High Speed Rail

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An Introduction to High Speed Rail - A Multidisciplinary Challenge

When it comes to high speed rail (HSR), the evolution of railway networks and services has been quite different across the globe. However, the need for highly efficient transportation, besides road and air traffic, cuts across all industrialized countries where passenger and cargo traffic must move efficiently in crowded and growing mega-regions. The similarities among areas like Western Europe, Japan or California are much greater than their differences.

Since HSR has become reality in Europe, Japan, Korea and Taiwan, it has proven to be a success story and the development in China of the high speed Passenger Dedicated Lines (PDL) programme will contribute significantly to people’s future mobility.

The introduction of HSR leads to a number of socio-economic advantages, such as increased competitiveness by linking strongly developed economic regions. The expansion and strengthening of the existing railway industry, in both infrastructure and rolling stock, creates a leading global sector which boosts technology as well as employment. With a continuous increase of passenger and cargo traffic, this electric-powered railway transportation solution provides a sustainable and environmentally friendly way to meet the transportation needs of tomorrow by reducing the amounts of carbon dioxide emitted by automobiles and aircraft. About 20% of the greenhouse gases emitted in the European Region in the 1990’s were attributable to automobile traffic. That percentage is perhaps doubled in the dense areas of the United States, such as California, where, according to the California Air Resource Board, transportation accounts for more than 40% of all GHG emissions. It therefore becomes important to focus on railway transportation, particularly high speed rail.

The perspective from North America

“Probably, all of us retain childhood memories of favorite toys, perhaps a bit like Charles Kane’s recollection of his sled “Rosebud” in Citizen Kane. For me, the memory is of my first set of electric trains—a replica of the steam powered, streamlined, 20th Century Limited, that appeared under our Christmas tree in one of the last years before the United States entered World War II. When I left home for boarding school in the 1950’s, it disappeared.” -Mort Downey

That recollection is relevant to the challenge we face today in bringing high speed rail to America. Before World War II, the United States was in a leadership position in rail technology. The top speed of the 20th Century Limited passenger trains, around 100 mph, was already being bested by Pennsylvania Railroad electrified trains moving at 120 mph on the Northeast Corridor, using a catenary system that was financed as a Depression-era public works project.

But during post-WWII times, the development of the American transportation system branched out in different directions. The Interstate Highway system and the jet aircraft set the standard for moving people across continental distances, and passenger rail was relegated to a declining base of intra-regional commuting and occasional passenger service among a few larger cities. In fact, by the mid-1970’s, the future of our entire US rail system was up for grabs. Only through a dramatic rescue effort by the Federal Government and a bold stroke of economic deregulation were we able to revive and rebuild our freight rail systems to the point where they are the envy of the world. At the same time, we have barely preserved passenger rail service in a few markets with the help of government support for the Amtrak network of corridor and inter-regional trains.

But as America begins to think about our real transportation challenges, we see that the predominant issue for the 21st century is how we maintain mobility inside our ever growing mega-regions. Federal support in the Washington-Boston corridor, beginning with research and development efforts in the 1960’s and culminating with the introduction of Acela service in 2000, has provided a start, but there’s still much to be done in the Northeast and, in fact, in corridors all across the United States. Government leaders and private sector visionaries are looking across the world to see what other nations are doing to meet their regional mobility challenges and are beginning to design the policies and programs that can get us there. It’s not an overnight effort, but the modest steps taken since the Obama Administration opened the doors to consideration of high speed rail have shown how much the public is ready to invest to see it accomplished.
Leadership, both governmental and corporate, will be critical in establishing the foothold for these investments to reach their maximum potential. US national and regional policy makers need to understand their options and make the choices that make for optimum investments with limited resources. If we can invest in HSR to move people within a mega-region like the Northeast Corridor or California, shouldn’t we reconfigure those region’s air services to serve different needs for international and intercontinental travel, rather than competing with the improved rail service? On the highway side, there’s talk of a new generation of Interstate Highways, closing gaps and making connections that aren’t there now even as we rebuild our fifty year old roadways and bridges. Wouldn’t it make sense to do that planning in a way that takes rail opportunities into account? That’s a role for government—federal, state and local—and as we look more and more to public-private partnerships to finance key assets, the private sector has an interest as well.

Considering the mega-regional opportunities, we may have to create new instruments of government to develop systems that transcend state and local boundaries but are smaller in scope than the nation as a whole. Cooperative efforts have taken us part of the way, but investments that serve broad regional needs and intersect with local services and facilities have to be approached with the perspective of the broad region.

And, since it is likely that the justification for these investments rests heavily on social, economic and environmental improvements, there needs to be a way to connect the investments with those who are charged with achieving those goals through the provision of governmental support.

