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Results of the Railway Capacity Questionnaire: Serious doubts and eloquent silence – rail experts pass judgment on premises of Stuttgart 21

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The discussion about the planned "Stuttgart 21" (S21) train station raised a number of basic questions in determining train station capacity. As existing textbooks and publications failed to answer these adequately, a survey was conducted in order to establish the opinion of rail experts with regard to these important questions. The great majority of the respondents classified the statements in the questionnaire as true, with an approval rate of 92 %. Several respondents did not agree with all the statements, mainly due to conceivable exceptions which conflict with the general applicability of the statement. In the case of Stuttgart 21, most of the special cases cited would not apply, thus further supporting the majority opinion.

Another important result of the questionnaire was the complete absence of responses from experts who are known to be in business or otherwise related to Deutsche Bahn AG. This suggests that an open discussion of the technical base of Stuttgart 21 is not taking place and raises the possibility of a conflict of interests in connection with the biggest player in the German rail sector, who is promoting the new railway station "Stuttgart 21" on the basis of the criticized assumptions.

Thus the international experts' answers to the questionnaire show that a number of the basic assumptions of the performance evaluations and promises of Stuttgart 21 are indeed questionable and the local rail expert community is reluctant to engage in an open discussion.

Contents

Motivation

From the beginning of the "Stuttgart 21" project there have been doubts that the planned underground through station with 8 platform tracks will be able to handle the promised 50 % traffic growth compared with the 17 track terminus station, which it is intended to replace. The hundred year old existing station handles 38.5 trains per peak hour today. Historically, e.g. in 1939, as many as 47.5 trains have been handled. The alleged superior capacity of the new station was one of the key factors which enabled it to obtain planning approval. But key parameters of this capacity as well as the underlying simulations remained unclear. Large capacity "reserves" of the new infrastructure have been described in non-binding and non-quantitative statements. In the end, the project was approved as being "future-proof and sufficiently dimensioned" without any precise quantification of the needs and the limits for the new station's peak hour performance which the same approval report stated to be crucial for dimensioning the station.

Later on, additional simulations (most recently the so-called “stress test”) were performed in order to reduce public doubts. These studies made further non-binding promises of a pronounced increase in peak hour performance (the “stress test” claims proof of 49 trains per hour at an economic optimum quality of service). The parameters of these simulations have been criticized for violating national or international standards. But this proved to be a difficult topic to discuss as some of the arguments appeared so self-evident that they are not even dealt with in textbooks or publications. In addition the German-speaking railway expert community is basically divided into three groups: The critics of Stuttgart 21 (experts who are independent of Deutsche Bahn AG), the proponents (the authors of expert reports commissioned by DB AG) and a silent third group (depending substantially on DB AG for work on projects, expert report requests and career options). Thus, between the first two groups judgment stands against judgment. No independent evaluation of the arguments has been given by experts from outside.

This meant that, during preparation of a publication on the S21 capacity calculations, there was no independent assessment of a number of questions. Furthermore, it was unclear if the silence of many of the German-speaking experts represented confirmation by the scientific community of its acceptance of the official performance statements or if it meant that part of the scientific community felt obliged to remain silent.

Method

Publications and conference contributions relating to the topic of railway capacity evaluation were identified and the authors’ latest affiliations and email-addresses were determined. 125 international experts in this field of research could be identified with their email-addresses. Six of the email-addresses were no longer valid and no replacement could be found. Two of the addressees answered that they were not experts in the field. Thus the total sample for the survey was 117 experts who received the survey by email.

As publications written in German were also considered, as many as 44 experts from Germany, Switzerland and Austria were identified, 27 of whom are working for Deutsche Bahn AG (DB AG) or in close relation to this company. The other 17 were known to be independent of DB AG. These attributes were determined and fixed prior to the survey in order to divide this large group into subgroups which might answer differently.

The survey was sent out on June 3rd 2013 with a deadline of June 14th. On June 11th, when ten answers had arrived, a reminder was sent, after which nine additional answers were received. One late response, received on June 17th, was also accepted.

Results

20 international experts answered the questionnaire, with their affiliation evenly dividing between university and industry. The results from the survey divide into two domains. In the first place, there are the ratings of the statements in the questionnaire, which are broadly confirmed. Secondly the response rates have been evaluated in the different groups of experts, this hints at a silent part of the German railway expert community, at least where topics relating to the controversial project Stuttgart 21 are concerned.

