenario "full network implementation":

- Extending travel-time gains by additional 0.1 % for IC passengers (from 2.5 to 2.6 %) results in 20 Million EUR NPV.
- Extending travel-time gains by additional 0.1 % for Sprinter passengers (from 3.3 to 3.4 %) results in 11.5 Million EUR NPV.
- Improving 3-min-Punctuality by 10 percentage points saves 11 Million travellor hours per year, which briefly means 110 Million EUR NPV.

- The different impact is caused by the different share of initial overall travel times in IC and Sprinter services (60 % vs. 40 %).

For the further assessment, we assume as follows:

- The relationships given above for the scenario “full-network implementation” can be approximately applied to the “HRN” scenario, too.
- There is a linear relationship between travel-time gains and socio-economic benefits.
- There is a linear relationship between punctuality gains and socio-economic benefits. (By definition, punctuality is a non-linear indicator. Taking into account the magnitude of change and the overall share of punctuality gains on the cost-benefit ratio, this simplification seams reasonable, anyway.)
- Converting 25 % more or less running-time gains to travel-time gains corresponds to 2 percentage points less or more punctuality gains. This effect is achieved by implementing less or more running-time supplements because of “unusable” running-times due to timetable constraints.

The samples underpinning the results on running-time gains (section 2.2 of [Pr105]) and minimum-headway time gains (section 2.4 of [Pr105]) are based on a comparatively small sample size, which is – according to expert judgement – representative for the overall network. Given this knowledge, it can be assumed, that an analysis of larger samples would not cause the average value per indicator to reside outside of the current maximum/minimum value of each indicator. In consequence, the 25-%-quantile and the 75-%-quantile may be supposed to form the outer bounds of the interval, within which the indicator would reside.

Since there is no formalisaton by means of samples related to travel-time gains (only the description given by [PrB6]), no use of quantile values can be made. Alternatively the assumption is done, that only 87.5 % of the (87.1 % of the) running-time gains can be translated to travel-time gains in the worst case. Vice versa, for the best case, of 112.5 % is taken into account.

The assumptions on running-time gains, travel-time gains and punctuality effects lead to the range of the cost-benefit ratio as provided by Table 1. Interpreting these numbers, one has to keep in mind, that extreme cases of non-correlating parameters are merged, which causes a very negative/positive scenario.

	Minimum	**Lower bound**	**Average**	**Upper bound**	Maximum
Running-time gain IC	2	**2.25**	**2.5**	**2.75**	3
Running-time gain Sprinter	2.3	**2.8**	**3.3**	**3.8**	4.3
Running-time gain to travel-time gain (· 87.1 %)	75 %	**87.5**	**100 %**	**112.5 %**	125 %
Cost-benefit ratio	0.73	**0.82**	**0.92**	**1.03**	1.16

Table 1 Simplified sensitivity analysis

5 Detailed appraisal of the setup and chosen assumptions

A broad set of assumptions is applied within [Pr105]. Below, their validity and their impact on the overall results are rated. The right column denotes, if an assumption may cause an overestimation (+) or underestimation (-) of the benefits related to ETCS.

[i]	The impact of ETCS on minimum headway times of pure crossing movements in junctions embracing the evaluated lines is ignored (also because there are not crossing in the timetable except for Uitgeest). Since reductions of minimum headway times are exclusively facilitated to improve punctuality and to avoid uitbuigingen on along the line, this simplification is acceptable. It can be approximated, that potential bending supplements due to conflicts with crossing movements from other line are affected in a comparable magnitude. With regard to the general proceeding, there is no need to derive network-wide capacity key figures and thus junction-related capacity figures may be ignored.	(o)
[ii]	Regarding the share of ATB-NG lines on the overall network and the fact, that they are mostly single-tracked, their partial neglectance is reasonable. (In the reviewers experience there were no cases, where a running-time reduction thanks to ETCS was that high, that the overall timetable nature on single-tracked infrastructures could be changed, since a different set of crossing stations was enabled. In specific local situations, an ETCS-related running-time reduction may indeed be one of various impacting summands, whose sum allows a modification of the operational concept. Nonetheless, such situations require specific analysis.)	(o)
[iii]	The chosen averaging procedure corresponds to the state-of-the-art.	(o)
[iv]	Improvements of travel times rely on an ETCS introduced only. Potential benefits due to increasing the speed up to 160 km/h are ignored.	(o)
[v]	Basically, also train sequences in contrast to the scheduled order should be evaluated for the purpose of capacity assessment. But since reductions of minimum headway times are directly “translated” to operational quality, the consideration of further train sequences may be skipped here.	(o)
[vi]	With regard to the general characteristics of a continiuous transmission of Movement Authorities and the outcomes of previous studies (cf. section 12), ETCS Level 2 permits the highest benefits, if there is an inhomogenerous train mix. This only partly related to the assumption that the benefit of ETCS Level 2 disappears, if there is a high share of poorly braking freight services. Nonetheless, the impact of the chosen simplification is of neglectable nature for the target of the cost-benefit analysis.	(o)
[vii]	The inaccuracy is that small, that additional multiplication may be skipped.	(o)

