MIROSLAV PULJIZ, B.Eng.
miroslav.puljiz@fpz.hr
University of Zagreb,
Faculty of Transport and Traffic Sciences
Vukelićeva 4, HR-10000 Zagreb, Republic of Croatia
IVAN KENĐEL, B.Eng.
SLOBODAN ŽNIDARIĆ
Croatian Railways
Mihanovićeva 12, HR-10000 Zagreb, Republic of Croatia

Traffic Infrastructure
Review
Accepted: Feb. 28, 2005
Approved: May 2, 2006

TECHNOLOGY OF ICN TRAINS ON CROATIAN RAILWAY LINES

ABSTRACT

The rolling stock of the Croatian Railways (HŽ) for the passenger transport has reached a very low point of reliability, which for the moment still guarantees travelling safety. Besides, the Croatian Railways are facing an important moment of applying the new Law on Railways which places the commercial sector of the system directly on the market. Within the modernization processes at the Croatian Railways 8 tilting trains DMB 7 124 have been purchased, which in VR 2003/2004 operated on the Zagreb-Split-Zagreb relation, implementing the new ICN brand. The work deals with the analysis of the technology applied on ICN trains, as a certain novelty compared to the previous technological solutions that existed at the Croatian Railways.

KEY WORDS

ICN (tilting) trains, brakes, transport, technology and logistics, passenger handling

1. INTRODUCTION

The Republic of Croatia is experiencing huge changes, and as part of its political and economic transformation the traffic and transport factors play an extremely important role. The traffic development has to be based on the actual, and therefore also specific Croatian circumstances, since only in this way can the actual interests of the Croatian Republic be formulated. The transport development in general, and as part of it the railway transport subsystem, face numerous issues and dilemmas. Regarding the land, Croatia is one of the relatively spacious small European countries, but this is not so regarding the distances between the end points of the government territory. Regarding its geotraffic and international position the Croatian Railways are located on the intersection of the European main routes, from the European West towards the East and further to the Near East and from Central Europe towards the Adriatic. This means that they also form an integral part of the European railway network with common standards and given functions. However, most of the HŽ transversal railway network was built in the 19th century or the beginning of the 20th century and therefore some of the railway lines and some sections feature many steep ascents and many small-radius curves. Considering in general, the HŽ railway infrastructure is rather obsolete or worn out, transport means are of very old age (no new vehicles for passenger transport have been purchased since 1990), and the accumulative and reproduction capabilities are not satisfactory. Therefore, the HŽ development has to be based on the actual and therefore specific circumstances.

When speaking of the development goals of the railway passenger transport in the function of international communication, then the primary interest is adequate HŽ connection with its European environment. The importance of tourist transport should be especially noted here, as well as the orientation towards insuring the best exploitation conditions to this branch of Croatian economy. Having in mind all that has been said until now, this undoubtedly leads to the conclusion that travelling comfort needs to be increased, and train travelling time reduced, first of all on the relations connecting the interior with the Adriatic. Therefore, it is possible to solve at the same time the problems of adequate traffic connections of certain parts of North Croatia with Zagreb.

2. IMPLEMENTATION OF ADVANCED TECHNOLOGIES ON TRANSPORT MEANS

Facing the very high costs of constructing new high-speed railway lines, recently almost all the

European railway authorities have decided to introduce the tilting trains on all their railway networks. At some railways, such as those in Italy, Germany, Sweden, Spain, Finland, etc. these trains have been operating for several years already and the positive experiences with this new transport technology have brought to its mass application. The possibilities of applying the tilting technique are very wide and their tilting trains were built in different versions. The first tilting trains were fitted with hydraulic tilting technique that proved very reliable in practice. In further research, some thirty electricity-propelled tilting devices were patented.

One of the best known European and world constructors of railway vehicles, the German concern ADtranz (today Bombardier Transportation), has fitted its modern tilting trains Regio-Swinger VT 611 and Regio-Swinger VT 612 with electric tilting technique. The seriousness of this manufacturer is reflected in the fact that fifty trains of series VT 611 were constructed and introduced into traffic and that 154 trains of the series VT 612 were ordered, all for the German Railways Ltd. (by June 2000 thirty two trains were delivered).