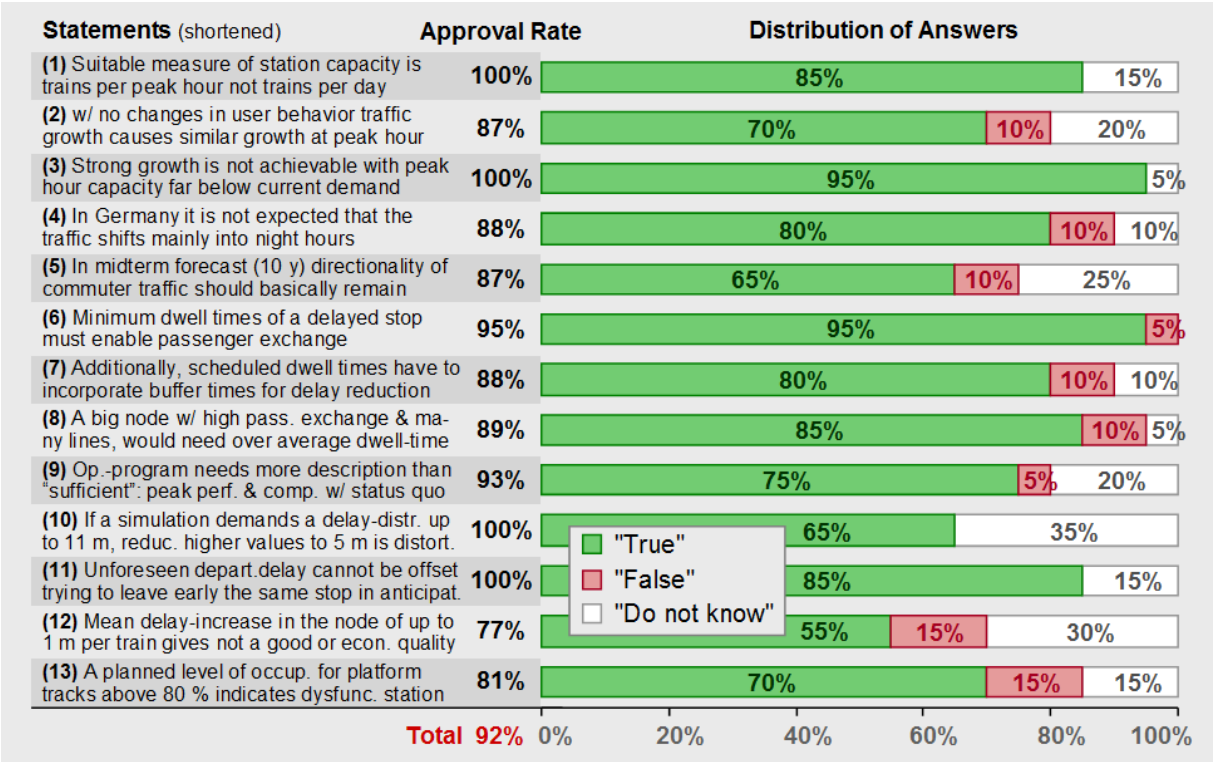

***Figure 1**: Statements (shortened) with the corresponding approval rate [true / (true + false)] and the distribution of the ratings. All statements are approved by a vast majority of the responding experts, affirming that several of the basic assumptions or consequences of the Stuttgart 21 performance evaluations are questionable. Where the statements are rated "false" this often applies to special cases or exceptions not covered by the general phrasing of the statements as is indicated by the remarks (see text).*

a) Ratings of the statements

Figure 1 shows how the ratings from the 20 returned questionnaires break down. The statements have been shortened. The approval rate gives the ratio of the "true" ratings to the total of the "false" plus the "true" ratings. In cases where both "true" and "false" have been checked, or in answers, where none of the three possibilities (not even the "do not know" answer) has been checked, the answer has still been counted as "do not know". The great majority of the responding experts support the statements – a result which throws the assumptions and consequences of the Stuttgart 21 performance evaluations into question (see chapter "Interpretation").

b) Detailed Results for each Statement

In the following the results are given in detail for the statements in their exact wording. The percentage of the valid "true" or "false" ratings from all answers is labeled as "knowledge rate". The remarks have been shortened to the key arguments in the cases of extensive entries. Remarks on a "true" rating are preceded by "(+)", those on a "false" rating by "(–)" and those on a "do not know" rating by "(0)".

(1) Railway station capacity is most suitably measured by trains per peak hour not by trains per day.

Result: 17 “true”, 0 “false”, 3 ”do not know”,
100 % approval rate, 85 % knowledge rate.

Interpretation: Clearly decided, that capacity is more suitably measured with trains per peak hour. But the remarks make clear, that a full description of a train stations capacity would go beyond this mere number.

Remarks: (+) Broadly this is true, and trains per day would give a false impression, but do not overlook the difficulty of planning an off-peak service. (0) By trains per peak and per day. (+) Assuming trains suitably loaded. (+) It depends on what it is you want to analyze, but the UIC measures both the 2h most congested hours and over 24h. (+) Still not a good way of measuring. (+) Useful to combine it with peak factor.

(2) Without changes in user behavior, overall traffic growth causes similar growth at peak hour.

Result: 14 “true”, 2 “false”, 4 ”do not know”,
88 % approval rate, 80 % knowledge rate.

Interpretation: Statement is accepted by the majority. No remarks to the “false” ratings. The other remarks indicate the statement to describe a first approximation and that detailed knowledge, which segments and user groups support the growth, would be helpful.

Remarks: (+) As a high-level, initial estimate this would be fair, but more detailed exploration for specific cases will show different behavior between the various markets. (+) However, the difference in the number of passengers might not lead to a proportional increase in the number of trains.

(3) When aiming for strong growth it is wrong to reduce peak hour capacity far below current demand.

Result: 19 “true”, 0 “false”, 1 ”do not know”,
100 % approval rate, 95 % knowledge rate

Interpretation: Clear voting with serious implication for the project Stuttgart 21.

Remarks: (+) Unless there is a very clear reason why commuter travel is expected to shrink within a growing overall demand – which is not really likely. (0) Leading and unclear question, that cannot be answered without clarification.

(4) For a metropolitan station in Germany it is not expected that the traffic shifts mainly into night hours.

Result: 16 “true”, 2 “false”, 2 ”do not know”,
89 % approval rate, 90 % knowledge rate.

Interpretation: Clear approval, there are only very special exceptions that can be thought of.

Remarks: (+) I can't really be sure about Germany, but the idea that people will work at night for the convenience of the railway company and transport planners as an alternative to working during the day like their friends and family is fantasy. (–) Depends on station location and transit oriented development: e.g. when a new theater/club/football stadium attracts more people. (0) I am not enough familiar with the context to give a proper answer. (+) One could not expect this for any station.

(5) In midterm forecast (10 y) one would expect that directionality of commuter traffic basically remains.

Result: 13 “true”, 2 “false”, 5 ”do not know”,
87 % approval rate, 75 % knowledge rate.

Interpretation: Statement is broadly agreed to, if changed commuter patterns are planned, these would have to be described and justified.

Remarks: (+) There are examples of significant growth of outbound commuting, but this is more of a commercial opportunity for the railway than something that will re-orient the basic flows of demand. (–) Depends on transit oriented development aiming at changing the demand pattern. (0) Only if everything else is equal. E.g. no new developments

(6) Minimum dwell times, to which a delayed stop may be reduced to, must enable passenger exchange.

Result: 19 “true”, 1 “false”, 0 ”do not know”,
95 % approval rate, 100 % knowledge rate.

Interpretation: Strong approval. Even the remark to the “false”-rating appears to support the statement. Short minimum dwell times in a simulation evidently need to be thoroughly justified to be sufficient.

Remarks: (0 → +) I don't really understand the question. On the face of it, if you mean that time allowed at station stops must be adequate for passengers to get on and get off, this is true [therefore rating changed to “true”], but it means that one of the key measures for increasing frequency of trains on a railway is management of the passenger flows and designing the trains for quick movements of people. (–) Dwell times to cater for passenger numbers only (boardings & alightings).

(7) Additionally, scheduled dwell times have to incorporate buffer times for delay reduction.

Result: 16 “true”, 2 “false”, 2 ”do not know”,
89 % approval rate, 90 % knowledge rate.

Interpretation: Strong approval. The generality of the question is problematic, the remarks hint to exceptions with reduced variability like a bottleneck with compensation outside the station or a commuter rail hub with a timetable designed around it.

Remarks: (–) I am a bit of skeptic about buffer times beyond a very small level, and think they lead to slack working with even worse results. The time allowed should be right, and the railway should work to it. (+) Might be exchangeable with running time supplements and stations/trips downstream, but in general time allowances are required. (+) The required amount of buffer times is strongly related to the expected variabilities and the layout of the network. (0) Depends on the current situation. (+) It is important to increase robustness.