[viii]	On single-tracked lines, the impact of reduced technical running times to operational quality via increased running time supplements was explicitly modelled before simulating the timetable by means of SIMONE. On multiple-tracked lines, no modification of train paths was performed. In general, an increase of running-time supplements on multiple-tracked lines may occur, since not all reductions of technical running times can be converted to travel times. This positive effect on operational quality is ignored.	**(-)**
[ix]	The chosen simulation setup corresponds to standards of executing Monte-Carlo simulation.	(o)
[x]	Applying the translation of dropped running times to reduced travel times merelgy on multiple-tracked lines is reasonable.	(o)
[xi]	Translating running-time gains to travel-time gains one-by-one between nodes is not fully precise, because the problem is not linear. Nonetheless, this assumption seems reasonable.	(o)
[xii]	The differentiation between running-time gains for IC and Sprinter is acutally only purposeful, if also a differentiation between travel time split in both types of trains (also taking into account journey in both trains) is performed.	(o)
[xiii]	**The computations provided in section 4.2 underpin the high sensitivity of the cost-benefit indicator on the assumed running-time reduction and on its “translation” to travel times. The overall cost-benefit ratio may vary from 0.82 to 1.03, based on the outcomes of the small set of analysed corridors. Extending the sample size by further studies would very presumably not cause this interval to grow but rather to shrink in size.** (Additionally has has to keep in mind, that choosing another overall “economic” scenario may cause the cost-benefit ratio to drop by 0.3.)	**!!**
[xiv]	Although the sample of lines was very small, both assessments have at least been executed on the same infrastructures. Since the outcomes are in the same direction, this underpins their expressiveness.	(o)
[xv]	To achieve more reliable indicators, a recompilation of the timetable with account to the new train kinematics, would be reasonable.	!!
[xvi]	There are no obligations regarding this working assumption.	(o)
[xvii]	Because ETCS Level 2 strictly requires a unidirectional GSM-R connection the train, a bearer for a bidirectional communication for the purpose of ETML might be created, too, allowing an on-top benefit (see Chapter 11 for a brief description).	(-)

6 Appraisal of the conclusions

[Pr105] gives various conclusions related on the possible interpretation of achieved results. If they were not already addressed in chapter 3 and appraised in chapter 4, they are commented below. Again, the potential impact on the overall results is provided on the right-hand side.

6.1 Running-time reductions (section 2.2.5)

All four conclusions are shared by the reviewer. (The last one basically only applies to ETCS Level 2 and Level 3, because route-dependent SPP require dynamic balises in the field, requiring a rather complicated interlocking setup. This solution can be found around Györ in Hungary.) (o)

6.2 Speed increase to 160 km/h (section 2.3.2)

Since benefits thanks to raising permitted speeds to 160 km/h are skipped in the overall indicators, a separate appraisal of this chapter is skipped. (o)

6.3 Minimum headway time reduction (section 2.4.4)

The authors state “Uit de steekproef blijkt dat per baanvak en situatie de individuele winsten nogal variëren. De schattingen vor de (landelijke) gemiddelden laten dus geen uitspraak toe over andere individuele baanvakken.” This restriction is indeed of major importance, but does not cause a restriction for the results of the socio-economic appraisal beyond the limitations already noted above. (o)

6.4 Minimum headway time reduction (section 2.4.5)

All four conclusions are shared by the reviewer. (o)

6.5 Punctuality increase (section 4.5)

The first set of conclusions is shared by the reviewer. (o)

The second conclusion (i. e. the punctuality benefit will be higher in a network with higher utilization) is shared by the reviewer, too. (-)

7 Advantages and shortcomings of the proceeding

The overall setup of the study, in particular the strict separation between the incorporation of minimum headway time effects and travel time reductions, is of high reasonability for the given purpose. In particular, it avoids an errorneous mixture and attribution of effects.