For several years already, a group of experts at HŽ have been carefully following and studying the advancements of the modern railway administrations and the world constructors of railway vehicles regarding the tilting technique and tilting trains. At first, only individual enthusiasts at HŽ studied the tilting technique, and they informed the HŽ employees about this new technique through the knowledge they acquired in direct contacts with foreign experts or from foreign magazines through HŽ technical and other magazines. In 1997 HŽ Administration brought a Decision on establishing a committee for introducing the tilting trains on the railway lines of the Croatian Railways. After that, several task groups were established, and they studied and dealt with the respective problems. Studying of tilting technology was transferred to the Croatian scientific institutions, and this led to close and constructive cooperation with the Croatian Scientific Society for Transport which showed great understanding and offered full support to this advanced and very useful project.

Beside theoretical considerations, practical realization started as well. Up to now several trial and promotion rides of tilting trains were performed on the HŽ railway lines, and the last one was with two-part diesel hydraulic train Regio-Swinger VT 612 in June 2000. The German train operated on the railway line Zagreb-Rijeka and on the relation Zagreb-Split, and the achieved results were really fantastic.

3. TECHNICAL EXPLOITATION FEATURES OF VT 612 – HŽ DMG 7 123

DMG 7 123 is a two-part train with hydrodynamic power transmission suitable for utilization on non-electrified railway lines featuring many curves. Both wagons are driving ones, and the traction element has been installed in identical way. One train can connect four two-part sets which are remote controlled from one control-room. The bogie houses the electric tilting technique which by tilting of wagon cases allows the train to pass through track curves by 15 to 25% faster than conventional trains. Apart from air and track brakes the train features also a hydrodynamic brake which contributes to reduced wear of brake linings. The wagon design and the attachment of powerplants are so good that they can reliably withstand impact loads of 5g (5×9.81 ms^{-2}), and lateral loads of 3g and vertical loads of 2g.

Diesel-hydraulic tilting train Regio-Swinger VT 612 consists of two wagons and the basic technical parameters are:

- track width 1435 mm,
- axle arrangement 2'B+B'2',
- traction force of 125 kN at friction coefficient $\mu = 0.23$,
- central acceleration of 0.0 to 40.0 kmh^{-1} amounts to 0.77 ms^{-2},
- maximum travelling velocity 160 kmh^{-1},
- minimum track radius 125mm,
- total length of the train over coupling 51,750 mm,
- length of the wagon case 25,400 mm,
- maximum wagon width 2852 mm,
- maximum height 4210 mm,
- clearance of the entry step from the running surface of the rail 1290 mm,
- number of seats:
  - in the 1st class : 24,
  - in the 2nd class: 110,
  - auxiliary seats: 12,
  - total number of seats: 146,
  - number of standing places (4 persons/m^2): 142.
- total train mass (with occupied seats and standing places): 120t,
- train mass: 96t,
- maximum mass per axle 15.3t,
- power of the diesel engine 2×559kW at 2100 rev./min.
- capacity of the fuel tank 2×1300 l,
- brakes:
  - air disc brake,
  - hydrodynamic brake,
  - magnetic rail brake,
  - hand spring brake.

- configuration of four two-part sets in one train,
- heating, ventilation and air-conditioning performed in accordance with the UIC Declaration 553,
- tilting electric technique (ADtranz/ESW),
- maximum tilting angle up to 8°,
- maximum rolling velocity (tilting velocity) 4°/s.

4. TECHNOLOGY AND LOGISTICS OF ICN DMG 7 123

4.1. Technology of ICN set handling at the Zagreb main railway station

Technological operations regarding ICN trains are performed today according to the 2005/2006 schedule at the Zagreb main railway station, where the entire task of passenger transport for the needs of Zagreb junction is handled, and this makes it especially important. Regardless of the fact that the infrastructure capacities are insufficient and non-functional, this railway station is the starting and the end railway station of all the ICN trains.

In the HŽ region the following ICN trains operate:

- 521/520
- 523/522
- 525/524

During the technological handling of the ICN sets, cleaning and garaging is carried out on the 20th track and the control in the locomotive depot of the Zagreb main railway station.

