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The Chuo Shinkansen Project: High Speed Rail in Japan

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Abstract

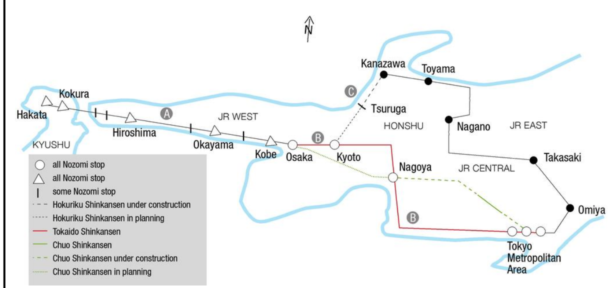
This article assesses the necessity, and provides a technical evaluation of options for a new railway line in the Tokyo - Osaka corridor. It discusses the introduction of SCMaglev technology for the Chuo Shinkansen project and the logic of decisions for its implementation. I examine problems in scheduling an effective timetable for the first phase of a new line between Tokyo and Nagoya. A capacity comparison is provided between the new line, using SCMaglev technology, and the Tokaido Shinkansen, using wheel-on-rail, technology.

Keywords: Timetable scheduling, railway technology, counterbalance of criteria, behavioural patterns in Japanese culture.

Introduction

Two years ago the Asia-Pacific Journal reported on the Chuo Shinkansen Project. Aoki Hidekazu and Kawamiya Nobuo, in their contribution "End Game for Japan's Construction State – The Linear (Maglev) Shinkansen and Abenomics" https://apjjf.org/2017/12/Aoki.html, examined technical and financial aspects of the project. The present article assesses it from the perspective of a guided land transport system comparing new project to the existing Tokaido Shinkansen in the Tokyo/Osaka corridor in light of cost, benefit and feasibility.

With the opening of the Tokaido Shinkansen high-speed line between Tokyo and Osaka in 1964, Japanese National Railway (JNR) introduced two kinds of trains: one that calls at every station (Kodama) and one that calls only at major stations (Hikari).



Overview of the area containing the main routes of JR Central and JR West in Japan (drawing S. Andersen)

The first timetable included one Hikari and one Kodama per hour in each direction. As ridership grew rapidly, in October 1980 JNR offered five Hikari and five Kodama per hour and direction. The rising number of Hikari trains led to increased overtaking in intermediate stations. From March 1985 the steadily mounting traffic demand led to a decrease in Kodama trains in favour of Hikari trains.

By March 1993 the Central Japan Railway Company (JR Central) had introduced a new type of train, Nozomi, which calls only at stations in the Tokyo metropolitan area (Tokyo Central, Shinagawa and Shin Yokohama), Nagoya, Kyoto and Osaka. From 2001 to 2003 the number of Hikari trains was decreased while the number of Nozomi trains rose. The present structure of the timetable on the Tokaido Shinkansen began with the timetable change of October 2003, when 145 Nozomi trains and 145 other trains, 65 Hikari and 80 Kodama, were running along the Tokaido Shinkansen. Whereas the number of Hikari and Kodama trains has remained almost the same, (65 Hikari and 83 Kodama in 2018), the number of Nozomi trains jumped to 225 by March 2019[1]. Since March 2014 the number of Nozomi trains increased to 10 trains per hour and direction during high peak time. Concerning peak time we must distinguish between daily peak time and high peak time. Daily peak time means the daily hours between 6:00 o'clock. and 10.00 o'clock and between 16:00 and 20:00. High peak refers to the following sequences: a public holiday before a weekend; a weekend before a public holiday; a public holiday/workday/weekend and weekend/workday/public holiday. In the two latter cases the workday is often taken as a holiday. In all these cases JR Central faces a huge traffic demand that far exceeds the daily peak traffic demand. The hourly service for the intermediate stations has remained at 2 Hikari and 2 Kodama each way since October 2003, thus providing a total of 26 and 25 stops respectively per hour and direction.

The service at the intermediate stations on the Tokaido Shinkansen has suffered greatly from the increased number of Nozomi trains, as is clear from a look at a typical hour during daily peak time.

Table 1 : Extract timetable valid from September 2019
(An example of the 10 Nozomi service, introduced in March 2014)

km		K 673 daily	N 243 daily	K 669 daily	H 481 daily	N 53 daily	N 395 only high peak	N 245 daily peak	N 397 only high peak
0,0	Tokyo dep.	16.56	17.00	15.56	17.03	17.10	17.13	17.20	17.23
6,6	**Shinagawa**	17.04	17.07	16.04	17.10	17.17	17.20	17.17	17.30
25,5	**S.Yokohama**	17.16	17.19	16.16	17.21	17.29	17.32	17.39	17.42
76,7	Odawara	17.35	↓	16.35	↓	↓	↓	↓	↓
95,4	Atami	17.44	↓	16.44	↓	↓	↓	↓	↓
111,3	Mishima	17.57	↓	16.57	17.46	↓	↓	↓	↓
135,0	S.Fuji	18.12	↓	17.12	↓	↓	↓	↓	↓
167,4	Shizuoka	18.26	↓	17.26	18.11	↓	↓	↓	↓
211,3	Kakegawa	18.40	↓	17.41	↓	↓	↓	↓	↓
238,9	Hamamatsu	18.55	↓	17.55	18.37	↓	↓	↓	↓
274,2	Toyohashi	19.13	↓	18.13	↓	↓	↓	↓	↓
312,8	Mikawa-Anjo	19.32	↓	18.32	↓	↓	↓	↓	↓
342,0	**Nagoya** arr.	19.43	18.41	18.43	19.07	18.47	18.54	18.59	19.04
	Nagoya dep.		18.43	18.45	19.08	18.48	18.56	19.01	19.05
367,1	Gifu-Hashima		↓	18.57	↓	↓	↓	↓	↓
408,2	Maibara		↓	19.19	↓	↓	↓	↓	↓
476,3	**Kyoto**		19.19	19.40	19.46	19.24	19.33	19.36	19.43
515,4	**S.Osaka** arr.		19.33	19.53	20.00	19.37	19.46	19.50	19.56