Also the elaboration of running time gains and minimum headway reduction per individual scenario seems, as far as it can be evaluated from [Pr105], precise and purposeful. The translation of running-time effects to travel-time effects is performed properly (with the restriction, that a dedicated timetable study would have been more reasonable, as noted below).

On the other hand, the set of three infrastructures, which form the basis for the network-wide extrapolation, is very small. It is merely judged by experts, that their nature is representative for the overall network population. (For good reasons the authors of [Pr105] restrict the applicability of the achieved numbers on other infrastructure situations.)

The small size of the sample used for computations on the impact on minimum headway time as well as the bypassing of a dedicated timetable study has to be taken into account carefully. Attention is drawn to the estimation of the possibly resulting imprecision as provided in section 4.2.

The choice of implementation scenarios, to which the key indicators resulting from [Pr105] are applied, is not part of this review.

8 Rating of achieved indicators

Below, the outcomes of [Pr105] are compared to other Dutch and international capacity studies. Additionally, it is tried to validate the results of the network-wide extrapolation by an international benchmark.

8.1 General trend

Assuming, that there is no considerable error due to the small sample of evaluated infrastructures and due to the bypassed timetable compilation, the appraisal given in chapters 5 and 6 leads to the conclusion that the benefits of ETCS are rather under- than overestimated.

8.2 Comparison to other capacity studies

Since [Pr105] provides the impact on capacity in terms of a minimum headway time reduction, a linkage between capacity and minimum headway times needs to be created in advance, before comparing results to external capacity figures. Section 2.4.4 of [Pr105] provides a range of minimum headway time reductions from 15 % to 40 %, depending on the individual situation and the type of minimum headway time. There is no explicit information, which type of minimum headway time happens how often. Without better knowledge we assume, that 60 % of the train sequences are related to opvolgtijden, 20 % of the train sequences to overkruistijden and 20 % of the train sequences to perronvolgtijden. (Train movement on single-tracked lines are ignored for this appraisal.) This leads to the following outer bounds of minimum headway time reductions:

- Scenario “laag” $r_{laag} = 0.6 \cdot 0.85 + 0.2 \cdot 0.91 + 0.2 \cdot 0.85 = 0.86$
- Scenario “hoog” $r_{hoog} = 0.6 \cdot 0.65 + 0.2 \cdot 0.79 + 0.2 \cdot 0.85 = 0.72$

We assume that there is a single-channel infrastructure server (e. g. jointly used overtaking section) with an average service time (minimum headway times) of mh_{ij}. The minimum headway times result from train series of the different types of train sequences as used in [Pr105], e. g. opvolgtijden, piektijden. Targeting to a maximum occupation ratio of ρ the feasible number of trains n_{Perm} per time interval t_I is $n_{Perm} = t_I \cdot \rho / mh_{ij}$. (Adhering to this proceeding according to UIC Leaflet 406 “Capacity” there is no need to care about the spread of minimum headway times, which simplifies this rough appraisal. A proper assessment of capacity should take into account the non-deterministic nature of minimum headway times, nonetheless.) This linear relationship may be one-by-one applied to capacity, leading to an average increased capacity of $n_{Perm,r} = 1.27 \cdot n_{Perm}$ whereas one has to keep in mind, that the interval lasts from $n_{Perm,r,min} = 1.16\ n_{Perm}$ to $n_{Perm,r,max} = 1.38\ n_{Perm}$.

In Table 2 (chapter 12) a summary of figures from previous Dutch and international studies on the impact of ETCS on capacity is provided. With regard to the nature of the three infrastructure analysed in [Pr105] (see also remark [i] in Chapter 4) a comparison should be restricted to such studies, which are related to lines. Taking into account, that the relative capacity increase is related to a non-optimised ATB-EG scenario, the achieved reduction of minimum headway times is in line to former studies and seems a reasonable input to the assessment of punctuality gains.

8.3 Literature review on network-wide extrapolation

To validate, if the achieved (isolated) key figures and in particular the chosen way of extrapolation to (network-wide) indicators are in line to former studies, a literature survey is conducted in cooperation with the Chair of Railway Engineering (VIA) of RWTH Aachen University. The literature survey was not restricted to pure ETCS-effects but to network-wide extrapolations in general.

8.3.1 Minimum headway-time reductions

A broad amount of literature allows comparing effects of ETCS on the capacity of network portions (cf. chapter 12), but an extrapolation of capacity effects to network-wide figures is not available. Nonetheless this is of minor relevance for the validation of [Pr150], since the general scope does not aim on raising the feasible number of trains by reduced minimum headway times but on improving operational quality. A very brief assessment is given in section 8.4 separately.