Also, there is much we can learn in the United States from the experience of other countries in the planning, implementation and operation of high-speed rail systems. We should take advantage of these important lessons learned in order to save costs and to optimize the benefits of our investment in new transportation. Both Parsons Brinckerhoff and Balfour Beatty have been extensively involved in the design and construction of high-speed rail around the world and are well positioned to assist our clients to plan and implement passenger rail programs that reflect the best the world can offer.

**The perspective from Europe**

Modern economies, such as the European Union and the US, and both mature and emerging economies in Asia and Asia Pacific, require all means of highly efficient transportation. Transport routes - such as highways, airways, inland waterways, coastal shipping and railways – can provide a fast and comfortable journey for people travelling between the different regions as well as an optimized and smooth transport of goods.

Europe provides a good example of a coherent transnational transportation plan. Even in a political environment of sometimes diverging national intentions and priorities, a coherent pan-European transportation concept has been realized, leading to the design and implementation of the Trans European Transport Network (TEN-T), an important prerequisite for enabling high speed train connections and services across Europe, along with other improvements, like connected waterways for better freight movement. And the European Union has also created the institutions that can make these plans a reality by providing the necessary funding and financing.

The densely populated regions of Europe, and the need to move quickly from one city centre to another, have led to a constant increase in traffic on the roads, rail, and in the sky. Europe is today suffering from air and road traffic congestion, and the need to limit the growth of those modes before the problems become insoluble is recognized. Therefore, reliable and fast alternatives like HSR have been developed. HSR serves the needs of the population by substantially cutting journey time and conveniently limiting transfer and check-in times. High speed networks already serve several countries, and HSR operations across national borders have commenced utilizing multi-standard onboard systems for enabling interoperability. A technically unified operation can be accomplished across Europe when standardized signalling systems, conforming to the European Train Control System (ETCS), will have been installed on board all trains and locomotives as well as on the network infrastructure.

Through the planning and constructing of HSR in Spain, Italy, Belgium, Germany, the Netherlands, and Switzerland, and by contributing electrification and power supply expertise, Balfour Beatty Rail (BBR) has participated in many of the major HSR projects in Europe. BBR has also supported the Ministry of Railways (MOR) in China with planning and supervision as well as materials supplies and continues today through knowledge transfer to local joint ventures (JVs) and the supervision of Chinese construction companies. Parsons Brinckerhoff and IVV GmbH (Parsons Brinckerhoff’s German engineering and design entity) have also contributed to major international HSR projects, including Taiwan HSR.

**In This Issue: Technical Challenges and Innovation**

This issue of Network (Issue 73) focuses on the various aspects of high speed rail: the socio-economic advantages, the technical challenges and achievements, the obstacles
and, of course, aspects of funding large-scale projects. The technical articles are organized into the major topics of train control systems and safety technologies, electrification and traction power systems, HSR tunnel design and technologies, HSR stations and maintenance facilities, and regulatory framework.

The technical and technological requirements imposed by HSR are not just related to the development of a new type of rolling stock that provides transportation capacity in a comfortable manner for several hundred passengers in a single train set. But, in order to ensure safe operation when travelling with velocities of more than 300 km/h (186 mph), HSR impacts almost the entire railway system and the operational modes and processes. To comprehend HSR in all of its complexity, various aspects must be considered, starting with the design and alignment of railway lines, meeting the resulting adequate gradients and curve radii leading to large and wide-spanning bridges as well as to long running tunnels. The trackwork design and realization is completely different from ordinary ballasted railroad tracks. Both the traction power supply and distribution, as well as the overhead catenary system (OCS) and feeder system, need to accommodate the higher power consumption demands and increased tensions along the OCS lines. And, of course, the signaling and safety protection systems, as well as the operations control centers, need to be significantly enhanced. Employing automated and real-time computer-based and electronically-controlled interlocking systems is required when subsequent trains follow each other on the same line in 5 to 10 minutes intervals at 300 km/h.

These challenges, prerequisites and constraints in regard to HSR will be discussed in more detail in the articles that follow. Both Parsons Brinckerhoff and Balfour Beatty have been significantly involved in major international projects around the globe since the early days of HSR. Colleagues from various Parsons Brinckerhoff entities, Balfour Beatty Rail and IVV GmbH, have been playing leading roles in supporting national railway operators in successfully designing and implementing their respective HSR projects. These include Deutsche Bahn (DB) in Germany, Trenitalia in Italy, THSRC in Taiwan, the Ministry of Railways (MOR) concerning China’s ambitious and challenging PDL programme, and various agencies in the United States regarding HSR studies and implementation.

For more than two decades, railway operators in Europe and Japan have experienced steadily growing and successful HSR operations. In 2007 Taiwan and, one year later just in time for the Olympic Games, China started their regular HSR operations. Other countries in the Middle East and Latin America already have systems in design phases and will follow soon. North America is still to commence its first line implementation, but we are confident of further successful development of high speed rail systems on a global basis in the future.