km		K 675 daily	N 55 daily	H 523 daily	K 801 only Sun-day	N 247 daily peak	N 399 only high peak	N 119 daily	N 401 only high peak
0,0	**Tokyo** dep.	17.26	17.30	17.33	17.37	17.40	17.47	17.50	17.53
6,6	**Shinagawa**	17.34	17.37	17.40	17.44	17.47	17.54	17.57	18.00
25,5	**S.Yokohama**	17.45	17.49	17.52	17.55	17.59	18.06	18.08	18.12
76,7	Odawara	18.03	↓	18.08	18.13	↓	↓	↓	↓
95,4	Atami	18.12	↓	↓	18.21	↓	↓	↓	↓
111,3	Mishima	18.24	↓	↓	18.28	↓	↓	↓	↓
135,0	S.Fuji	18.39	↓	↓	arr.	↓	↓	↓	↓
167,4	Shizuoka	18.55	↓	↓		↓	↓	↓	↓
211,3	Kakegawa	19.10	↓	↓		↓	↓	↓	↓
238,9	Hamamatsu	19.22	↓	↓		↓	↓	↓	↓
274,2	Toyohashi	19.41	↓	↓		↓	↓	↓	↓
312,8	Mikawa-Anjo	19.58	↓	↓		↓	↓	↓	↓
342,0	**Nagoya** arr.	20.09	19.11	19.17		19.19	19.28	19.31	19.36
	Nagoya dep.		19.13	19.18		19.21	19.30	19.33	19.38
367,1	Gifu-Hashima		↓	19.30		↓	↓	↓	↓
408,2	Maibara		↓	19.52		↓	↓	↓	↓
476,3	**Kyoto**		19.49	20.13		19.57	20.07	20.10	20.16
515,4	**S.Osaka** arr.		20.03	20.26		20.10	20.20	20.23	20.30

Notes:
Daily peak is the time between 6:00 o'clock. and 10:00 o'clock and between 16:00 o'clock. and 20.00 o'clock
High peak refers to the following sequences: a public holiday before a weekend; a weekend before a public holiday, a public holiday/ workday/weekend and weekend/workday/public holiday. In the two latter cases the workday is often taken as a holiday. In all these cases JR Central faces a huge traffic demand that far exceeds the daily peak traffic demand.

Extract from the current valid timetable in 09/2019 for the hour 17.00 o'clock until 18.00 o'clock for the departure from Tokyo bound for Osaka.

Table 1 shows the service from 17:00 to 18:00 o'clock, when 10 Nozomi-trains run between Tokyo and Osaka with traffic demand steadily increasing. The travel times of the Nozomi trains -- 2h 27min (N 53), 2 h 30min (N 245/247), 2h 33min (N 243/395/397/55/399/119) and 2h 37 min (N 401) -- show a corresponding increase. In contrast the three fastest trains, which face no obstructions from trains stopping in front of them, run in the early morning (N 1) and late evening (N 265, N 64) and need only 2h 22min.

The newest Annual Report 2019 describes an interesting improvement. Due to the fact that from spring 2020 all trains (Nozomi, Hikari and Kodama) can be operated with the EMU class

N700A, all trains can travel at a top speed of 285 km/h. This fact allows JR Central, first, to run during high peak season up to 12 Nozomi per hour and direction and, second, to reduce the travel time for all 12 Nozomi to within 2 h 30 min[2].

Using the fastest speed as a baseline, we can note that from spring 2020 every Nozomi train is held up by an average of 8 minutes, when Hikari and Kodama trains move out from the main track in order to call at intermediate stations. Kodama 669 on its run between Shin Yokohama and Kyoto during high peak season is overtaken by 16 faster trains, 14 Nozomi and 2 Hikari. The infrastructure on the Tokaido Shinkansen simply doesn't allow fast overtaking. For example Hikari 481 is overtaken by the two Nozomi trains 53 and 395 in Shizuoka and by the two Nozomi trains 245 and 397 in Hamamatsu. But in both cases the second Nozomi runs only during high peak seasons meaning that at other times H 481 loses 6 minutes in travel time in the section from Shizuoka to Nagoya. This is unsatisfactory.

The present timetable for the Tokaido Shinkansen

- means that people living along the Tokaido Shinkansen must accept slower travel times, because there are too few trains and their travel times are too long and
- the schedule prevents achieving the shortest possible travel time for the fastest train category, Nozomi, because of the hindrance of stopping trains on the line ahead.

JR Central came to realize that only a new railway line could relieve the pressure on the Tokaido Shinkansen. The new SCMaglev line will include the 42.8 km long section of the Yamanashi test line, already in place by 2018. The Construction Implementation Plan according to Article 9 of the Nationwide Shinkansen Railway Development Act was submitted on 25 September 2017 and approved on 2 March 2018[3]. It delineates conditions for the start of construction.

A clear separation of the different train types is intended to maximize the overall capacity on both high speed lines in the Tokyo - Osaka corridor: the existing Tokaido Shinkansen will be used exclusively to meet the traffic demands from all intermediate stations to the hub stations in the Tokyo metropolitan area as well as Nagoya, Kyoto and Osaka, whereas the new Chuo Shinkansen will take over all Nozomi services. This step requires assuring the same capacity for the Nozomi trains on the Chuo Shinkansen as is present on the Tokaido Shinkansen. Torkel Patterson, a member of the board of directors of JR Central, explained the logic of the new plan in terms of coping with a potential large-scale disaster: "Our responsibility is to the future of Japan. We have a central responsibility to provide infrastructure for the country, so that in the event of a large-scale disaster the economy won't be disrupted"[4]. If operation on the Tokaido Shinkansen is disrupted for any reason, in other words, Nozomi trains will continue to run on the Chuo Shinkansen. The Nozomi trains thus represent the backbone of the Japanese economy.

Patterson's observation is accurate, but the plans to build the infrastructure he imagines are seriously flawed. We take a look at the problems below.