The operation of the Zagreb main railway station is characterized by the flow of train traffic according to the valid timetable and in-advance determined plan of the number and type of passenger trains, their arrival times and the set formation, resulting in a number of technological operations which requires strict specialization of the tracks, i. e. strictly defined work on the ICN sets. The technological process of work determines the procedure and handling method of ICN sets on the handling and garage station tracks, determining the time norms for individual operations and the sequence of their execution. This forecasts better throughput capacity and parallel operations in ICN set handling, as well as better utilization of technical means. This task should include the production and technical characteristics of railway stations, purposeful dedication of the railway tracks and platforms, work technology with ICN sets, as technical standards and indicators.

According to the technology of work in case of ICN trains at the Zagreb main railway station it is necessary to perform a number of operations and the sequence of their execution in handling the formations and the technological standards for their execution determine to a great extent the utilization of the throughput capacity of the railway station, necessity of the number of sets, number of employees, etc. The technology of ICN train handling should be based on the maximum concurrency of operations, minimization of time consumption for each operation, elimination or minimal stay of ICN sets waiting for further operation in the handling process. Therefore, we distinguish the following technological operations:

- to set the ICN train sets on exit tracks 35 to 40 minutes before the train departure,
- upon arrival the train stays on the platform some 25 to 30 minutes more due to the catering,
- after catering the set is sent to cleaning on the 20th track, and then to the locomotive depot for checking.

Cleaning time:

- 1 set of train 520 from 12.15 to 14.30,
- 1 set of train 522 from 18.00 to 20.30,
- 3 sets of train 524 from 23.50 to 02.30.

Special attention should be paid to:

- regularity of ICN trains, and the monitoring of the operations in order to provide the passengers and the interested personnel with information about the possible delay;
- quality of work of ICN train staff taking into consideration the regularity of arrivals to work and reporting to distributive office, traffic office as well as meeting the train, appearance and wearing of official uniforms, and performance of tasks in compliance with the regulations;
- quality of working of the wagon office workers related to marking of the sets and control of the work during washing and cleaning of the DMG 7 123;
- one ticket office (counter No. 8) must be intended exclusively for the ICN train passengers 40 minutes before each ICN train departure.

In order to be able to perform all operations upon arrival of the train at the end railway station, it is necessary to timely perform all secondary and preparation operations. Rational technology of ICN train handling is based on the in-advance information and timely information of the involved personnel about the train arrival, and this is the task of the train traffic controller, while the train is still at the previous station, which obligates all the workers who are involved in the train handling to wait for it ready on the platform. The types and duration of operations that have to be carried out depend to the greatest extent on the work and task distribution among individual services towards the technology of work.

Apart from the passengers getting off the train, at the handling entrance tracks usually also the opera-

tions of part-unloading of luggage are performed. The disembarking of the passengers is the most time-consuming operation, and parallel other operations that take 6-10 minutes are performed.

Upon arrival of the train and disembarking of the passengers, the registration train foreman takes over the accompanying documents of the train, and the train staff and the personnel of the Railway Catering (Željezničko ugostiteljstvo) perform the takeover of the catering food rests. After these operations are completed, the set is taken to the tracks where cleaning, washing and refuelling by technical water is done, and then the set is moved to the locomotive depot. Upon arrival to the depot, the set is inspected and certain inspection levels are performed, according to the manufacturer's instructions.

Upon departure from the departure railway station, the set is set on the departure track, the accompanying documents for the train are issued, and the train staff together with the personnel of the Railway Catering perform the takeover of the catering foods. Upon the performed catering takeover and inspection of the set, the passengers start to board, and the maximum time necessary for the boarding of passengers is determined according to the formula:

$$T_{ul} = \frac{l_v}{v_{put}} + \frac{\alpha_{ul} t_{ul}}{b_{vr}} \text{ (min)}$$

where:

l_v = length of train in meters,
v_{put} = velocity of passengers along the platform,
α_{ul} = number of passengers that need to board the first or last train vehicle,
t_{ul} = time necessary for one passenger to board the train,
b_{vr} = number of doors on the platform side of the wagon.

4.2. Technology of ICN sets handling at the junction Split

Upon arrival of the train 521 into the railway station Split, after passenger handling, i. e. their disembarking, the set together with train staff goes to the railway station Split Predgrađe. The workers of the Railway Catering wait with a vehicle for the respective set at that railway station, and the rests of the catering food are taken over. After that, the train staff shift ends, and the set is relocated to the track intended for cleaning. After this operation the set is ready for operation of train No. 524.