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My entire career has been dedicated to the industry. As a fifth-generation railroader, I can say that, without question, this is one of the most transformative times in U.S. history for freight and passenger railroading. When President Obama and U.S. Transportation Secretary LaHood asked me to serve as Administrator of the Federal Railroad Administration (FRA) – especially at a time of renewed focus on the industry – I was not only honored, but tremendously excited.

The fact is, not since President Abraham Lincoln nearly 150 years ago, has an American president paid as much attention to America’s railroads as Barack Obama is doing today. During the tumult of the Civil War, there were those who told the President that, with the future of the union so deeply uncertain, it was no time to make big investments. But Lincoln knew that, for the post-war nation to rebuild and unify, it would need a truly national transportation system. It is for this reason that he signed the seminal legislation that hastened completion of the transcontinental railroad. It moved people and goods alike to and from places like never before. It allowed America to evolve from an assemblage of small, disparate local economies, to a national one — which would in time bring about economic prosperity never before achieved in human history.

By 2050, America’s population is projected to grow by 100 million people. That is the equivalent of adding the population of another California, New York, Texas and Florida.

Yet, the capacity of today’s transportation system fails to meet our current, let alone future, demand. Traffic congestion on highways and at our airports costs the economy nearly $130 billion each year. And in many cities there is simply no room to expand roadway capacity or airport facilities. This is where rail comes into play.

After decades of disinvestment, Americans want fast, efficient, affordable and reliable passenger rail, and this is critical to our nation’s future. High-speed intercity passenger rail provides a cost-effective option for travel between cities of 500 miles or less – linking major urban areas within a three hour trip time.

President Obama’s vision is to connect 80 percent of Americans to an integrated high-speed intercity passenger rail network in 25 years. And, here at FRA, we are working to fulfill this vision, developing a multi-tiered passenger rail network that takes into account different market needs and geographic conditions. In doing so, we will also ensure that America’s world-class freight rail system is expanded as we build a world-class rail network.

Beyond critical transportation improvements, rail investments will also enhance the global economic competitiveness of America’s cities and metropolitan regions, support domestic manufacturing activity, reduce reliance on imported oil, and create a new economic base of highly-skilled, well-paying jobs. Our “Buy America” policy ensures this new rail system will be built by an American workforce. High-speed intercity passenger rail offers an opportunity for equipment, component, and supporting manufacturers to build robust and sustainable businesses.

Rail improvements can’t come soon enough for Americans. In June 2011, Amtrak posted its 20th straight month of ridership growth and is on track to break a record with 30 million passengers in 2011 alone. The support and momentum for a nationwide high-speed rail system only continues to grow and intensify. In early 2011, FRA received nearly 500 applications from 39 states and DC requesting more than $75 billion in funding—with just over $10 billion available thus far. States are aggressively competing to get into the rail business, with 32 states and the District of Columbia moving forward with high-speed rail projects. As of today, more than 135 million Americans (44% of our population) are living in regions connected by a rail corridor that has received federal dollars through our high-speed rail program.

Bottom line, rail will provide faster, safer and more efficient travel options. Getting to that point will require that we recognize and respond to the unique transportation needs of specific regions and corridors—and invest in levels of service that make the most transportation and financial sense. While we lay the foundation for a national intercity passenger rail network, it’s worth emphasizing that it will take a long-term commitment at the federal, state and local levels to make it a reality, just as it did with the Interstate highway system.
The ultimate goal of a connected and balanced transportation network is one that maximizes the benefits of every mode. Convenient, efficient, and affordable transportation is a major building block of America’s economic strength and quality of life, and it is our duty to ensure that we are continuing to provide new and better mobility options. High-speed rail will transform the way we travel and do business, but it won’t be built overnight. Just imagine what tomorrow will look like if we don’t take action today.

The success of high-speed rail and public transportation depends on all of us working together: railroads, states, manufacturers, suppliers, labor, transportation planners, and many others. With your continued support we will design, build and operate a transportation network that will serve America for generations to come with an integrated, national passenger rail system. That means pushing forward even when times are tough. I remain as optimistic as ever that we will keep growing momentum to build the passenger rail network that the American people deserve.

Nominated March 20, 2009, and confirmed by the United States Senate on April 29, 2009, Joseph C. Szabo is the twelfth Federal Railroad Administration (FRA) Administrator, responsible for overseeing the operations for the eight hundred plus person organization; managing a comprehensive railroad safety assurance program and regulatory initiatives; enforcing railroad safety laws and regulations; developing and implementing national freight and passenger rail policy and financial assistance programs; and overseeing wide-ranging advanced research and development projects in support of improved railroad safety.