(8) A big node with highest passenger exchange rates, connecting many lines, would need significantly more than the country-wide average dwell-time.

Result: 17 “true”, 2 “false”, 1 ”do not know”,
89 % approval rate, 95 % knowledge rate.

Interpretation: Strong approval, as far as is assumed, that timetable design does not waste time.

Remarks: (0) This all depends on specific circumstances. A big node designed properly may well need lower dwell times than a small one designed badly, or built within legacy infrastructure. (+) The exact amount should be estimated. (–) Larger dwell times at major stations due to numbers of passengers only but not for the reason of inter-change between lines, etc.

(9) An operating program designed to provide significant growth is not suitably described to be “sufficient”, it needs to be characterized by its peak performance and should be compared with the existing timetable.

Result: 15 “true”, 1 “false”, 4 ”do not know”,
94 % approval rate, 80 % knowledge rate.

Interpretation: Strong approval, the statement might have been put in even more detail.

Remarks: (0) Not clear what program is being referred to. (0) Unclear question.

(10) If a simulation demands a distribution of delays of up to 11 min. reducing higher values to 5 m is distorting.

Result: 13 “true”, 0 “false”, 7 ”do not know”,
100 % approval rate, 65 % knowledge rate.

Interpretation: Very strong approval, but lowest knowledge rate, appears to be more difficult to evaluate. The long remark gives the counter example but makes clear this would not apply for a terminal and a traffic with low homogeneity.

Remarks: (0) Not necessarily, depends on type of railway. At a through route with high homogeneity, once a train is delayed by a time roughly equal to a headway interval, it causes as much domino-delay as one that is running even later. So the extreme delays in the simulation become only as important as the small ones, and what matters is the number of delays more than their magnitude. But for a terminal where the pattern of occupation of the platforms is important, or for a railway with low homogeneity where fast trains if delayed can fall behind slow ones, the magnitude of delays will be more important. (0) Unclear question. (0) Depends on the current situation.

(11) An unforeseen departure-delay cannot be offset by trying to leave early at the same stop in anticipation.

Result: 17 “true”, 0 “false”, 3 ”do not know”,
100 % approval rate, 85 % knowledge rate.

Interpretation: Very strong approval, as expected for a case of infringed causality.

Remarks: (0) All depends on the type of railway! At an intensively-used terminus the train cannot leave early anyway as there is no path for it between conflicting trains, unless the number of trains is below the capacity limit. At a non-urban through station, in effect the suggestion is to add buffer time, and this may be effective. (0) Unclear question (+) for public transport it would be unacceptable to be able to depart before timetabled time

(12) Allowing a mean delay-increase in the node of up to 1 min. per train does not result in a good or economic quality of service.

Result: 11 “true”, 3 “false”, 6 ”do not know”,
79 % approval rate, 70 % knowledge rate.

Interpretation: Statement with the lowest but still with strong approval and also a low knowledge rate. The not decided answers make clear, that generally more information would help. It is also stated, that a node with up to 1 min. mean delay-increas would be a bottleneck or need compensation.

Remarks: (0) I cannot judge this without more knowledge of the actual case. (–) Depends on buffer times downstream and station capacity (0) The increase in the delay depends on the running time margins. (0) It all depends on the total set-up of the entire timetable for a particular train. What does "the node" refer to? (0) If it is a bottleneck it may be to force trains through as fast as possible accepting delay-increase. (0) This may or may not be acceptable depending on the customer charter and the service agreement with government.

(13) A planned level of occupation for the platform tracks above 80 % indicates a dysfunctional train station.

Result: 14 “true”, 3 “false”, 3 ”do not know”,
82 % approval rate, 85 % knowledge rate.

Interpretation: Strong approval. Again the statements generality is problematic, as it would strongly apply for a mixed traffic node station but less for a central commuter rail hub with the rest of the network designed around it.

Remarks: (–) Many not dysfunctional examples exist. Details of each case have to be considered. High levels of occupation need the station and trains as well as other locations in the network to be designed for it. So a city terminus in a metropolitan hub working at 80% could be accepted so long as the rest of the railway could be planned around that. But an InterCity line connecting two city terminals both working at 80% would not be a good idea. (–) Depends how long occupancy persists. (0) Cannot answer without knowing how this figure of 80% is computed and how the usage is distributed over the day and per train. But generally, UIC has defined levels of capacity usage that specifies that 80% track usage of a line section is considered "sensitive" to the traffic system and I imagine that 80% usage of platform tracks is worse than for the line w.r.t. congestion and sensitivity. But on the other hand, the in- and outflow of the trains might force the trains to wait longer than necessary at the platforms. (0) Normally yes, but it depends on the track layout too. (+) I would be concerned if one was planning for this high level of occupation.

The questionnaire had to be designed to strike a balance between conciseness (to avoid lengthy text that would deter participants from responding) and preciseness (to avoid ambiguity). This appears to basically explain the rate of “false”-valuations, that are indicated in many remarks to be due to the special cases and exceptions that can be imagined.

c) Non-response bias?

In order to test for a non-response bias the answers before and after the reminder email have been compared (table 1). The first ten answers showed an approval rate of 87 % and a knowledge rate of 91 %. The last ten answers showed an approval rate of 96 % and a knowledge rate of 78 %. Therefore experts who do not have the experience to rate all the statements appear to be answering more reluctantly, which is to be expected. A non-response bias in favor of a more critical view of the statements for late or absent responses is not seen; in fact rather the opposite is true. Therefore the support of the statements by the vast majority of the responding experts appears to be valid also after considering a systematic non-response behavior.