Avoidance of Overtaking at Intermediate Stations

The following paragraph is addressed mainly to railway engineers. But given the description of the daily traffic pattern on the Tokaido-Shinkansen in the paragraphs above anyone can understand the logic of measures to avoid trains overtaking one another in an intermediate station. The timetable of the high-speed lines in Japan, Taiwan and mainland

China account for overtaking at intermediate stations. But from the perspective of the service and operation of a high-speed line, every overtaking is a negative. First, passengers cannot change between the train that stops and the through train. Second, the process presents an operational problem: both trains must be absolutely punctual in order to carry out the overtaking in time. Third, the through train and the one that follows may be hindered by the train ahead of it, if the infrastructure of the intermediate station doesn't allow a quick overtaking. Fourth, the travel time for the stopping train must be extended, because of the wait at the intermediate station. And finally the train being overtaken needs different paths before the stop and after the stop thus causing a negative influence on a high use to capacity situation (see train diagram in picture 3).

If the Japanese could have foreseen the huge traffic demand from the beginning, they would have built the Tokaido Shinkansen as a four-track railway line, the outside tracks for trains that stop and the inside tracks for the fast trains that call only at the hub stations. With this sort of regulation and intelligent timetable scheduling any overtaking in an intermediate station could be avoided. Also on a two-track railway every overtaking in an intermediate station can be avoided. I have recently shown this in my article "Angebotsgestaltung auf kurzen Hochgeschwindigkeitsstrecken am Beispiel Taiwan" Careful timetable scheduling based upon an avoidance of overtaking in an intermediate station can reduce travel times, which in turn raises traffic demand[5].

These goals must be realized on the new Chuo-Shinkansen as well as on the existing Tokaido Shinkansen.

SCMaglev Technology for the Chuo Shinkansen

Initially both the proven wheel-on-rail technology and the superconducting magnetic levitation (SCMaglev) technology were options for the planned new line between Tokyo and Osaka. In a test of a prototype vehicle on 26 July 1996 Japanese wheel-on-rail experts from JR Central had already reached a record speed of 443 km/h. For this trial the engineers used the existing Tokaido Shinkansen between Kyoto and Maibara and carried out the test between midnight and 6:00 a.m., achieving a great performance in such little time.

But shortly thereafter the CEO of JR Central, Kasai Yoshiyuki, decided to use SCMaglev technology for the Chuo Shinkansen and to suspend research on wheel-on-rail technology. The first trials of SCMaglev technology on the Yamanashi test line began in 1997. Since then JR Central has kept both the general public in Japan and international experts in the dark about critical details of the Chuo Shinkansen project: the service concept of the first phase Tokyo - Nagoya, the capacity of the MLX train and the time needed to switch the points in a turnout. At three international congresses on high-speed rail between 2002 and 2007 the Japanese engineers, who carried out tests on the Yamanashi test line, merely reported in a brochure: "These tests simulate various functions required for service operation, including waiting, passing, and following etc. and it was confirmed that such events could be performed smoothly."[6]

Certainly all these "various functions" would be necessary only to account for overtaking at an intermediate station. But as explained above, such a manoeuvre should be avoided altogether. Without further details the JR Central statement is useless. Tests to reverse the points of a turnout would be crucial to realize the time needed to guide trains to another track. Yet no such information was provided at the international conferences.

Although Japanese engineers gave no specific information about the time to switch the points in a turnout, evidence from the brochure *The Review,* published in 2002, 2005 and 2007 for the benefit of foreign experts, suggests that early in their research the Japanese came to realize that SCMaglev technology would never be able to compete with proven wheel-on-rail technology in this critical regard. When a new technology is proposed to replace existing engineering it must have at least the same capability; to succeed, it must also offer a decisive advantage in at least one area. Maglev technology does not fulfil this important criterion.

The Chuo Shinkansen Route

Every new railway line in the corridor Tokyo/Osaka should be built right from the start over the whole distance, because the main traffic demand in this corridor leads from Tokyo to Osaka. The argument to build the new line in two phases poses the big problem that it requires subsequently changing a terminus station into a through station in Nagoya, when the second phase is realized. This means a considerable loss of investment.

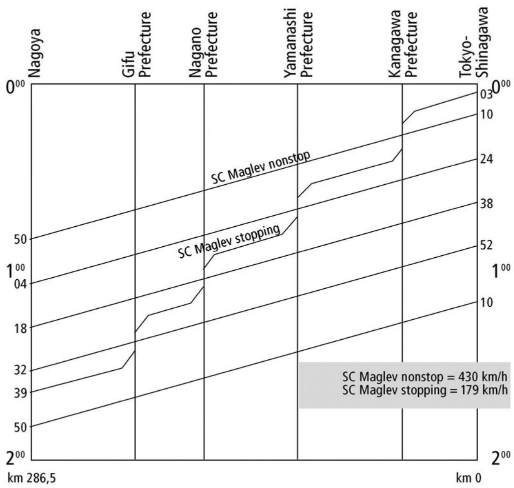
On 18 September 2013 JR Central announced the route of the planned Chuo Shinkansen. At the same time it released the draft environmental impact assessment of the route. The next day, the two leading newspapers in Japan*, Asahi* and *Yomiuri,* published the service program for the first phase: four nonstop trains and one train that would stop at every intermediate station. The top railway magazine in the world, *Railway Gazette International,* reported on the Chuo Shinkansen twice that year yet failed to provide this important detail of the service.[7]

The first phase of the new Chuo Shinkansen route between Tokyo and Nagoya, due to open in 2027, is shown in picture 1 by a broken green line. The second phase between Nagoya and Osaka is shown by a green dotted line. Although this second section was originally scheduled to be opened in 2045, JR Central accepted a loan from the government that would allow it to move the date forward to 2037. JR Central took on the Chuo Shinkansen project on its own, a huge undertaking for a private company, unheard of anywhere else. Given these circumstances the company should have made every effort to get every technical detail of the engineering right. Part of this goal should have been to avoid any intermediate stop on the Chuo Shinkansen. Yet the company failed to do so[8]. JR Central is performing a skilful balancing act concerning this key issue[9].

Overview of the route of the first phase Tokyo - Nagoya of the Chuo Shinkasnen project (drawing S. Andersen)

The First Phase of the Chuo Shinkansen: Tokyo - Nagoya

The route of the first phase Tokyo - Nagoya shown in picture 2 contains four intermediate stops; one in every prefecture. The service program provides crucial information that can allow experts to design a train diagram study and to carry out a capacity comparison as I do below.