Mr. Szabo was Vice President of the Illinois State Federation of the AFL-CIO between 2006 and 2009. He has served as mayor of Riverdale, Illinois, a member of the South Suburban Mayors Transportation Committee, and Vice Chairman of the Chicago Area Transportation Study’s Executive Committee. In 2002, he chaired the Governor’s Freight Rail Sub-Committee and, in 2005, was assigned by the United Transportation Union International to the FRA’s Railroad Safety Advisory Committee (RSAC), where he participated in the development of rail-safety regulations. Mr. Szabo has served on the Executive Council of Chicago Metropolis 2020, focusing on Land Use Planning and Transportation issues and the Board for the Historic Pullman Foundation. He was a member of the Chicagoland Metropolitan Planning Council. He holds a baccalaureate degree in Labor Relations from Governors State University and is the recipient of an honorary doctorate from Lewis University for his lifetime commitment to public service.
In all the hype about 200 mph speeds and futuristic-looking trains, the fundamental focus of a high-speed rail (HSR) program often gets overlooked. While the engineers necessarily must define alignments and build tracks and trains, the ultimate objective of a HSR project is to convince travelers to get out of their cars and off the airplane and to ride the train instead. Failure to focus from the beginning on what it takes to achieve this objective can have serious consequences and undermine the full potential of HSR service.

From a customer perspective, HSR is not a one-size-fits-all proposition. Trip time, reliability, station services, amenities, creature comforts and train aesthetics all must be honed to match the perceived market needs, the traveler profile, and the competition. While top speed grabs the headlines, it is only one small piece of the package that tempts a traveler to select the train. It is essential to understand the market from the outset, and then to shape the service. The passenger experience should drive the engineering, never the other way. Yet, many HSR programs in the US simply make broad assumptions about the passenger market; creating the HSR brand almost is an afterthought.

The passenger’s HSR travel experience includes much more than the train ride. It starts with the “how should I get to my destination” and includes all key elements of the transportation journey straight through access to the final destination. The potential passenger’s perception of each step along the transportation journey will determine whether he or she ultimately decides to take the train. As a result, HSR planning must embrace a wider range of issues and potential improvements than simply the alignment, stations and trains. The “HSR Brand” – the amenities and services that define the HSR experience – may be the most important factor shaping the HSR system design and the planning necessary to implement it.

Most ridership analyses point to three key factors in the modal choice made by a potential traveler: trip time, price and frequency. Clearly, these are critical factors. However, there are many others that play a role as well. The successful HSR service will attempt to define and control many other physical and emotional factors as part of the HSR brand. These include:

- Trip Planning (websites; reservations/information phone lines; printed materials; advertising)
- Ticketing (on-line; mail; at the station; on the train; fares)
- Station Access (location of the station; ease of access by public and private transportation; waiting/lounge areas; signage and way-finding; safety and security; parking)
- Departing Station Experience (station feel and aesthetics; on-site amenities; retail shops; cleanliness; restrooms; signage; safety and security; crowd control; information and announcements; personnel)
- Platforms (lighting; safety; distance to walk; movement of luggage; air quality)
- On-Board Train Experience (class of service; food service; seat reservations; cleanliness; friendliness of employees; information; at-seat entertainment; food service; baggage storage; safety; noise; availability of wifi and electrical outlets; seating arrangements; temperature control)
- Train Service (reliability; frequency; safety; trip time; price)
- Arriving Station Experience (amenities; information and assistance; access to public transportation; signage and way-finding; customer service problem resolution)

The HSR passenger experience should be considered from the very outset of the HSR planning process as it helps to define the business case for HSR service in the first place. Moreover, designing to the HSR brand is a dynamic process that should drive decision making at each step along the planning and implementation process. Too often, these important branding factors are left almost to the end of the project, long after fundamental engineering decisions regard-
General Challenges of High Speed Rail

As soon as there is a perceived need for or benefit from HSR in a transportation corridor, a business case should be developed that defines the “why” (transportation; environmental; economic development) and the steps and available funding approaches to get there. At that point, it becomes essential to determine what it will take – what the HSR service must deliver – in order for potential travelers to actually ride the train. The answers will greatly impact the alignment, the level of service, the train technology, and the broader scope of the project. While there may be multiple approaches to understanding what drives the potential traveler to take the train, all require a systematic and comprehensive analysis of the travel market in which the train will operate. Who is the prime competitor(s)? What can the train provide that the competitor cannot? How important are emotional attributes in determining modal choice – safety; cutting edge technology; convenience; the ‘wow’ factor; who else is using the mode – and which attributes are the most important? How critical is public transportation access to and from the stations? This work might take the form of surveys, focus groups and various other data collection means.

Whatever the form, the data serve as the foundation for development of the HSR brand. This is not an engineering exercise. It should be led by a team familiar with both the attributes and discriminating factors of HSR and the art of understanding what really drives the customer. At the end of the day, does it still come down to trip time, price and frequency, or do these other brand factors genuinely make a difference in the market place? If they do, then the success of the HSR program may well depend on how well these other factors are integrated into and define the system, particularly the station and on-board experiences.