Upon arrival at the railway station Split the sets of trains 523 and 525 have a whole night at the railway station Split Predgrađe, so that the next day they are intended for the operation of the trains 520 and 522. Thus, during night, both sets are located at the wagon workshop of the respective railway station. It should also be emphasised that the set of train 523 is cleaned in the afternoon, i. e. evening hours of the same day, so that it would be ready for the morning departure of train 520 the next day, whereas the cleaning and catering operations of the set of train 525 are done the next day before the train 522 departs.

Since timetable 2004/2005 the supply and removal of the catering food is performed at the railway station Split Predgrađe, which significantly facilitates the implementation of an entire technology in order to raise the quality of passenger handling.

5. OPERATIONS REGARDING ICN PASSENGER HANDLING

ICN passengers transported by ICN trains have to be served at the high-quality level, in compliance with the highest class of passenger trains on the HŽ railway lines. The comfort in trains and at railway stations, high-speed of passenger transport, traffic flow strictly in compliance with the timetable, these are the basic and inevitable present demands for passenger transport.

The technological process of railway station operation and the respective passenger flows should be organized so that they successfully fulfil the high requirements of modern passengers. Therefore, it is necessary to base the technological process of railway station operation and the passenger service technology on the scientific organization of work, marketing orientation, and implementation of automation and transport process mechanisation. The passengers are provided onboard comfort by adequate train formation, equipment and tidiness of the wagons, behaviour of the train staff and the scope of services. The high level of passenger service depends to a great extent on the quality of the timetable, train dispatch from the departure railway station, arrival to the end railway station, then passages through intermediate stations as well as transport means turnaround that needs to be as short as possible. As important components of transport service quality, it is necessary to insure also complete safety of ICN train operation, as well as personal passenger safety, and to provide fast and comfortable transport.

It is also necessary to establish the intermodal cooperation with other transport modes, as well as to increase the productivity of passenger transport, and to reduce the transport costs. For the implementation of these, and for the rational organization of passenger transport by ICN trains it is necessary to monitor and analyse the traffic flows in detail and continuously.

They vary a lot during the year, especially over weekends and from season to season.

If it is determined that the mean daily passenger flow is "A" for the considered period, the number of passenger places in ICN trains "α" and "ß" part of passenger flows carried by ICN trains, then the necessary train traffic volume is determined in the following way:

$$\text{ICN trains: } N_p = \frac{A_p}{\alpha_p} \text{ (of trains)}$$

where:

α_p – number of seats for passengers on ICN train.

The increase of the passenger flows is calculated on the basis of sold tickets for all relations of ICN trains, and the number of passengers is estimated by the statistical methods, i. e. by applying the correlation relation. First, linear correlation is tried out but according to this correlation the number of passengers would increase only slightly in the next period, in spite of a high correlation coefficient.

By using the correlation of second order we obtain an even higher correlation coefficient, i. e. greater security of data with a number of passengers that seems more credible. The correlation curve is calculated according to the following formula: $y = b_0 + b_1 x + b_2 x^2$, which yields the expected number of passengers.

For the ICN train service users, it is necessary to organize the pre-sales of passenger tickets and in-advance reservations, thus requiring a separate ticket counter only for the ICN train passenger handling. Since transport documents for ICN trains are also sold in travel agencies, i. e. the tickets are sold at several points, it is necessary to organize ticket selling by means of highly reliable electronic selling systems.

The necessary number of ticket counters is calculated on the basis of throughput capacity and intensity of passenger flows during the peak period of the day, so that if the average time of issuing a ticket takes about 1-2 minutes, the number of counters is calculated according to the formula:

$$N_{blag} = \frac{N_p t_{opsl}}{T} \text{ (ticket counters)}$$

where:

N_{blag} – number of ticket offices / counters,

N_p – number of passengers for ICN trains,

t_{opsl} – time necessary to serve one passenger,

T – time of ICN train passenger handling, the most intensive part.

Besides, and in order to provide high-quality service, it is necessary to develop a technological scheme of passenger flows along the railway station platform and the order of passenger service channels. The result is that on the platforms for ICN trains the number of wagons in the train formation and the seat arrangement should be marked, so that the passenger does not have to look for the train and the seat, and the passengers have to be informed frequently and accurately at information desks, via public address systems or by means of written messages that can be easily observed by passengers.