Train diagram study for the first phase of the Chuo Shinkansen (drawing S. Andersen)

Examination of the train diagram study

This train diagram study shows two negative aspects: overtaking in an intermediate station and the small number of trains. A railway company that actually plans for overtaking in an intermediate station, rather than taking any action to avoid overtaking is clearly not in control of scheduling a train diagram. The railway company always has to explain to and convince politicians of what measures it considers viable. Given an operating speed of more than 500 km/h JR Central should have told politicians that in such a situation the only viable possibility would be a pattern service which schedules either all trains to call at the station or all trains to pass through.

The train diagram study shows a big space between two train paths. The actual spacing involving the two train paths isn't known. But at a conference in Bilbao in spring of 2019 JR Central board member Torkel Patterson stated that "service will be operated by a fleet of 16-car driverless trains running at 10-minute headways"[10]. But a headway of 10 minutes would present a great step back in a guided land transport system: state-of-the-art wheel-on-rail technology achieved a 3-minute headway many years ago, and exists as well on the Tokaido-Shinkansen. So, what is the deeper reason for such a negative development? The answer lies in a technical issue: it takes much more time to switch the points in a turnout built in SCMaglev technology than in wheel-on-rail technology. A look at the hydraulic turnout of the Yamanashi test line demonstrates this fact.

Hydraulic Traverser Turnout Switch in Yamanashi test line, photo JR Central

In a terminus station turnouts are now vital. Steel-wheel technology can handle trains arriving at 3-minute intervals, with trains routed into different platforms: this is not possible with SCMaglev turnouts. SCMaglev technology like the abandoned Transrapid technology in Germany simply cannot outperform existing technology. The extended time required to switch the points in a turnout causes the proposed new technologies to fail to compete with wheel-on-rail technology. Although JR Central prefers not to disclose the figures, there are sufficient signs to suggest that the time to switch the points in a turnout is 10 times higher in SCMaglev technology compared to proven wheel-on-rail technology.

Table 2 Capacity comparison

Guided land transport system	SCMaglev (proposed) Tokyo - Nagoya 2027	Wheel-on-rail Shinkansen Tokyo - Osaka, 2019	Wheel-on-rail Shinkansen Tokyo - Osaka, proposed from spring 2020 according to Annual Report 2019, page 19
Highest number of trains per hour and direction	5	14	16
Number of trains for	4 (nonstop)	10 (Nozomi)	12 (Nozomi)
Seat capacity per EMU[a]	1.000[9]	1.323	1.323
Total seat capacity	4.000	13.230	15.876
Intermediate stations	4	9 (section Tokyo - Nagoya)	9 (section Tokyo - Nagoya)
Number of trains per hour and direction serving intermediate stations	1	4	4
Seat capacity per EMU[a]	1000[9]	1.323	1.323
total seat capacity	1000	5.292	5.292

Remark: [a]EMU = electric multiple unit

Capacity comparison between a Chuo Shinkansen built in SCMaglev and the Tokaido Shinkansen built in wheel-on-rail-technology.

Capacity comparison between Chuo Shinkansen in SCMaglev technology and Tokaido Shinkansen in wheel-on-rail-technology

Table 2 shows the capacity comparison between a Shinkansen line built using the different technologies.Given the future situation of spring 2020 the capacity comparison makes clear that a Shinkansen line built in SCMaglev technology would provide only 25% of the capacity for the Nozomi trains, and only 19% of the capacity for the stopping trains (Hikari and Kodama). And yet 15 years ago the CEO of JR Central at that time, Kasai, promised in an interview that the Chuo Shinkansen would double the capacity in the Tokyo-Osaka corridor.[11] Given Kasai's statement the capacity comparison suggests a great fiasco.

After the Fukushima nuclear disaster of 2011 increasing capacity became an urgent goal in a national land transport system. But as matters stand with the Chuo Shinkansen project, Japan will fall far short of this goal. What stands in the way is a fundamental contradiction: transportation capacity versus passenger demand.

What about the final stage of the Chuo Shinkansen project? When will it be extended to Osaka? As of now, eight trains per hour and direction are envisaged, seven nonstop trains and one stopping train. This goal is limited by the poor performance of an SCMaglev terminus. Someone who today sets a goal to be reached in 18 years has no idea how to achieve this goal. With the final stage of the Chuo Shinkansen currently projected to be in 2037, the operation of eight SCMaglev trains in one hour in a terminus station is pure theory.

The capacity comparison shows a disproportionate negative result for trains that call at intermediate stations. By lengthening the Chuo Shinkansen from Nagoya to Osaka we can assume a fifth and sixth intermediate station will be included thus reducing the average speed of the train stopping at the intermediate stations to somewhere in the range of 130 km/h. This is an absolutely unsatisfactory prospect.

The JR Central Annual Report and Company Guide

Every year JR Central publishes two important brochures. The first, its Annual Report, describes all financial aspects of the company and is addressed primarily to the stakeholders of the company as well as the general Japanese public. The Central Japan Company Guide, formerly called the DATA Book, is meant mainly for foreign experts. In it Japanese engineers provide facts and details for the benefit of their international colleagues. For a number of years I have examined these two annual works with one thought in mind: how do they describe the progress of the Chuo Shinkansen project? These documents are the basis for much of the following analysis.

Pros and Cons of the Two Railway Technologies

To understand why JR Central decided to use the questionable SCMaglev technology, we might begin by looking at the advantages and disadvantages of each technology that could have been chosen for the Chuo Shinkansen. Although it would seem obvious right from the start of the Chuo Shinkansen project that a comparison was necessary, we do not know whether JR Central management in fact carried out this important step.

Pros and cons of SCMaglev technology

Tokyo - Nagoya - Osaka

JR Central's Annual Report of 2016 points to the goals of the Chuo Shinkansen: travel time Tokyo metropolis to Nagoya City 40 minutes; Tokyo to Osaka City 67 minutes. But the Central Japan Company Guide from 2016 doesn't contain this information. The same happens in 2017, 2018 and 2019. Kasai hoped the Chuo Shinkansen would capture market share from the airlines. But 100% of market share from Nagoya to Tokyo and 85% from Osaka already favour the railway[12]. So the remaining market volume of Osaka (15 x 1.450 = 21.750 passengers/day) is the maximum volume a Chuo Shinkansen in the form of an SCMaglev train could capture. Besides greater traffic demand based upon shortened travel times, this is the main pro for SCMaglev technology. But the small available capacity for this market is a con for a Chuo Shinkansen built with SCMaglev technology.