Defining and integrating the HSR passenger experience into the new HSR service has proven very successful on many European and Asian systems. In Spain, development of the AVE brand helped to create what has become one of the best HSR systems in the world. In the United States, Amtrak’s Acela brand, developed in the mid-1990s, is a case in point. Because Amtrak sought to create a new HSR service that broke from Amtrak’s troubled past, it recognized the need for an entirely different and comprehensive branding effort. Work commenced with a small internal team to review extensive focus group data regarding concerns with existing service and the type of attributes a future HSR service should have to meet their travel needs. The focus group data drilled deep into the station and on-board experiences and included unique exercises to design an on-board, friendly bathroom; test food service seating arrangements and menus; and test alternative seat hardware. Most of this research was incorporated into the Acela brand and eventually into the train and station design. Support for this approach was so strong that several change orders were authorized to revise the interior design of the trains to incorporate refinements to the Acela brand.

Because HSR has become commonplace around the world, it is easy to assume that there is a common understanding of what it is, how it works, and the type of service it will provide. In the United States, at least, that simply is not the case. It is critical that those planning new HSR systems in the US – both stand-alone systems and those using existing tracks and Amtrak – undertake the preliminary work to understand their unique HSR market, identify the defining passenger experience attributes, and create a HSR brand that will drive the system design.

David Carol serves as Parsons Brinckerhoff’s Market Leader, High-Speed Rail. He is responsible for developing a long-term global strategy for participation in high-speed and other passenger rail opportunities, as well as helping to advocate for, and advance, high-speed rail (HSR) in the United States. He also is serving as the project manager of the program management team for Connecticut’s New Haven-Hartford-Springfield HSR program.

Mr. Carol worked for Amtrak for 20 years, where he led implementation of Amtrak’s $2.5 billion Northeast Corridor HSR program. He also served as Amtrak vice president for HSR Corridor Development, where he worked with federal and state officials to improve passenger rail in many of the nation’s ten designated HSR corridors.

Mr. Carol received his B.A. (magna cum laude) from Amherst College in 1977, and his J.D. and M.A. (Foreign Affairs) from the University of Virginia in 1981.
High Speed Rail in Europe –
A Three Decade Success Story
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It has already been three decades since the first high speed train started its regular service in Europe. On 22nd September 1981, the French National Railway Operator (SNCF) commenced regular high speed railway (HSR) services between Paris and Lyon with its TGV (Train à Grand Vitesse) trains. Since then, about 1.7 billion passengers have chosen the TGV as their favorite transportation mode. Ten years later, on 29th May 1991, HSR operation in Germany was marked by the maiden trips of six ICE (Intercity Express) types of trains starting at different locations and joining each other at the Kassel “Wilhelmshöhe” station, which is in the geographic center of Germany.

As of today, HSR systems are in operation in Belgium, France, Germany, Italy, the Netherlands and Spain as well as in the UK, where London is connected to continental Europe via the channel tunnel. These countries represent 342 million inhabitants, about 68% of the entire population of the current European Union which incorporates 27 autonomous states. The HSR network - enabling train velocities of higher than 250 km/h - in this geography encompasses 6,600 km of rail currently in operation, 2,350 km under construction and a further 8,700 km planned to complete the network.

The Eurospeed Union has developed and agreed to implement a plan for a Trans European Railway Network linking the metropolitan areas and the most powerful industrial regions across Europe by 2025.

The introduction of HSR is not just the launch of powerful rolling stock but is really the implementation of an extraordinarily complex system comprising almost all railway design, building and operational elements. The investment required to realize a railway network spanning all across Europe is tremendously high. On one hand, due to the network size itself; on the other, due to new technologies involving trackwork, the electrical and mechanical systems and appropriately designed stations. Furthermore, accommodating an increased number of passengers and their respective needs must be taken into account as well as interoperability requirements to enable seamless HSR operation across national borders.

Due to continental European topology, with flat terrain, low and medium mountain areas and the Alps - the high mountain region ranging from Austria in the east via Germany and Switzerland to France in the west and dividing northern and southern Europe - a considerable number of tunnels and high rising, as well as wide spanning, bridges are required to accommodate HSR section alignment needs. The constructing of the Swiss Lötschberg, Ceneri and Gotthard base tunnels, as well as the Austrian Brenner base tunnel, are technical challenges which require multi-billion euros and are financed by the public and private sectors to enable an integrated European railway network.

Since the commercial launch proved successful, the extension of the HSR network in Europe continues steadily. Travelling by train becomes the means of transportation for the future. It is competitive with air travel and more convenient to passengers, at least in the medium distance range. Annually, about one and a half billion passengers travel not less than 410 billion kilometers on Europe’s long haul railway network.