Groups of Responses	Approval Rate	Knowledge Rate
10 responses before reminder email	87 %	91 %
10 responses after reminder email	96 %	78 %
Total	92 %	84 %

***Table 1**: Rates of approval and percentage of known answers for the early and late responses.*

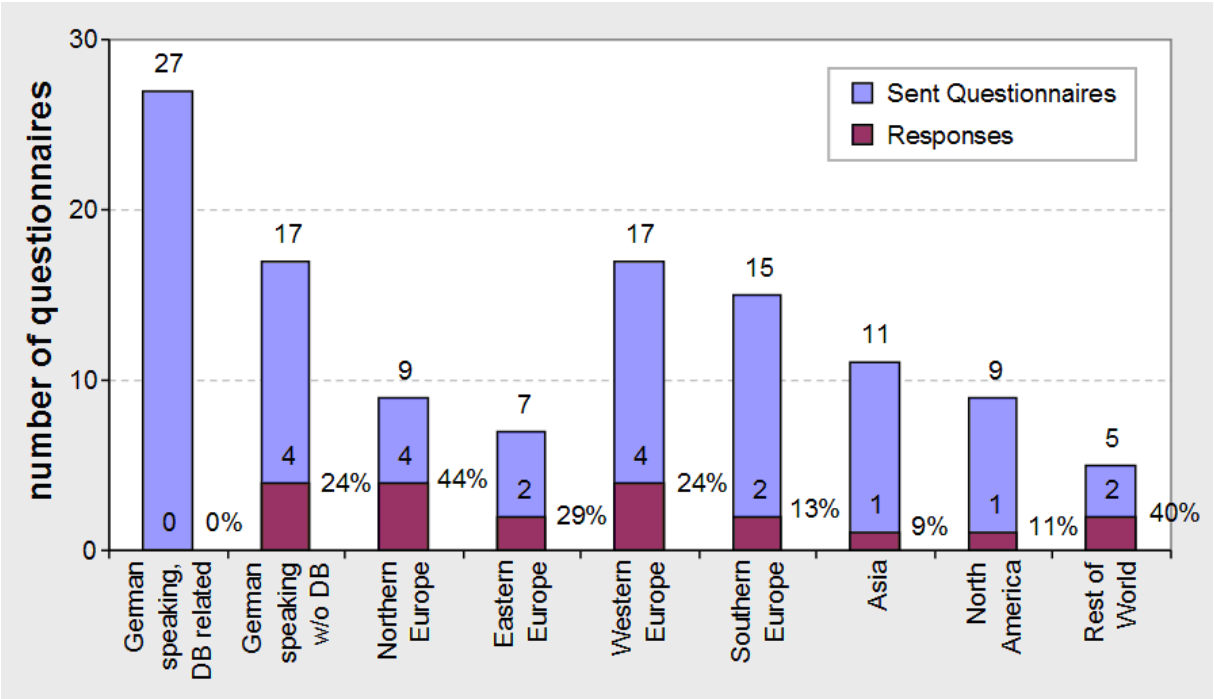

***Figure 2**: Responses and response rates by region. The German speaking countries (Germany, Austria and Switzerland) have been divided into two groups: Experts working at Deutsche Bahn AG or connected otherwise to this biggest player in the German railway market and those who are known to be independent of DB AG. The non-response from the DB-related experts is highly statistically significant pointing to a silenced group of railway experts.*

d) <u>Response rate</u>

Figure 2 and table 2 (next page) give the results from comparing the regions and their subgroups with regard to the response rate and, in the case of the latter, also with regard to the approval and knowledge rate. Most striking is the absence of responses from the large group of experts related to Deutsche Bahn AG (again: this attribute had been determined before starting the survey). A response rate of 22 % outside the group of the DB AG-related experts indicates a good value. A higher response rate would not be expected for a voluntary effort.

Due to the limited number of experts in this special field of railway science, the statistics of this survey are limited from the very beginning and this limitation is compounded inevitably by the large proportion of non-responding addressees. The situation gets even more difficult when subgroups of experts are considered. One response more or less in one group makes a big difference. Therefore it is not clear if e.g. the high response rate in northern Europe and the relatively low response rates in Asia and southern Europe indicate cultural differences or in part also linguistic barriers. The latter should not account for the low response from North America.

The odds of receiving no response from the 27 DB AG-related experts by chance at an expected worldwide response rate of 22 % would be around 1:900. If for comparability Europe is considered without the experts related to DB AG a response rate of 24.6 % is observed, which would change the odds for an accidental non response of the DB AG-group to $(1 - 24.6\ \%)^{27} \approx 1{:}2000$.

Groups of Addressees	Number Requests	Number Answers	Response Rate	Approval Rate	Knowledge Rate
German speaking Europe (DE, CH, AT) related to Deutsche Bahn AG	27	0	0 %	–	–
German speaking Europe (DE, CH, AT) independent from Deutsche Bahn AG	17	4	24 %	90 %	92 %
Northern Europe (SE, DK)	9	4	44 %	94 %	67 %
Eastern Europe (CZ, SK, HR)	7	2	29 %	100 %	88 %
Western Europe (GB, NL, FR, BE)	17	4	24 %	86 %	85 %
Southern Europe (ES, IT, GR)	15	2	13 %	100 %	92 %
Asia (CN, TW, JP)	11	1	9 %	92 %	92 %
North America (US)	9	1	11 %	100 %	92 %
Rest of World (IR, AU)	5	2	40 %	81 %	81 %
Total World	117	20	17 %	92 %	84 %
World w/o relation to Deutsche Bahn AG	90	20	22 %	92 %	84 %
Europe w/o relation to Deutsche Bahn AG	65	16	24.6 %	91 %	82 %

***Table 2**: Response rates for world regions. Due to the small samples regional differences should not be overvalued. Statistically highly significant is the absence of responses from the many German-speaking experts that are related to the Deutsche Bahn AG. The average response rate from all other groups is 22 %. The approval rate is 92 % worldwide. Only in 16 % of the answers a statement has been rated "do not know".*

Thus the DB AG-related non-response points to a systematically atypical behavior (see below). Beside the response rate there appear to be no significant regional differences in the answers themselves. Both the decisions for rating a statement as "false" or as "do not know" show no regional pattern both in overall approval and knowledge rate and also in the individual statements.

e) <u>Conclusion</u>

In the group outside the DB-related experts the overall response rate of 22 % lies at a comparatively high level. A non-response bias pointing to a more critical view of the non-responding experts was not observed, rather the opposite. Thus despite the limited number of experts in this special field of railway science the survey delivers the following two statistically significant results:

1. A broad approval of the statements by quite a number of international experts in the field has been gained. When looking at the remarks of the respondents it becomes clear that most of the "false"-ratings are due to special cases and exceptions that are conceivable, but would not apply to a big metropolitan central station with mixed regional and long-distance traffic. Therefore the experts' voting appears especially critical of the Stuttgart 21 project (see below).
2. The DB-related experts show such a level of reluctance in responding that this suggests a systemic origin.

Interpretation

The two dimensions of the survey results lead to two main interpretations relating to the train station project Stuttgart 21:

1. Quite a number of basic assumptions and consequences of the Stuttgart 21 planning are wrong, according to international experts in the field. Consequently, and contrary to the official promise, Stuttgart 21 would not enable a substantial traffic growth; according to the original expert reports it will rather create a bottleneck on a European magistrale.
2. Those German-speaking experts depending for their business or career on Deutsche Bahn AG do not answer a questionnaire on topics about which they otherwise publish their own works or in connection with which they appear in public defending the Stuttgart 21 project. This provides the first scientific evidence that the German-speaking railway expert community is in danger of losing its independence and acts in anticipatory obedience to the dominant player in the German railway market.

a) Will Stuttgart 21 create a bottleneck?