8.3.2 Running-time reductions

There is various literature describing network-wide impacts of running-time reductions in a qualitative manner, whereas the running-time reductions are of higher order than for the Dutch ETCS case, since they are achieved by tremendous infrastructure actions (e. g. NEAT project in Switzerland). Partly they were indirectly linked to an introduction of ETCS, because the implemented infrastructure actions required a Full Supervision system due to high speeds. In consequence, even a qualitative comparability is missing.

Unfortunately, a quantitative analysis setting up a relationship between isolated actions and their propagation to the overall timetable was not found at all.

8.3.3 Operational quality

[7] describes an improvement of punctuality by 2.1 percentagepoints upon implementing ETCS Level 2 compared to the lateral Swiss ATP. This is realised through a higher availability (better signals) and due to more possibilities concerning dynamic traffic management. (This benefit was already mentioned by [µ0] in section 2.4.

8.4 Comparison of punctuality effect by means of OnTime

To compare the results achieved by SIMONE computations according to chapter 4 of [Pr105], a computation run with OnTime (in use at various European infrastructure managers like Swiss Railways SBB, Infrabel, DB Netz AG, see [5] for further reference) was performed to a national network of comparable size. In two scenarios, initial minimum headway times and minimum headway times reduced by 20 % were taken into account. The incorporation of additional buffer times leads to an increase of 3-min-Punctuality by 1.43 percentage points or by 1.8 % punctuality index. The table given in section 4.3 of [Pr105] covers an average value (for IC and Sprinter and "ERTMS middle") for the punctuality index of 2.5 %, thus, the magnitude is of reasonable order.

9 NA outcomes in the light of NKS results

During the NKS phase, a first assessment of the ETCS effects on capacity and operational quality was conducted. It came to the following key figures:

- [µ0] states in 2.3, that ETCS Level 2 allows running-time reductions of 3 to 5 % compared to ATB-EG.
- [BCG0] states in 2.3.1, that an optimized ETCS Level 2 installation allows a capacity increase by 8 % compared to ATB-NG instead of 16 % compared to ATB-EG.

Now, [Pr105] shows key indicators as follows:

- In section 2.2.4 it is summarized, that the running-time reduction ranges within 2 up to 3 % for IC and 2.3 % up to 4.3 % for Sprinters.
- In section 2.4.4 a countrywide reduction of minimum headway times of 15 % to 40 % for following train sequences and 10 to 20 % for crossing train sequences is summarized. For the “average” scenario,

The change in both key indicators is subject to a brief evaluation below.

9.1 Running-time reductions

In general, the relative indicators are located in a comparable interval, whereas the NA numbers are slightly more conservative. Anyway, according to the table given on slide 8 of [PP1], the socio-economic benefit of running-time reductions related to the Hoofdrailnet was 1484.- Million EUR per year for the NKS results and dropped to 1043.- Million EUR per year for the NA results. This effect is caused by two reasons:

- In [Pr105] socio-economic benefits in reduced travel times thanks to avoided bendings (“uitbingengen”) are quantified separately. This may lead to lower indicators but allows a more concerted attribution of benefits.
- During the NKS phase, the relative running-time reduction was errorneously scaled to whole train paths, including dwell times. Dwell times form about 10 % of the overall running time. Thus, the benefit was overestimated.

In general, the figures elaborated in the NA are of higher reliability.

9.2 Minimum headway time reductions

According to the table given on slide 8 of [PP1], the socio-economic benefit of minimum-headway reductions translated to increased operational quality (“betrouwbaarheid”) related to the Hoofdrailnet was 408.- Million EUR per year for the NKS results and dropped to 150.- Million EUR per year for the NA results. Since [Pr105] assumes to incorporate reduced minimum headway times to avoid bendings and to improve operational quality – in terms of increased buffer times – the benefit is partly expressed by the number of 1043.- Million EUR per year given in section 9.1. This explanation is reasonable.

10 Usage and communication of the results

The outcomes of [Pr105] are a major but not the only input to the overall cost-benefit analysis currently conducted. For the further decision-making process, the following recommendations are given.