This article sheds some light on the high speed railway development in Europe and aims to provide a perspective towards its future.
The European Vision – A Transcontinental (HSR) Railway Network

Today, the European Union (EU) comprises 27 member states: from Portugal and Spain in the west to the Baltic States in the northeast down to Italy and Greece in the southeast Mediterranean region. The vast majority (about 68%) of the EU population lives in seven countries: Belgium, Germany, France, Italy, Netherlands, Spain and UK.

The economic power and the importance of these seven member states to the community are evident from their Gross National Product (GNP). Their GNP is 9,350 billion euros as of FY 2009, which is 79% of the European Union’s total GNP of 11,788 billion euros.

Thus, it is evident that HSR has first developed in these strong economies, not only because of their economic power, but also because of their geographic spread and their comparatively large railway networks.

The existing operating railway networks (including cross border connections) of Germany, France, the United Kingdom, Italy and Spain are 112,000 km in length and represent slightly more than half of Europe’s entire railway network of about 213,000 km. These countries, plus Belgium and the Netherlands, constitute the current HSR network of about 6,600 km.

Europe’s economic centers and national capitals are already linked by HSR connections: from London through the channel tunnel via Brussels to Paris and further on to Berlin, Vienna and Copenhagen in Denmark. Once the Swiss and Austrian tunnels are in operation, the high speed railway will connect to the Italian network, enlarging the possibilities of travel to Milan, Rome and even Palermo in utmost southern Italy. Although the long distance hops across Europe, e.g. London to Rome or Stockholm to Madrid, will still be dominated by air travel, for medium range travel (up to 600 - 800 km) HSR will be a serious and passenger-attracting competitor.

Excellent examples for reflecting on the passenger development and resulting modal shift of two main routes in Europe are: Paris - Brussels and Madrid – Seville.

Paris – Brussels

In the days before HSR, journeys between “Europe’s Capital” Brussels and Paris, with a distance of 320 km, were dominated by individual car and coach traffic (69% in 1994) whereas train
travel was just a fourth (24%) of transportation means. Just four years later, when the Thalys HSR train connection was in operation, it already covered 50% of the entire traffic, having doubled the number of train passengers while individual car traffic lost a third. A journey time of 1 hour 20 minutes, which represents an average speed of 240 km/h city to city, is definitely unbeatable by car and even by plane, considering the remote airport locations and metropolitan traffic.

Madrid – Seville

With a distance of 530 km, the preferred transportation means was, of course, air travel, amounting to two thirds of passenger travel compared to one third train journeys in the early 1990’s. A decade later, after successful operation of the Spanish AVE HSR train, the picture was completely the opposite. Achieving a journey time of two and a half hours by AVE HSR – with an average speed of 210 km/h – air travel lost its dominant role and decreased to a bit more than 16% while train traffic increased to 84%, five times more than air travel.

Besides these two paramount examples, there are other ones: the HSR journey from Germany’s capital Berlin to the country’s financial market place Frankfurt / Main takes slightly more than 3½ hours at a distance of 545 km. Considering city-to-airport journeys in both cities, which can last up to an hour each, plus a regular flight duration of a bit more than one hour, HSR cannot be beaten by domestic flight any more.

Further examples of travel time savings by HSR transportation compared to standard railway operations (less than 200 km/h maximum speed) are given in Figure 7.

The given structure of Europe, the relative proximity of national capitals and major economic regions, the further political and economical integration of its 27 member states as well as their people’s increasing demand for mobility are the solid base for a further successful development of a Trans European Railway Network.

Back in 1990, the European Union agreed amongst its member states to implement a Trans European Networks development programme, called TEN-V plan. Besides the enhancement of energy and telecommunications networks, emphasis was given to the development of all transportation means, focusing as well on railway transport. As per the year 2020, the European railway network shall grow to a size of about 94,000 integrated line kilometers, incorporating an HSR network of up to 20,000 kilometers, enabling train velocities of, at minimum, 200 km/h. To achieve this, a total length of 12,500 km of new railway lines has to be designed and built. This does not include the challenges of rehabilitating and upgrading existing lines. Major improvements for passengers in reduction of travel times (see Figure 7) and comfortable city-to-city journeys will be achieved. Beyond that, the European road and highway traffic will be reduced by at least 14% and, considering the different levels of CO2 emissions, HSR will by far provide the most environmentally friendly and sustainable approach. (See Figure 8 below)
Interoperability - The Technical Challenge

As previously mentioned, implementing an HSR system in Europe is not just about introducing powerful rolling stock. The national railway systems in Europe were developed quite differently in various aspects. While only two different track gauges exist across Europe (the system on the Iberian Peninsula differs from the rest of Europe), it becomes significantly more complex in regard to national signaling systems, where as many as 20 different systems are in operation in Europe.