Kyoto - Tokyo

Because Kyoto lies outside of its planned route the Chuo Shinkansen would be unable to capture this market. The situation for changing passengers in Nagoya will worsen considerably, however, because the platforms for the Chuo Shinkansen lie 30 m below the platforms of the Tokaido Shinkansen. This is a clear con for SCMaglev.

Traffic demand from Tokyo to cities west of Osaka (area A)

As with Kyoto, the Chuo Shinkansen in SCMaglev technology will not capture the market in the area west of Osaka. The October 2003 timetable change on the Tokaido-Sanyo Shinkansen with more through services from Tokyo to destinations west of Osaka has already shown how important through services are to improve market share in favour of the railway[13]. In this respect, too, SCMaglev is a clear con.

Service concept from the intermediate stations east of Osaka towards Tokyo (area B)

Serving stations east of Osaka is an important justification for a new railway line. Given what we've just seen, the present Nozomi trains must remain critical on the Tokaido Shinkansen. Between 8:00 o'clock and 16:00 o'clock these trains depart from Tokyo on the hour at 00, 10, 30, 50 minutes after the hour and from Shin Osaka at 06, 20, 40, 53 minutes after the hour. A small number of additional trains during daily peak hours and during high peak should remain as well. Under the proposed plan for the Chuo Shinkansen, then, there is little room to increase the number of stopping trains.

Technical details of SCMaglev

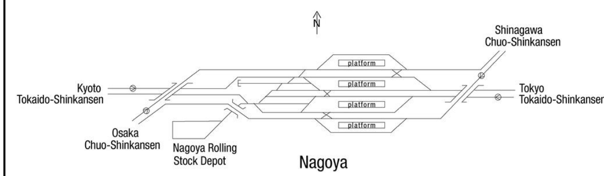
SCMaglev is a new technology and all its basic characteristics should have been carefully checked before its application was approved. The time to switch the points in a turnout is a decisive criterion for a technology in the guided land transport system. In this respect, SCMaglev clearly falls short.

Pros and cons of proven wheel-on-rail technology

Using current wheel-on-rail technology trains would run with a maximum speed of 350 km/h over the Chuo Shinkansen. Trains would need to meet the 40‰ gradients with a forward impetus, as on the Cologne - Frankfurt am Main high-speed line in Germany. For this variant no stops could be scheduled on the Chuo Shinkansen.

Tokyo - Nagoya - Osaka

A Chuo Shinkansen built with wheel-on-rail technology would similarly capture part of the remaining traffic demand from Osaka to Tokyo - and could actually provide the necessary capacity for this goal.



Track diagram of Nagoya station including the proposal to lead the planned Chuo Shinkansen with one-direction running through this station (drawing S. Andersen)

Kyoto - Tokyo

Although Kyoto presents a problem, because it lies outside the Chuo Shinkansen route, wheel-on-rail technology could provide a solution. The Chuo Shinkansen could enter the station from the east like the existing Tokaido Shinkansen. But in the area of Nagoya the Chuo Shinkansen must cross the Tokaido Shinkansen, since the planned Chuo Shinkansen route leads south from Kyoto to Osaka, (see green dotted line in picture 1). As shown in picture 5 the track diagram for Nagoya station would need to allow for a change in routes between the Chuo Shinkansen and the Tokaido Shinkansen after the stop[14]. Trains in Japan keep to the left. The departure times between the two trains in the direction of traffic must be 1 minute apart. This is clear from Table 3 see discussion about area B below.

Traffic demand from Tokyo to cities west of Osaka (area A)

As explained above, the traffic demand from Tokyo to destinations west of Shin Osaka is an important part of the overall traffic demand and can be captured only with through service from Tokyo. From a technical point of view this market share can be gained only with wheel-on-rail trains. From 2012 to 2018 the number of through services from Tokyo to destinations west of Osaka remained exactly the same, while the travel time of some Nozomi trains between Tokyo and Hiroshima (821 km) was shortened by 9 minutes (= - 3,8%) This reduction in travel time increased the market share for the railway as against airlines from 62% (2012) to 68% (2018) for this route. So we can assume that through services from Tokyo to destinations west of Osaka would generate considerable additional traffic demand, if the travel times were shortened.

Table 3: Basic timetable for 1 hour in the Tokyo - Osaka corridor
→ (with best running times) ←
Part I Tokaido Shinkansen

km		N101	H101	H201	H301		N107	H107	H207	H307
0,0	**Tokyo** a					and				
6,6	**Shinagawa** a	07.05	06.03	06.06	06.09		07.50	06.48	06.51	06.54
25,5	**S.Yokohama**		06.15	06.18	06.21	so		07.00	07.03	07.06
76,7	Odawara	via			x		via			x
95,4	Atami			x		on			x	
111,3	Mishima	Chuo	x				Chuo	x		
135,0	S.Fuji				x	**eve-**				x
167,4	Shizuoka	Shin-		x			Shin-		x	
211,3	Kakegawa		x			**ry**		x		
238,9	Hamamatsu	kan-			x		kan-			x
274,2	Toyohashi			x		**15**			x	
312,8	Mikawa-Anjo	sen	x				sen	x		
342,0	**Nagoya**	07.51	07.52	07.54	07.57	**min**	08.36	08.37	08.39	08.42
367,1	Gifu-Hashima	↓	via	↓	x		↓	via	↓	x
408,2	Maibara	↓	Chuo	x	↓	un-	↓	Chuo	x	↓
476,3	**Kyoto**	08.25	Shink	08.35	08.38		09.10	Shink	09.20	09.23
	Kanazawa	09.25				til	10.10			
515,4	**S.Osaka** b		08.23	08.48	08.51			09.08	09.33	09.36

Part II Chuo Shinkansen

km		N101	H 101	N201	N203	and	N107	H107	N213	N215
	Tokyo a					so on				
0	**Shinagawa** a	07.05		07.09	07.15	**every**	07.50		07.54	08.00
286	**Nagoya**	07.51	07.52	07.55	08.01	**15 min**	08.36	08.37	08.40	08.46
?	**S.Osaka** b		08.23	08.26	08.32	until		09.08	09.13	09.19

Notes:
a = JR Central has yet to make its final decision regarding stations between Tokyo and Shinagawa,
b = The final destination (terminus at S. Osaka, or a station between Osaka and Hakata) to be decided by JR West in consultation with JR Central.
x = Train calls at this station

Basic timetable for 1 hour in the corridor Tokyo/Osaka on the condition that all Nozomi switch to the Chuo-Shinkansen.