Table 1 - Operations in ICN passenger departure

Ord. No.	Operation	Adequate space
1.	entering the passenger building	entry vestibule
2.	gathering of information	information desk
3.	purchase of tickets	ticket office or machine
4.	buying newspapers and daily press	kiosks or vending machines
5.	waiting for the train	1st class waiting lounges
6.	usage of sanitary facilities	sanitary facilities – toilettes
7	using the restaurant	restaurants
8.	delivery of mail, bank transactions, money exchange	post offices, banks or exchange offices
9.	other information provided by agents on duty	administrative offices
10.	exit to the platform and boarding the train	platform level passage or pedestrian underpass

Table 2 - Services onboard ICN train

Ord. No.	Type of service	Direct service performer
1.	accommodation of passengers and baggage	train purser, attendant
2.	serving of beverages, food and headphones	train purser, attendant
3.	information on possible delay, possible connections, waiting, etc.	train purser, attendant
4.	information on timely preparation to exit	train purser, attendant
5.	possible complaints	train purser

As one can see from the table of service operations there are quite a number of the same and similar operations for the outgoing and incoming passengers, and for some of them the conditions should be provided, either at the station or on the train, if these have not been organized yet. ICN passengers require fast and comfortable transport, enriched by additional services. Therefore, these should be the basic guidelines in creating and maintaining the ICN services.

Table 3 - Operations in ICN passenger arrival

Ord. No.	Operations	Applicable space
1	exit from the platform	platform passage or underpass
2.	various information about the town, hotels, etc.	information desk
3.	purchase of books, daily press, or using phone	kiosks and machines on exit
4.	passage to lounges	halls and lounges
5.	use of bathroom, sanitary facilities, and barber's	public bath and barber's
6.	using restaurants	restaurants
7.	sending mail and telegrams	post office
8.	other information	administrative offices
9.	exit from the station	exit vestibule

6. TRANSPORT BY ICN TRAINS

According to the tariff rank, the ICN trains feature a special ICN tariff and transport conditions, and in traffic rank they belong to IC-trains, i. e. trains of the highest rank at the HŽ railway lines. To travel by ICN train, the reservation on the entire itinerary is obligatory, and the travelling ticket cannot be bought without having a reservation ticket. In order to make this possible on the whole transport route, a new electronic system for train seats reservation was installed into the existing travelling ticket sales system. This system allows all the railway stations that have been connected to it, to access the database that processes the requests of the ticket offices. In this way each railway station "occupies" its own seats on the train, according to the passenger personal needs. Currently, the ticket electronic reservation system includes all the railway stations that are equipped with the new electronic system for the sales of the travelling documents and the telecommunication link with the server in Zagreb. Other railway stations on the HŽ network can request the seat reservation indirectly (by phone) over the Zagreb Main railway station. In this way, all the railway stations have the possibility of timely occupation of the train seats, as well as passenger dispatch.

Before the journey, in front of the train, the ICN--train purser and the stewardess control the tickets and after confirming the validity of reservation and of the ticket they let the passengers board. If the passenger did not buy the ticket at the railway station ticket office, he may purchase the ticket on the train but then loses the possibility of any benefits, i. e. the passenger then has to pay the full fare and reservation amount.

The number of seats on the train for which the ticket may be bought is limited, i. e. four in the first class and four in the second class. These seats are not included in the electronic selling-reservation system, which eliminates the possibility of double reservations of the train seats.

All the employees of the Croatian Railways and their dependent associations that have the right, can use the P-4 cards, but they have to pay at the ticket office the allowance for the ICN-train and reservation fare, as well as the passengers who have the P-1 card. Transport using other P cards (except for P-5) is not allowed either to HŽ employees or to the employees of the HŽ dependent associations.

Only HŽ employees may undertake a business trip with P-5 order, but with a limited number of seats in each ICN train (four seats in 2nd class wagon). Such a trip has to be reserved on time, by purchasing a reservation ticket with obligatory production of the travel order form.

Legal benefits are not valid on ICN-trains, whereas commercial benefits have been partly changed. In accordance with these changes, the return trip consists of two single-trips without the benefit of 20%, whereas the transport of children and press-people is without restrictions, and groups, youths with cards and senior citizens with cards have retained the previous scope of benefits, provided their usage is limited to certain days and certain trains.