Origin for the statements in the questionnaire is the debate about whether the capacity of the multibillion Euro underground metropolitan main station “Stuttgart 21” (S21) will meet the needs of the predicted growing railway traffic demand. Recently, the cost estimate rose by 2.4 billion Euros to a total of 6.8 billion Euros, even before major construction work started. Estimates of total costs around 11 billion Euros are reported from sources inside Deutsche Bahn AG.[1] This is a large amount of money when in Germany funds are lacking for the elimination of serious bottlenecks and fulfillment of international treaties like the four track extension of the “Rhine Valley Line” as the main northern approach to the Gotthard Base Tunnel.

In Stuttgart the new underground through station S21 with 8 platform tracks shall replace the existing 17 track terminus station, in which today 38.5 trains are regularly handled during the morning peak hour. S21 was justified by the claim that it would enable strong growth in railway traffic. 50 % growth in traffic was contractually concluded in the financing contract.[2] But according to the original expert report from the approval process, the underground station is limited to a maximum of 32.8 trains per hour:[3] A figure which was not mentioned in the report's summary, despite its importance, and which therefore did not find its way into the decision to approve the project. Also the framework timetable, for which sufficient operating quality was determined, had a maximum of 32 trains per hour,[4] but this was another key parameter of the performance evaluation which was not clearly displayed. Also the pedestrian facilities have been laid out for the passengers of only 32 trains per peak hour, but this analysis was not made public during the approval process, even though the passenger flows were part of the approval decision. Not less than 17 measures of unclear, incomplete and unscientifical presentation of the results from expert reports made these works misleading, thus causing the actual capacity reduction to be overlooked.[5]

Therefore a station will be built at extremely high cost and at a very high risk (due to the unstable geology and critical hydrology of the region) to enable allegedly a substantial growth but being limited in peak hour performance to a value 15 % below current demand (statement 3). In plan approval neither a clear statement on peak hour performance of the new station was given nor

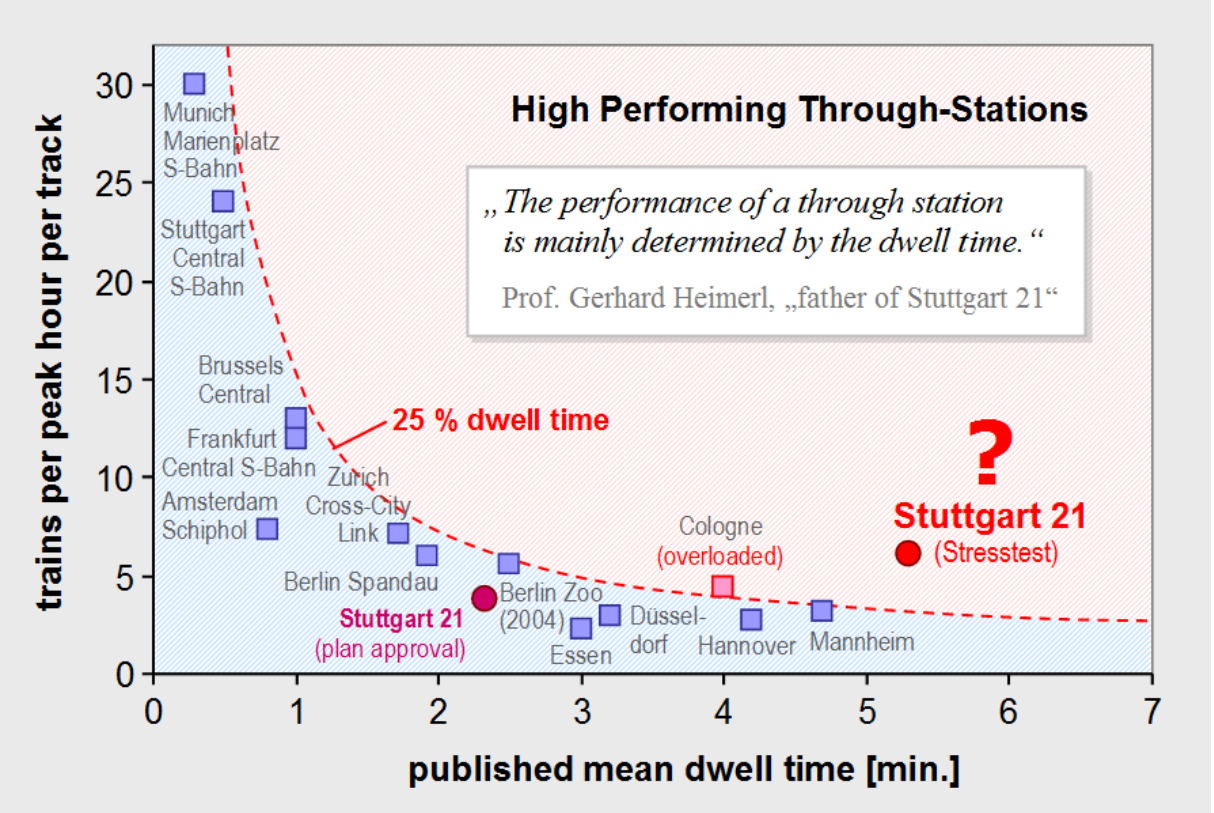

***Figure 3**: Dwell time and hourly frequency of platform occupation. With increasing dwell time, fewer trains can be processed, which is the main limitation in a through station. High platform occupation rates are only achieved in stations with short dwell times, as reached in the S-Bahn (suburban commuter rail) stations of Munich and Stuttgart. Also international benchmarks fit below the line, where the rate of occupation corresponds to the dwell time being a quarter of the total time per train. Cologne is known to be one of Germany's most overloaded stations. The stress test's 49 trains per hour on 8 platform tracks appear to represent an unattainable increase compared with the 32 trains of plan approval.*

was it compared with the actual traffic, even though the same document states that this number is crucial for dimensioning of the station (statements 1, 9).[6] A substantial growth of 43 % in daily train rides was planned[7] without cross checking this with the needs and limits in peak hour performance (statement 2). Also it went unnoticed, that in order to reach the daily train number based on the expected traffic growth, more trains would have to operate during night hours as compared with midday (statement 4). In order to demonstrate the ability to transport more passengers during the peak hour, the empty train rides have been almost abolished, but it was not explained why today's largely one-directional commuters in future would ride in both directions in the same peak hour (statement 5).[8]

The simulations proving the “future-proof and sufficient dimensioning” of the station were based on 32 trains per hour at maximum, in these simulations the desired quality of service was reached. Here minimum dwell times of two minutes and a published mean dwell time slightly over 2 Minutes have been assumed. Even one of the authors of the expert reports judged this too short for passenger exchange at a station like Stuttgart Central with high passenger exchange.