Service concept from the intermediate stations east from Osaka towards Tokyo (area B)

This service concept for one hour is shown in Table 3. It consists of four sections with the same service pattern. The main criterion are the four Nozomi-trains N 101/103/105/107, which would run over the Chuo-Shinkansen between Tokyo/Shinagawa and Nagoya. After the stop in Nagoya, these trains would switch over to the Tokaido-Shinkansen in order to call at Kyoto, thus providing a quick trip between Tokyo and Kyoto. On the Tokaido-Shinkansen only Hikari-trains would operate with at most four stops. These trains call alternately at intermediate stations as the *Chinese Code for Design of High-speed Railway* proposes[15]. Because there would be no overtaking, the commercial speed of these trains would exceed the commercial speed of the existing Hikari. All intermediate stations would receive quick service to the hub stations Tokyo/Shinagawa, Nagoya, Kyoto and Osaka every 15 minutes. This would be a huge improvement over the current service.

An important rule for timetable scheduling for trains reads: better service for the majority of passengers. And the majority of passengers always want to travel from the intermediate stations to the hub stations in the Tokyo Metropolitan area, Nagoya, Kyoto and Osaka.

An early brochure about the Chuo-Shinkansen formulated the following goal: “It is essential that the economic, political and social functions served by the major Tokyo metropolitan area are transferred and distributed throughout the nation and that efforts be made to promote the transfer of power to local governments and regions so as to correct the imbalance created by the overcentralization of people, power and resources in Tokyo, one of the most serious problems facing Japan today”[16]. The proposed service concept meets this ambitious goal.

Through trains from Tokyo/Shinagawa to Kanazawa via Kyoto (area C)

The four Nozomi-trains N 101/103/105/107 can be extended after a turning of 4 minutes

(new train driver!) at Kyoto to stations on the planned Hokuriku-Shinkansen with the final destination at Kanazawa. The Hokuriku-Shinkansen at present is under construction between Kanazawa and Tsuruga and in the planning stage between Tsuruga and Kyoto. If local politicians were made aware that they could receive quick Shinkansen through services to Tokyo, the construction of the Hokuriku-Shinkansen in this area would no doubt be accelerated. The restriction of the four Nozomi-trains to Kyoto on the Tokaido-Shinkansen makes possible four hourly routes in the direction of Kagoshima-Chuo - Hakata - Osaka - Kyoto - Kanazawa - Nagano. This is a further advantage.

Faster realization of all described goals in wheel-on-rail technology

The construction of a Chuo Shinkansen line in proven wheel-on-rail technology could have begun much sooner than 2018, making possible much earlier completion of the project. This would have been an essential advantage of wheel-on-rail technology.

The German experience with Transrapid Technology for a New Long-Distance Railway Line

A comparison of both technologies shows that they aren't compatible with one another. Germany learned a similar lesson 30 years ago. At that time the German Transrapid industry was looking for a field of application for its new technology. With a high-speed line between Cologne and Frankfurt am Main then in its planning stages, executives persuaded Deutsche Bahn to consider Transrapid technology. After comparing it to proven wheel-on-rail technology for the new line Deutsche Bahn found that wheel-on-rail technology would be the better choice. The deeper reason for this decision was the realization that Transrapid-technology wasn't compatible with wheel-on-rail in the important terminal stations of Cologne and Frankfurt am Main. But politicians insisted that Deutsche Bahn plan the new line with the goal of minimizing construction costs with a gradient of 40‰, because Transrapid technology could meet this requirement. The inadequate performance of Transrapid technology at a terminus station had not yet been identified. The new line was traced with an average gradient of 35‰, but two short sections have a gradient of 40‰. The InterCityExpress always meets gradients with a forward impetus. Japanese engineers built the Yamanashi test line with a maximum gradient of 40‰ as well, in order to be able, to use the new Chuo Shinkansen with wheel-on-rail trains - a wise decision.

Chuo Shinkansen Planning from 1997 to 2019

The disastrous result shown in the capacity comparison leads to the question: Why does JR Central continue to insist on SCMaglev technology? To understand this we must look at behaviour patterns typical of Japanese culture. The first is the behaviour between an employee and his superior. Once a CEO has made a decision all employees in the firm try to fulfil that decision. A Japanese employee would never contradict a CEO or try to explain to the CEO that certain details of a plan might not work as expected. The second cultural norm involves contact between people: no one in Japan would correct an opponent, if the truth would hurt him.

Furthermore we must look at who handed down JR Central's original decision, Kasai Yoshiyuki. Kasai holds a degree in law from Tokyo University, the most prestigious university in Japan. Graduates from its faculty of law receive the top jobs in administration and industry in Japan. It would be unthinkable to question a CEO with such an education. Kasai made the final decision in favour of SCMaglev technology in 1997, before the relevant trials started on the Yamanashi test line - and before SCMaglev had been put into operation over as long a distance as that designed for the Chuo-Shinkansen. The critical detail of these tests was to check the exact time necessary to switch the points in a turnout. Finding that SCMaglev fell short, the engineers from Yamanashi test line were faced with telling Kasai the unhappy results of their research. Obviously, adhering to cultural norms, they did not.

In 2008, citing article 5 of the Nationwide Shinkansen Railway Development Act, the Japanese government ordered a report about the researches of the SCMaglev technology from JR Central. JR Central answered one year later in December 2009. In this answer JR Central confirmed ongoing research on four items: transportation capacity versus passenger demand, development of facilities and vehicles, construction costs, and other necessary items. Taken together, the issues suggested serious difficulties that called into question the decision to rely on SCMaglev technology. The Annual Report contains the information.