The ICN-train, as the main novelty on the HŽ railway lines features the modern tilting technique. Of other novelties, one should first of all mention the catering service which allows serving at the seat, and high-quality audio system with links at every seat (the music is not heard by other passengers). This systems allows passengers to listen to music using the audio headsets that can be purchased on the train from the purser.

7. CONCLUSION

In the planned modernization of the HŽ rolling stock, the tilting trains DMG 7 123 represent a very acceptable solution since they:

- can be used immediately on the existing railway lines,
- can reach higher velocities compared to the conventional trains owing to the mechanism which tilts the wagon case when the train passes a curve.

If the extremely poor condition on certain sections of HŽ railway lines were to be improved (which is being worked on), then the travelling times could be re-

duced even more, i. e. the effects of the tilting technique would be even more expressed. Under certain circumstances, the ICN train technology offers adequate alternative to the expensive improvement of the track equipment, but the implementation of the tilting train should always be carefully analysed for each individual case separately, which means that the following should be analyzed:

- whether the reduction of the travelling time is sufficient (taking into consideration all that is offered by other transport modes such as aircraft, passenger cars and buses),
- which improvements are required on the infrastructure,
- whether the price of the project would be competitive compared to other transport modes,
- whether the return of the invested means would be satisfactory,
- possibilities of minor improvements such as e. g. improvement of the number of passenger seats in the 1st class, fitting with adequate curtains on the windows, better solutions for baggage racks, large room for bicycles and larger things,
- possibility of purchasing also four-part tilting trains, Regio-Swinger Quadro which would be better equipped by passenger compartments with luxurious seats, etc.,
- problems with maintenance, spare parts, personnel training, etc.

Everything said speaks in favour of the purchase of these modern transport means that were to replace the relatively poor condition of the HŽ infrastructure, and directs to continuous research and analyses regarding exploitation effects of the respective means. In this respect it is necessary to develop constantly the services and the technology of ICN trains, so that these would in turn develop competitive advantages over other transport modes, thus maximally justifying high investments. Besides, the implementation of this would provide conditions for HŽ to take over the leading transport role on certain relations, which would certainly imply also significant revenue effects.

MIROSLAV PULJIZ, dipl. ing.
miroslav.puljiz@fpz.hr
Sveučilište u Zagrebu, Fakultet prometnih znanosti
Vukelićeva 4, 10000 Zagreb, Republika Hrvatska
IVAN KENĐEL, dipl. ing.
SLOBODAN ŽNIDARIĆ
Hrvatske željeznice
Mihanovićeva 12, 10000 Zagreb, Republika Hrvatska

SAŽETAK

TEHNOLOGIJA ICN VLAKOVA NA PRUGAMA HRVATSKIH ŽELJEZNICA

Vozni park HŽ za putnički prijevoz dosegnuo je veoma nisku točku pouzdanosti, koja za sada još jamči voznu sigurnost. Uz to, Hrvatske željeznice su se našle pred važnim trenutkom primjena novog Zakona o željeznici koji komercijalni sektor sustava izravno postavlja na tržište. U sklopu modernizacije HŽ nabavljeno je 8 nagibnih DMG 7 123, koji su u VR 2003. /2004. povezivali relaciju Zagreb-Split-Zagreb, implementirajući novi ICN brand. Predmetni rad bavi se obradom tehnologije koja se primjenjuje na ICN vlakovima, kao stanovitim novitetom u odnose na dosadašnja tehnološka rješenja koja su postojala na Hrvatskim željeznicama.

KLJUČNE RIJEČI

ICN (nagibni) vlakovi, kočnice, prijevoz, tehnologija i logistika, prihvat i otprema putnika.

LITERATURE

[1] **Čičak, M., Eror, S.**: *Organizacija železničkog saobraćaja*, Beograd
[2] HŽ- Poslovni red kolodvora Zagreb Glavni i čvora Split
[3] HŽ-Tehnološki proces rada kolodvora Zagreb Glavni i čvora Split
[4] **Milošević, B.**: *Železničke stanice i čvorovi*, Beograd, Saobraćajni fakultet
[5] Tehnički materijali tvrtke ADtranz, Henningsdorf 2000.
[6] Tehnički opis nagibnog vlaka VT 612 "Regio-Swinger Hrvatska", 2003.
[7] **Wescha, A.**: *High-speed rail and tilting technology*, 3rd World Congress on High-Speed Rail, Berlin 1998