He recommended three minutes for mean minimum dwell time for both regional and long-distance travel. In addition, the timetable prescribed by the state of Baden-Württemberg as a base for the final proof of performance (the so-called “stress test”) set the mean published dwell time to 5.3 minutes, in order to fulfill the needs for passenger exchange, buffer times and implementation of connections (statements 6, 7, 8). Also, from looking at stations with similar high passenger exchange like Hannover or Cologne, one would expect at least 4 minutes mean published dwell time. Handling 49 trains an hour in a station with 8 platform tracks would never be a realistic proposition with such a dwell time. (figure 3, preceding page).

A simulation of Stuttgart 21 preceding the stress test achieved a maximum of 51 trains per hour only by using dwell times down to 1 minute, a regularly spaced timetable, and by omitting the bottlenecks in the approach tracks.[9] When this was later criticized as being unscientific, the author could only defend it as having been “ordered” like this (by Deutsche Bahn).[10] As this simulation was no longer tenable, the stress test was demanded. The stress test, as a voluntary effort, delivered a non-binding performance statement; it was not incorporated into the plan approval. Although the stress test does not guarantee a future performance of the station, it is cited as if this would be the case by Deutsche Bahn and by the state and federal government.

In the stress test, despite its demanding parameters of 49 trains per hour at 5.3 minutes mean dwell time, surprisingly Stuttgart 21 attained an “optimum economic quality”.[11] This result has been approved by a Swiss auditor.[12] But concerning possible errors or overlooked violations of standards by the auditor himself nobody else than the Deutsche Bahn can claim infringed quality standards.[13]

Indeed, a close look at the stress test reveals that, within the simulation, quite a number of international standards and Deutsche Bahn regulations have been violated:[14] Without being explicitly planned as a bottleneck, S21 has been allowed to increase the average delay by up to one minute per train (statement 12). A hidden procedure has been used to reduce delays from critical levels to levels within the scope of buffer times (statement 10). Departure delays have been fed into the simulation but have been removed instantly as if they stem from a delayed arrival by shortening the dwell time (statement 11). Furthermore, non-usable travelling time reserves have been used for reducing delays, trains have been omitted from the timetable just before and after peak hour to relieve the strain, punctuality has been set much more optimistically than the officially reported values, minimum dwell times have been set below actual demand, and signals have been set as if departure delays were known in advance, keeping successive tracks open for other trains. All of this enhances the performance unacceptably.

During plan approval the authors of the expert reports defended the layout of Stuttgart 21 with a level of occupation of the platform tracks at about 50 % as being just acceptable.[15] In the stress test with 49 trains and a mean dwell time above 5 minutes, a level of occupation well above 80 % is reached (statement 13). But the levels of occupation, despite being demanded by the guideline, are not shown. Deutsche Bahn argues either to have levels of occupation from the simulation falsifiying these values[16] or not to be able to get the values from the simulation,[17] but anyhow not needing to show the values as this would only be necessary if an infrastracture is to be evaluated (as one would expect was the aim of the stress test).

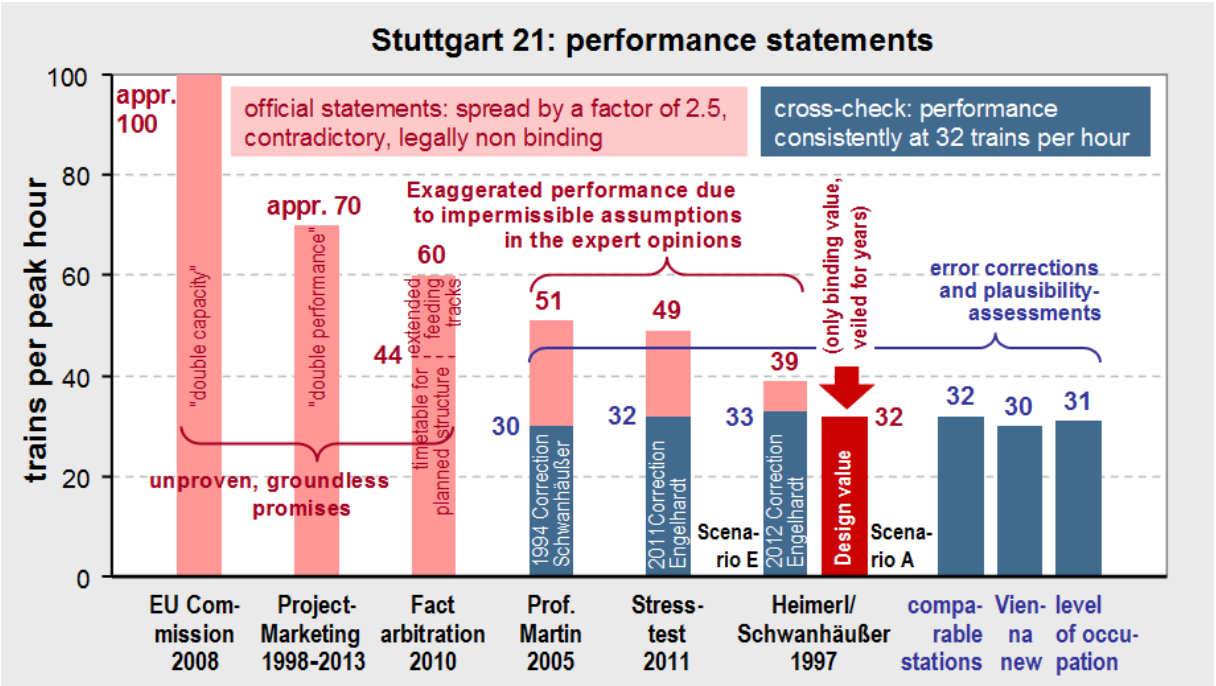

***Figure 4**: Capacity statements concerning the "Stuttgart 21" train station. The official statements vary over an unscientifically broad range and they contradict each other. To the public and even the European Commission totally untenable promises were made, which have never been corrected, even if the expert opinions justified only decidedly lower capacity values. And the expert opinions themselves are flawed by false assumptions violating scientific standards and Deutsche Bahn regulations. On the other hand, all independent error corrections and comparisons for plausibility yield a value close to 32 trains per hour. This matches exactly the only legally binding value for S21 of "Scenario A", but its 32 trains per peak hour and its performance limit of 32.8 trains per hour have been kept hidden all these years and could be disclosed only recently.*