The capabilities of conventional railway systems enable trains to reach speeds up to 200 km/h. The reasons can be found in the railway network infrastructure (track, electrical power supply and catenary, safety & signaling) and in capacity as well as in operational issues when trains at very different speeds are attempted to be run within one network. On the one hand, the European network is composed of pure HSR sub-networks as in France, Italy and Spain and on the other hand it is composed of combined, densely meshed networks encompassing dedicated HSR sections as well as sections for a combined passenger and cargo traffic utilization like in Germany.

Interoperability across national borders is, as of today, realized by multi-system locomotives and trainsets meeting the different traction power requirements as well as signaling systems employed.

Introducing a standardized safety control and signaling system means not just replacing the existing national systems, but also technical and financial challenges for both railway network managers and railway service operators when upgrading of infrastructure and rolling stock is required. When operational requirements have to be met, the impact on automation and highly sophisticated real time communication-based train control and management systems becomes obvious. For example, the ability to serve up to 15 trains per section in one hour (4 minute separation, equivalent to 20 km at 300 km/h speed) and physical constraints, such as a braking distance of almost 5 kilometers when driving at 300 km/h.

The system defined in Europe – ERTMS (European Rail Traffic Management System) - comprises three main elements, the ETCS (European Train Control System) and the GSM-R (mobile communications for railway applications), operating via an ACTC (Automatic Centralised Traffic Control) center. A respective intermediate standard (2.3.0.D) has been agreed upon in 2008, allowing compatibility of the train onboard equipment with trackside elements. The standardization process is expected to be finalized by 2012, enabling long term cost reductions in both infrastructure investments and rolling stock equipment.

As of today, 6,900 km of railway lines are equipped with ETCS technology in 14 member states. Countries like Denmark, Switzerland, Sweden, Belgium and the Czech Republic have already decided to migrate their entire network to ETCS.

Denmark, covering less than 2% of the entire European railway network with about 2,640 km, has already achieved a parliament decision to launch a network wide replacement programme to renew the entirety of railway signaling system elements. Budgets of 3.2 billion euros have been allocated and respective call for tenders for the long-haul network (F-Bane) and the metropolitan railway network in the Copenhagen area (S-Bane) have been released. Tenders are in progress and contract awards to industry are expected at the end of this year.

In other countries, like Germany, the national railway organization operates an automated train control system (LZB) at a national level which has not yet reached its end of life conditions by far but provides almost the same protection level and similar features as ERTMS.

In conclusion

In three decades Europe has successfully implemented a powerful HSR network linking major European capitals and metropolitan regions by corresponding rail services. This success story will continue to evolve thanks to railway systems standardization promoted by the European Union and supported by the International Union of Railways (UIC), enabling seamless operations across the entire European geography. It has boosted technological development and European corporations have shown their ability to provide cutting-edge technology and systems for both HSR network infrastructure elements and rolling stock. As of today, Europe’s HSR network incorporates more than 6,600 km currently in operation and will extend within the next decade to an integrated HSR network of approximately 20,000 km.

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Although the development of intercity passenger rail (IPR) has advanced steadily worldwide during the past half century, in North America this mode has been underutilized to date, and has received limited investment. Europe and Asia have advanced their IPR systems well beyond those in the United States, Canada, and Mexico. If North America is to remain competitive in the global marketplace, it must invest in a world-class transportation system that includes intercity passenger rail, and specifically state-of-the-art high-speed ground transportation (HSGT) systems. The term “high-speed rail” is commonly used to describe the full range of steel-wheel-on-steel-rail HSGT systems. This article provides a brief overview of high speed rail (HSR) from a North American perspective - identifying key issues, societal benefits, and cost, and discussing HSR technology advancements and implementation challenges.

**Key Issues, Societal Benefits, and Cost**

**Key Issues.** The intent of all passenger system designs is to offer safe and comfortable transportation at an affordable cost. The design of high-speed rail transportation requires attention to those criteria that differ from the traditional established standards and specifications for railroad construction. Design and construction issues need to be addressed in the areas of technology development, infrastructure requirements, cost, system safety, and environmental effects.

High-speed rail is emerging in North America as not just viable but essential to the improved mobility of the densely populated Northeast, Southeast, West Coast, and Midwest corridors, as well as other potential emerging corridors in the Gulf Coast states, Texas, and Eastern Canada. These systems are most likely to succeed in corridors with strong business travel, where local airports are capacity-constrained, and HSR trip times from downtown to downtown would be truly competitive with air and auto. Clearly, these conditions do not currently exist in all major US city-pairs.

For the introduction of HSR to succeed in North America, it would be best to focus the initial major investments in the most commercially viable routes, principally the Northeast Corridor (NEC), California (Bay Area – LA...