Transportation capacity *versus* passenger demand presents a fundamental contradiction, one the Japanese engineers must have recognized and come to realize would not be resolved using SCMaglev technology. Did the JR Central management personnel and government officials in charge of the matter not read the fine print? Why didn't they ask the author of the Annual Report for an explanation?

From 2010 to 2014 the Annual Report as well as the JR Central Company Guide referred to "transportation capacity versus passenger demand". But from 2015 the Annual Report reworded the issue as "items related to transportation capacity in response to the transportation demand,"[17] This is a meaningless formulation that disguises a serious problem. What is more, the Company Guide retains the original formulation. The conflicting information is incontrovertible proof that this is no simple mistake of translation from Japanese into English. In the Company Guide Japanese engineers sought to inform their foreign colleagues that they assess the capacity comparison between the two technologies on the basis of international criteria. The practice of informing the Japanese public on the one hand and foreign experts on the other about the same issue in a different way points up an underlying difficulty.

Similarly, at the leading international high-speed congress, held in Tokyo in 2015, Prime Minister Abe Shinzo spoke very highly of the Tokaido Shinkansen in his opening speech but didn't mention the Chuo Shinkansen, This, too, indicates a serious problem with the Chuo Shinkansen.

At the end of 2016 a member of the board of directors of JRCentral sent me information that the newest turnouts in wheel-on-rail technology from JRCentral would need a turnout time of only 3.5 seconds. But why was this information not conveyed to all rail experts in Japan? The answer is clear. JR Central should have released information about the time for the turnouts in SCMaglev technology at the same time. But that would have allowed every expert to offer evidence for the fact that Kasai's 1997 decision to choose SCMaglev technology for the Chuo Shinkansen was wrong. Kasai would have lost face. For this reason such information is being suppressed.

But there are now signs that Kasai stands alone in his decision among the management of JR Central. Kasai is 79 years old. Since the age of 65 he has been chairman emeritus and director on the company's board. But when Kasai held the leading positions as president and representative director and as chairman and representative director, the position of chairman emeritus and director didn't exist. Why did the regulation change? The only explanation can be that the rest of management does not stand behind Kasai. In photos of foreign visitors to the Yamanashi test line, only Kasai appears as a representative of JR Central. If his successors had been convinced of his decision, Kasai would no longer be on the board of directors after his retirement. His successors would, in fact, have taken over the responsibility for his decision in 1997. This hasn't happened. Nor it is likely to happen as long as Kasai is alive.

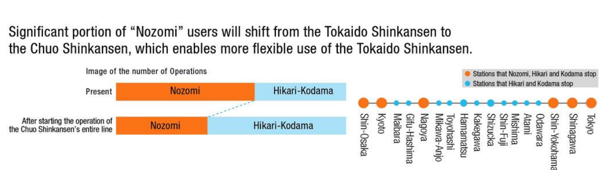
Exporting SCMaglev Technology Abroad

For several years JR Central has been actively engaged in marketing the use of SCMaglev technology in a project in the north east corridor of the United States between Washington DC and New York. According to information in the Annual Report 2018 there has been a rise in awareness and support of this project in the governments of both Japan and the U.S[18]. Torkel Patterson of JR Central has also written about it[19]. But he failed to disclose the disadvantages of SCMaglev technology as described here. Although I wrote a letter to the editor of the *Global Railway Review* in which Patterson's piece appeared, the editor simply passed the letter along to the author. It is high time the hidden disadvantages of SCMaglev technology become public.

Assessment of distribution between Nozomi, Hikari and Kodama on the Tokaido-Shinkansen

After having finished my manuscript (01 November 2019) I received the Annual Report 2019.

This latest Annual Report for the first time presents information about the distribution of Nozomi: Hikari and Kodama on the Tokaido Shinkansen after the entire Chuo Shinkansen is realized.



Change of distribution between Nozomi on the one hand and Hikari and Kodama on the other hand on the Tokaido Shinkansen between the present and the time of operation on the entire Chuo Shinkansen. Picture taken from p.5 of the Annual Report 2019.

The presentation in the first row shows that at present (2019) 60% Nozomi trains (orange colour) and 40% Hikari and Kodama (blue colour) are operating. For scheduling over the whole week, this information might be correct. But this is misleading. We have to analyze distribution during high peak, because high peak time is the basis for determining the possible number of Hikari and Kodama trains. In 2019 during high peak in total 14 trains run per hour and direction, 10 Nozomi and 4 Hikaris and Kodama. This corresponds to a distribution of 71.4% (Nozomi) to 28.6% (Hikari and Kodama). And this distribution is to change in spring 2020 to 75% (Nozomi) to 25% (Hikari and Kodama).

The second row contains very interesting information. Most important is the fact that this diagram is only valid when the entire Chuo Shinkansen is in service. This will happen in 2037 or later. It is hard to take seriously a view in 2019 concerning a goal that can first be achieved 18 years later. Furthermore this information confirms my earlier prediction that a substantial number of Nozomi trains will remain on the Tokaido Shinkansen after the entire Chuo Shinkansen goes into operation. We can now analyze the distribution of Nozomi services during high peak between Chuo Shinkansen and Tokaido Shinkansen. This can be based on the following calculation: During high peak in total 12x1323 = 15876 passengers per hour must be transportated in the direction Tokyo – Osaka. 7 x 1000 =7000 passengers may travel over the Chuo-Shinkansen. The remaining 8876 passengers (=56%), that is the majority, will also in future use the Tokaido Shinkansen. For this sum 8876:1323 = 6,7~ 7 Nozomi will be necessary. So at most 2 additional trains for the smaller stations (2 Hikari) may be possible. And this calculation is based upon a performance of 8 SCMaglev trains in the terminus station Osaka, which is pure theory as I described before. This points toward a disastrous result for the Chuo Shinkansen.