Officially a doubling of the station's performance was promised by realization of Stuttgart 21[18] and 114 million Euros of funding from the European Commission was granted on the "condition" that the station's capacity would be doubled,[19] what was also widely promoted[20]. Both promises are as untenable as other promises, because even the flawed simulations showed much lower performance. In the existing terminus station 38.5 trains are handled today during peak hour according to timetable; historically 47.5 trains per hour have been achieved in 1939 and 45.5 trains in 1970, and today a capacity of 50 trains per hour has been approved by the Baden-Württemberg ministry of traffic.[21] The promises of a doubled performance and a doubled capacity still were officially communicated when the financing contract was signed in 2009, as well as when there has been a referendum in 2012. After persistent criticism of these statements they have been removed only in recent months from the website of the European Executive Agency and from the Deutsche Bahn's Stuttgart 21-exhibition.

In contrast to the high performance promises for S21 the original expert opinion stated a performance limit of 32.8 trains and the draft timetable showed a peak of 32 trains per hour, which was uncovered only recently. This capacity value fits well with the expectations based on a 60 % level

of occupation of the 8 tracks at a published dwell time of 5.3 minutes yielding 31 trains per hour or when compared to similar existing or planned stations like Vienna Main Station (figure 4).

Also the error corrections of the flawed simulations yield values in the range of 32 trains per hour: The first one was performed already in 1994 by one of the authors of the original expert opinions. He corrected the dwell time from 2 to 3 minutes (see above) and concluded the operating program with 35 trains per hour would need 10 platform tracks for "future-proof dimensioning".[22] This would correspond to a maximum of 30 trains on 8 tracks. Doing the same correction to another scenario with 39 trains (which would need extended feeding tracks) would yield 33 trains. The estimated performance of the stress test, if the above violations were to be corrected, yielded 32 trains per hour (figure 4).

Thus, it appears as if Stuttgart 21 will create a bottleneck on the "Magistrale for Europe" between Paris and Bratislava, neither being able to handle todays peak hour traffic of 38.5 trains nor enabling traffic growth. Presumably during plan approval this passed unnoticed due to incomplete and misleading presentation in the expert opinions in quite a number of the statements.

b) German-speaking rail science partly fallen silent?

When it comes to Stuttgart 21, the scientific principle of open discussion ceases to apply in Germany. Here, people who are not retired or otherwise completely independent of Deutsche Bahn AG avoid written communication. Only on the phone or behind closed doors is one told that there are quite a few cases even outside Stuttgart 21 in which research results are not published if this interferes with a Deutsche Bahn application for funding of research or a major project.

The German speaking established scientific community is silent. To date, no publication has described the technical peculiarities enabling Stuttgart 21 to deliver the extraordinarily high performance shown by the stress test. The authors of the expert reports defended the project vigorously on several occasions, but they do not respond when challenged to a discussion of the arguments mentioned here.[23]

The total non-response of the DB-related experts in this survey stands out from all the other responses in a statistically highly significant way. It appears as if this result provides first scientific evidence that a portion of the German-speaking railway expert community is in danger of losing its scientific independence. The experts are selectively falling silent and act in anticipatory obedience to the dominant player in the German railway market.

The above survey was designed, performed and analyzed to the best of the author's knowledge and judgment. All the results from the analysis of the responses may be verified by a notary if a sponsor for this effort is found. The interpretation given here is open to discussion in the scientific community.

Christoph Engelhardt, Garching, 24.06.2013

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[2] 02.04.2009, The contract on the financing of Stuttgart 21 as well as the important appendices are found here: www.bahnprojekt-stuttgart-ulm.de/details/kosten-und-finanzierung/
The 50 % traffic increase is found in: Anlage 3.2a Anhang 1 Number 3.1 p. 6.

[3] Wulf Schwanhäußer, „Stuttgart 21 Ergänzende betriebliche Untersuchungen, Teil 3, Leistungsverhalten und Bemessung des geplanten Stuttgarter Hauptbahnhofes und seiner Zulaufstrecken", Verkehrswissenschaftliches Institut der RWTH Aachen, 20.07.1997, p. 58,

[4] Gerhard Heimerl et al., „Stuttgart 21 Ergänzende betriebliche Untersuchungen, Teil II, Kapazitätsreserven beim geplanten Stuttgarter Hauptbahnhof sowie beim Betriebskonzept Stuttgart 21", Anl. 21-24

[5] 04.03.2013, wikireal.org , C. Engelhardt, „Warum der Rückbau in der Planfeststellung übersehen wurde"

[6] 28.01.2005, Planfeststellungsbeschluss nach § 18 Abs. 1 Allgemeines Eisenbahngesetz (AEG) für den Umbau des Bahnknotens Stuttgart „Projekt Stuttgart 21" Planfeststellungsabschnitt 1.1 (Talquerung mit neuem Hauptbahnhof) (Az.: 59160 Pap-PS 21-PFA 1.1 Talquerung) (pdf bahnprojekt-stuttgart-ulm.de), p. 150 "Belastung in den für die Bemessung der Infrastruktur maßgeblichen Spitzenstunden" (load in the peak hours, that are crucial for dimensioning). On p. 204 a performance of "32 bis 35 Gleisbelegungen" (32 to 35 track occupations) has been mentioned, but this is misleading as it does not give the usual performance measure "trains" and as it is compared with the mean (not the peak) number of an operating program "25.5 Gleisbelegungen", see also [5].