10.1 Definitions and abbreviations to use

There are merely a small number of definitions and abbreviations, which have to be kept on a high level while communicating the achieved results:

- The general setup as summarized in Chapter 4 introduces a strict separation between effects of reduced running times and effects of reduced minimum headway times (leading to increased buffer times). To avoid interpretation errors it is proposed to consequently distingush between:
  - Running-time supplements / running-time reserves, allowing a reduction of delays,
  - Buffer times, damping a propagation of delays.
- In general, there is a frequent usage of “ERTMS Level 2”. Actually, ERTMS is the envelope around its subsystems ETCS, GSM-R and ETML, whereas there is no “ERTMS Level 2” as such. It should be addressed as “ETCS Level 2”.

10.2 Remarks to provide

While communications the outcomes, the following issues should be denoted:

- The general setup as summarized in Chapter 4 has to be described.
- The “0” variant, assuming no major upgrades within the possibilities of ATB-EG, has to be clarified.
- The limitation of minimum headway time studies to a small subset of lines – due to time restrictions – has to be mentioned. Furthermore attention has to be drawn, that there is no quantitative proof, that the chosen subset of lines is really representative for the overall population of lines.
- The assumption, that running-time benefits are one-by-one translated to travel-time benefits is of essential nature.
- The high dependency of the socio-economic benefits on the estimation of travel-time gains needs to be marked.

10.3 Recommendations of general nature

In addition to the recommendations given above, more general remarks, which came up during the review process, are enlisted below:

- Infrastructure planning guidelines should be revised to enable the full benefit from a full supervision ATC like ETCS (and to avoid shortcomings due to insufficient design). Infrastructure design related to train operation under full supervision impacts, for example, the length of safety distances, the choice of switchpoints and the location of speed steps. If there is a clear target scenario, planning rules should be adopted accordingly.

- In addition to the infrastructure planning rules, there should be at least a clear vision of the future operational rules, since the application of ETCS might lead to a notable revision of the operational proceedings. In the Danish case, there was a full redesign of the operational rules even at a very early stage, since various upcoming steps depend on the ruleset.
- With the introduction of ETCS, also the amount of interdependencies between the infrastructure, the operating program and the operational rules swings up. For instance, a computation of running times requires knowledge on the braking capabilities of the used rolling stock. This may trigger the need for (new) organisational interfaces to ensure a purposeful exchange of data during the planning processes.
- Running times and occupation times strongly depend on the parametrisation of the ETCS Braking Model. Before and during designing infrastructure, a profound representation of the Braking Model has to be ensured.

11 Potential vision and benefits of ETML

The European Rail Traffic Management System (ERTMS) was intended to have three main components: ETCS, GSM-R and the European Traffic Management Layer (ETML). Although the latter one is out of scope in the NA, its potential benefits are summarized here to round up the picture.

With much of the effort in recent years being focused on the first two elements, little progress had been reported with ETML. However, ETML is a rather promising component of ERTMS, which might show its potential and possibilities especially in conjunction with a continuous communication channel as it is established with ETCS Level 2 and the usage of GSM-R. ETML is intended to optimize train movements by the "intelligent" interpretation of timetables and train running data. It involves the improvement of real-time train management and route planning (rail node fluidity), customer and operating staff information.

With an ETCS Level 2 based continuous communication and supervision of trains, positions and movement characteristics of a train can be used efficiently by a centralized traffic management instance (e.g. operation control center) to produce essential benefits for the overall operation on the network. With the ETML layer, a new and extended level of traffic management can be established, that faces the complexity and interrelationships of railway networks and a dense operation in it.

While ETCS and GSM-R are approaches focusing on a technical standardization and interoperability to communicate between the infrastructures respectively the interlocking and a specific train, ETML allows controlling, synchronizing and managing the traffic on the network in a way, that is not possible for individual units like single trains.

Research and first productive projects like DisKon/FreeFloat (Germany), CATO (Sweden) or ADL (Switzerland) etc. are following these global-view oriented ideas of traffic management and realize single management aspects. The core idea of all these projects is to support an increasingly smooth and fluent railway operation targeting several primary and secondary aspects and benefits for the whole network like delay deduction, energy efficiency, reduced maintenance requirements or throughput increase.

With discrete train position detection functionality which corresponds to a wide variety of legacy ATP/ATC systems (like ATB) as well as message exchange formats (e.g. following UIC Leaflet 407-1), the ability to monitor the operation in reliable detail is quite restricted. This restriction also applies to train detection in case of ETCS Level 2. Nonetheless, since the unidirectional continuous communication channel becomes mandatory with ETCS Level 2, the ability to continuously track train movements renders possible, too, if this link is applied in a bidirectional manner instead. For non-safe purposes additional transmission of positions and speeds may happen on this channel from train to a centralized instance. Based on this information, several advanced traffic management functionalities become possible. (Safety is still granted, since traffic management is conducted "on top" of interlocking.)