Summary and Conclusion

SC Maglev technology is designed for a guided land transport system. A guided land transport system needs turnouts, in order to lead trains in different directions. Turnouts are crucial, to provide high performance in a terminus station. And that high performance can be reached only with wheel-on-rail technology. Transrapid technology in Germany failed to compete with proven wheel-on-rail technology and was abandoned. Yes, despite taking 10 times as long to switch the points in a turnout, SCMaglev has won over the Japanese railway system based on wheel-on-rail technology.

In a guided land transport system, speed is never a goal. It is always a means to achieve a goal. The goal in a guided land transport system is always to provide the highest possible commercial speed for the highest number of passengers. This is always a very difficult task.

The economy in Japan requires the same capacity for the Nozomi-trains on the Chuo-Shinkansen as on the Tokaido-Shinkansen. Only wheel-on-rail technology can meet this important criterion. The stakeholders in Japan must realize that only a Chuo-Shinkansen built on proven wheel-on-rail technology will lead to the economic success of the project. It is highe time that this decision will be made. The continuation of the Chuo Shinkansen in SCMaglev technology will inevitably end in an economic fiasco.

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Notes

[1] Central Japan Railway Company, Annual Report 2019, p.19.
[2] Central Japan Railway Company, Annual Report 2019, p.19
[3] Central Japan Railway Company, Annual Report 2018, p.22.
[4] Keith Barrow: "JR Central's Shinkansen 'dual system' to create Japanese megaregion", report in "International Railway journal" issue April 2019 pp. 34 - 37. especially p.35.
[5] The Japanese have exported the Shinkansen technology to Taiwan. But they have also advised the Taiwanese to take over the Japanese service scheme with the three train categories of Nozomi, Hikari and Kodama for their relatively short high speed line between Taipei and Kaoshiung (339 km). The traffic demand in Taiwan is much lower than in the Tokyo/Osaka corridor, with at most only three to six trains per hour and direction. Given such a low number of trains, the relatively frequent overtaking has a much more negative effect than on the Tokaido Shinkansen. Since the inauguration of the high speed line in March 2007 the Taiwan High Speed Rail Corporation has suffered losses. Passenger traffic estimates have damaged the company's balance sheet. Based on a consultant's survey results and other data, the company expected 240 000 passengers a day in 2008. In 2014 daily passenger traffic came to just over 130 000, far below the initial estimate. In "Angebotsgestaltung auf kurzen Hochgeschwindigkeitsstrecken am Beispiel Taiwan" (Eisenbahntechnische Rundschau July-August 2019, pp. 14 – 21, in German) I explain how a timetable revision could substantially reduce travel time from intermediate stations to the three hub stations of Taipei, Kaohsiung and Taichung resulting in travel time reduction by 12% to 27%. This would boost traffic demand thus providing a basis to improve the company's balance sheet.
[6] In May 2002, June 2005 and September 2007 JR Central published a brochure it called "The Review" for an international congress on high-speed rail. Every year's brochure contains the same quoted statement.
[7] *Railway Gazette International* "Maglev decision" October 2013 p. 15 and "*JR Central commits to Superconducting maglev*" December 2013 pp. 26 - 29. The magazine did not report on the service program of the first phase Tokyo - Nagoya of the Chuo Shinkansen in either article.
[8] Sven Andersen: "Questions concerning the CHUO Shinkansen-Project in Japan" *ZEVrail Glasers Annalen* 132 (2008) 6-7 June-July 2008, pp. 232 - 240 (in German)
[9] JR Central "Chuo Shinkansen: The Superconducting Maglev transforming 21st Century Japan; September 2003. Although this brochure was not officially available at JR Central's information at the Eurailspeed congress in Milano 2005, I received a copy from a JR Central engineer after discussing with him the operational problems of SCMaglev technology. The ambiguous pictures on pp. 3 and 5 of the brochure do not clarify where the future Chuo Shinkansen will call at intermediate stations.
[10] Keith Barrow: "JR Central's Shinkansen 'dual system' to create Japanese megaregion", report in "International Railway Journal" April 2019 pp. 34 - 37. especially p. 35.
[11] *Railway Gazette International* reported on an interview with JR Central CEO, Kasai, in October 2004, pp 677 - 680, quoted him as saying: "Looking at the Tokaido and Chuo Shinkansen together, they would effectively double the transport capacity in the Tokyo - Osaka corridor." In this report on page 679 for the first time the capacity of a MLX trainset is

mentioned: "One MLX trainset would have around 1000 seats, so a fleet of 100 trains would be able to carry 100,000 passengers a day in each direction." (p. 679).

[12] JR Central Annual Report 2019 p. 2.

[13] "Shinkansen Recovery boosts growth" "*Railway Gazette International"* October 2004, pp. 686 - 688. JR West manager, Ise, is quoted in this report " The October 2003 timetable change brought a 'much better structure' with many more Nozomi through trains from Tokyo to cities along the Sanyo corridor (area A). The introduction of additional Nozomi services and their extension beyond Shin Osaka to Hiroshima or Okayama has allowed JR West to provide *Nozomi* services from intermediate stations such as Tokuyama, Shin-Yamaguchi, Fukuyama and Himeji for the first time, 'We had not identified much demand for through services in the past, but ridership on the *Nozomi* services to Tokyo has already generated a high increase in patronage and revenue", Ise admits.

[14] The track diagram for Nagoya station was taken from the DATA Book 2012 topic 7 Station and Track Layout on the Tokaido Shinkansen (p. 5) and completed with the proposal of leading the Chuo Shinkansen through this station on the level of the existing Tokaido Shinkansen.

[15] The Chinese *Code for Design of High Speed Railway*, TB 10621 - 2014, explains under topic 4.1.2.2 on p. 11: "Both passenger trains running without intermediate stopping and those stopping at alternate stations shall be organized between stations with large passenger traffic demand."

[16] JR Central "The LINEAR technology press", October 1995

[17] From 2010 until today (2019) the Annual Report and the Central Japan Railway Company Guide (from 2010 to 2013 still the annual DATA Book) report this. From the year 2015 the critical statement was reworded, but only in the Annual Report.

[18] Central Japan Railway Company, Annual Report 2018, page 29.

[19] Torkel Patterson, "Approaching a tipping point for high-speed rail in 2019,"*Global Railway Review"*, April 2019, pp. 34-37, especially p. 35.