[7] [6] p. 154 in combination with: DBProjekt GmbH, „PFA 1.1 Erläuterungsbericht Teil I Allgemeiner Teil" p. 17

[8] 25.10.2012, C. Engelhardt, „Stuttgart 21: Rückbau, Planrechtfertigung war nie gegeben" (wikireal.org). See also wikireal.org/wiki/Stuttgart_21/Leistung

[9] Ullrich Martin et al., „Vergleich der Leistungsfähigkeiten und des Leistungsverhaltens des neuen Durchgangsbahnhofes (S21) und einer Variante umgestalteter Kopfbahnhof (K21) im Rahmen der Neugestaltung des Stuttgarter Hauptbahnhofes (Abschlussbericht)", 2005. Veröffentlicht in: Landeshauptstadt Stuttgart (Hrsg.): Stuttgart 21 – Diskurs, Stuttgart 2007, p. 2287–2369 (pdf)

[10] 25.10.2010, Prof. Martin, discussion after his talk at the university of Stuttgart: „Ausgewählte, insbesondere eisenbahnbetriebliche Aspekte zum Bahnprojekt Baden-Württemberg 21"
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28.11.2010, stuttgarter-zeitung.de, „Kritiker reden vom »Engpass S 21«"

[11] DB Netz AG, "Stresstest Stuttgart 21, Fahrplanrobustheitsprüfung", 30.06.2011 (pdf: part 1, part 2, netplan)

[12] SMA und Partner AG, "Audit zur Betriebsqualitätsüberprüfung Stuttgart 21, Schlussbericht", 21.07.2011 (pdf)

[13] The audit was commissioned and paid by the Deutsche Bahn AG; therefore according to civil law nobody else can sue the auditor in case of poor performance, for which examples are found here: wikireal.org/wiki/Stuttgart_21/Stresstest/Kritik_an_SMA.

[14] wikireal.org/wiki/Stuttgart_21/Stresstest

[15] • 1994, Gerhard Heimerl et al., „Projekt Stuttgart 21, Machbarkeitsstudie Verkehrliche und betriebliche Untersuchung, betriebs- und gesamtwirtschaftliche Bewertung Ergebnisbericht der Fachgruppe 2", 1994, p. 36 "Belegungsgrad" (level of occupation) with 3 minutes dwell time "im oberen Bereich einer üblichen Bahnsteiggleisanlage" (in the upper range of the typical station), the given 45 % level of occupation have to be corrected for an extra minute dwell time of 35 trains, which gives 52 % level of occupation.
• 2006, Wulf Schwanhäußer in the court hearing: Verwaltungsgerichtshof Baden-Württemberg, Aktenzeichen 5 S 848/05, „Erfolglose Klage eines mit enteignungsrechtlicher Vorwirkung betroffenen Miteigentümers eines Grundstücks gegen den Planfeststellungsbeschluss für den Umbau des Bahnknotens Stuttgart", 06.04.2006 (landesrecht-bw.de), No. 59: "Gleisbelegung" (level of occupation) 50 % as in similar through stations.

[16] 17.11.2011, Kommunikationsbüro, „Richtigstellung der Anschuldigungen" (stuttgarter-zeitung.de), p. 6

[17] 13.04.2012, Meeting "railsys wikireal" at the Baden-Württemberg ministry of transport, protocol, p. 11/12

[18] • 1995, „Das Synergiekonzept »Stuttgart 21«" (pdf), S. 6, 10: +80 % in regional travel.
• 1998, Projektmagazin, S. 1: „… kann die Zahl der Ankünfte und Abfahrten in der Hauptverkehrszeit mehr als verdoppelt werden." (doubled number of arrivals and departures)
• 2002 Frühjahr, Projektmagazin: „Mehr als dop-

pelt so viel Züge wie bisher können den neuen Durchgangsbahnhof anfahren“. (doubled number of trains, similarly in many other publications)
• 22.02.2013: In the S21-exhibition in the “Turmforum” still can be read: „Die 8 Gleise des zukünftigen Durchgangsbahnhofs können mehr als doppelt so viel Züge bewältigen wie der derzeitige Hauptbahnhof mit seinen 16 Gleisen".

[19] *12.12.2008, European Commission, „Entscheidung über die Gewährung eines Zuschusses für eine Maßnahme bezüglich der Gewährung eines Gemeinschaftszuschusses für Vorhaben von gemeinsamem Interesse „Aus- und Neubaustrecke Stuttgart-Wendlingen einschl. Stuttgart 21” - 2007-DE-17200-P - auf dem Gebiet der transeuropäischen Verkehrsnetze (TEN-V) (pdf). Under „Hauptziele“ (main goals): „Stuttgart 21 hat [...] die doppelte Leistungsfähigkeit“ (double capacity) (p. 11). The contents of this appendix are „Bedingung“ (condition) of granting the funds (p. 3).*
25.10.2012, wikireal.org, C. Engelhardt, „Stuttgart 21: Rückbau, Planrechtfertigung war nie gegeben“. 25.02.2013, stuttgarter-zeitung.de, „Zuschuss der EU zu Unrecht erhalten?“

[20] *Other promises of doubled capacity:*

05.2007, DB Projektbau GmbH, „Neubauprojekt Stuttgart-Ulm“ (pdf), S. 3: „Der neue Bahnhof: doppelt so leistungsstark mit Option zum Ausbau.“

20.07.2007, Stuttgarter Zeitung, „Neue Verbindungen und eine zweite City“: „... durch einen nur achtgleisigen aber flexibleren unterirdischen Durchgangsbahnhof ersetzt werden. Dessen Leistungsfähigkeit ist laut Bahn doppelt so hoch wie die des Kopfbahnhofs.“

10.2007, DB Infrastruktur ProjektBau, „Neubauprojekt Stuttgart – Ulm, Fragen und Antworten zum neuen Verkehrskonzept für Stuttgart und die Region“ (pdf, S. 4: „Stichwort Zukunftsfähigkeit: Der Durchgangsbahnhof wird schon bei seiner Eröffnung die doppelte Leistungsfähigkeit des heutigen Hauptbahnhofs haben.“.

[21] *Analysis of timetables by the author and coworkers:*
• 2011, hour starting at 6:50 o’clock, 38,5 trains (plus allocated paths for 2 special trains)
• 1970, hour starting 6:30, 6:40: 45,5 trains
• 1939, hour starting 5:50, 6:10: 47,5 trains
The historic maximum values have been achieved before changes at the feeding tracks for the commuter rail system “S-Bahn”. But layout of platform tracks and rail heads was kept practically unchanged, if not improved. Therefore the confirmed capacity of 50 trains for the terminus station is plausible:
• 22.11.2011, mvi.baden-wuerttemberg.de, „Kopfbahnhof könnte heute schon mehr Züge abwickeln als S 21“

[22] *Wulf Schwanhäußer, „Eisenbahnbetriebswissenschaftliches Gutachten zur Kapazität des geplanten Bahnhofes Stuttgart Hbf Tief im Vergleich mit dem bestehenden Kopfbahnhof Projekt Stuttgart 21“, 11.1994, p. 14 ff*

[23] *07.12.2013, wikireal.org, C. Engelhardt, E-mail cover letter to the position paper concerning redeemability of the financing contract. At the end of this text: Prof. Dr. G. Heimerl, Prof. Dr. W. Schwanhäußer and Prof. Dr. U. Martin are challenged for a scientific discussion of the critical points.*