The centralized view allows first of all the realization of a dispatching functionality. Train movements combined with the restrictions introduced by interlocking logic highly influence each other.

Therefore the interrelationships have to be considered. The currently most practicable approach is to concentrate this traffic management centrally at the infrastructure manager responsibility. This corresponds to the essential tasks an IM has to deal with like enabling a good railway operation.

The rescheduling and synchronization of train movements can – on the other hand – continuously be submitted to the trains when using GSM-R and an appropriate traffic management approach. The ability to propagate management decisions is another brick within a closed traffic control and management loop. With this propagation loop, trains can be instructed to follow recommended speeds, driving styles and stopping behavior to achieve.

A railway traffic operation with less conflicts and red signals, because possible (interlocking) conflicts can be detected from the centralized traffic control in advance. With (manual or automatic) dispatching systems solutions can be derived to avoid ("solve") the detected conflict by adapting train movements sufficiently. This conflict resolving can only be done in a centralized manner, because only in such a way the interrelationships and side effects of train movements can be estimated sustainably. Less conflicts and red signals imply several downstream effects and benefits for infrastructure managers (IM) as well as for traffic operation companies (TOC):

- For IMs, the capacity of the network increases when conflicts within the railway operation process decreases, since less buffer times are require to ensure the same quality of operation. This is essentially implied by the fact, that red signals and decelerating trains usually indicates bottlenecks of the network, areas with a high occupation ratio and track usage.
- Whenever arising conflicts can be resolved in advance, trains might not come to standstill (or to a very low speed), passing times of such bottlenecks can consequently be decreased and the capacity of relevant parts of the network increases.
- With such an increased throughput operation becomes more robust against disturbances or – on the other hand – more train runs and scheduled trajectories become possible while remaining at the same robustness level.
- While increasing the robustness means, that less knock-on delays occur and have to be charged or justified, an increased capacity would allow increasing track access charges earned by the IM.

For TOCs, a more fluent operation with less or slighter acceleration and deceleration phases primarily implies better running times and – maybe even more important – an essential reduction of energy costs. Especially acceleration phases and high speeds consume a large amount of energy, which partially is wasted, if trains have to decelerate and accelerated in an unscheduled manner.

12 Summary of capacity figures

The table below summarizes outcomes of various studies related to ETCS and capacity (the table was already included in the NKS review):

Source	Infra	Target system	Source system	Capacity increase	Remark	Relevant
[8]		Level 1 LS	Legacy (PZB)	0 %		
[8]		Level 1	Legacy (PZB)	"slightly higher"		
[8]		Level 2 block optimisation	Legacy (PZB)	10..15 %		x
[6]	Conventional main line	Level 2 no SBI no increase of speed	Level 1, SBI	10 %		
[6]	Conventional main line	Level 2 no SBI, block optimisation no increase of speed	Level 1, SBI	38 %		
[6]	Conventional main line	Level 2 no SBI, block optimisation no increase of speed	Level 1, no SBI	32 %		x
[1]		Level 2	Legacy	up to 10 %		
[9]		Level 2	Legacy	up to 10 %		
[3]	Junctions	Level 2 no SBI no increase of speed	Level 1, no SBI	4 %	Initial sectioning already optimized	
[3]	Junctions	Level 2 no SBI, block optimisation no increase of speed	Level 1, no SBI	6 %	Initial sectioning already optimized	
[3]	Junctions	Level 2 no SBI, block optimisation no increase of speed	Legay (L1 LS)	8 %	Initial sectioning already optimized	x
[2]	Conventional main line	Level 2 no SBI, block optimisation no increase of speed	Legacy (ATB EG)	15 %	No Level of Service considered	
[2]	Conventional main line	Level 2 no SBI, block optimisation no increase of speed	Legacy (ATB EG) block optimisation	12 %	No Level of Service considered	
[2]	Conventional main line	Level 2 no SBI, block optimisation no increase of speed	Legacy (ATB EG)	21 %	Related to 75 % occupation ratio	
[2]	Conventional main line	Level 2 no SBI, block optimisation no increase of speed	Legacy (ATB EG) block optimisation	14 %	Related to 75 % occupation ratio	
	Local line	Level 2 no SBI	Legacy (ATB NG)	5..7 %		

Table 2 Summary of ETCS-related capacity studies

GENERAL LITERATURE

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