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**Definitions**

- **IPR** is the generic term used to describe all intercity passenger rail systems regardless of speed or trip-time competitiveness with other forms of intercity passenger transportation.

- **HSGT** is self-guided intercity passenger ground transportation that is time-competitive with air and/or auto on a door-to-door basis for trips in the range of 100 to 500 miles. This is a market-based, not a speed-based definition; it recognizes that the opportunities and requirements for HSGT differ markedly among different pairs of cities. High-speed ground transportation comprises a family of technologies ranging from upgraded existing railroads to magnetically levitated vehicles (maglev).

- **HSR** is a subset of HSGT comprising steel-wheel-on-steel-rail technologies. In the United States, HSR already exists in the Northeast Corridor (NEC). (A corridor is a natural grouping of metropolitan areas and markets that, by their proximity and configuration, lend themselves to efficient service by ground transport.) High-speed rail normally refers to rail systems with top speeds above 90 mph (145 km/hr) and generally with top speeds of 125 mph (200 km/hr) or greater.

- **VHSR** Very-high-speed rail (sometimes referred to as “true HSR”) describes the current advanced HSR systems in Europe and Asia being built and operated in the 186 mph (300 km/hr) to 220 mph (350 km/hr) top-speed range. The proposed California High-Speed Train System and Amtrak’s proposed NEC “Next-Gen” high-speed rail would fall into this category.
Basin), Dallas-Houston, Miami-Orlando, and Chicago-St. Louis. A range of HSR technologies is available, from incrementally improved existing rail service (including improvements to the existing 125 – 150 mph Amtrak NEC), to VHSR, using new, very-high-speed trainsets on dedicated tracks designed for speeds up to 220 mph or higher (as are being built in Europe and Asia), and possibly (ultimately) to maglev (as is being planned from Tokyo to Osaka in Japan). (See Figure 1.) It is important to pick the right technology and performance characteristics to meet the commercial and service needs of each corridor. (The higher-speed capability of maglev has yet to be proven to be needed or commercially viable and is not currently being contemplated for any US application.)

There are many challenges to overcome before the development of HSR in these corridors can be realized. Most of these are not technological but political, institutional, and financial. In particular, the absence of a long-term, dedicated funding source, such as the Highway Trust Fund (which financed the Interstate Highway system) or the Aviation Trust Fund (which pays for airport expansion), has been a major impediment to the implementation of HSR in North America. This and other implementation issues are discussed further below.

**Societal Benefits.** HSR offers significant long-term societal benefits in the areas of safety, speed, and reliability of intercity passenger travel; sustainability (energy use, environmental impact, and land use); economic stimulus; and global competitiveness. These include:

**Safety, Speed and Reliability**
- Safety record: Lowest fatality and injury rate of all intercity travel modes
- Door-to-door trip time: Competitive with air and auto modes
- Passenger-mile cost: Less than short-haul air; competitive with other forms of public transportation
- All-weather reliability: Better than other intercity modes
- Line-haul capacity: High capacity; expandable to meet travel demand
- Congestion relief: Can free up short-haul-airline gates and regional airport runway capacity and reduce need for interstate highway expansion

**Sustainability**
- Energy use: Low passenger-mile energy consumption; conserves fossil fuels; electric power is highly reliable, not as prone to supply shortages; allows use of renewable energy sources
- Environmental footprint: Low carbon emissions (depending on fuel source used to generate the power used); relatively low environmental impact (except noise impacts near the right of way); potential for shared-use rights-of-way in densely developed urban areas; and transit-oriented development opportunities around passenger stations

**Economic Stimulus and Global Competitiveness**
- Jobs: An estimated 20,000+ jobs are created per $1 billion of investment in HSR according to the American HSR Alliance.
- Manufacturing base: Utilizes and expands US railroad equipment and high-tech manufacturing capability; improves US international competitiveness to supply HSR technology worldwide
- Competitiveness in the global economy: Must be based on a world-class transportation system

**Cost.** One of the principal stumbling blocks in developing HSR systems from a technological standpoint is cost. High-speed rail is very expensive to deploy. Unfortunately, this is a fact of life, and while advances in technology may lower costs in the future, recent history indicates that infrastructure and vehicle system costs will continue to rise despite improved methods of construction and enhanced design and manufacturing techniques. This is true outside the U.S., as well. The good news is that other competing transportation systems face similar, if not greater, cost pressures, and HSR is increasingly becoming the most cost-effective means of meeting the rising demand for intercity passenger transportation. Thus, while cost is an important issue, and ways of economizing are always being sought, cost should not be a long-term impediment to greater deployment of HSR systems.

**HSR Technology Advancements**
Since HSR system technology is being developed and improved primarily outside the U.S., technology transfer is a key step toward the implementation of HSR systems in...
North America. It is ironic that a nation as technologically advanced as the United States is lagging the world in HSR know-how. But the fact is that the United States has not invested in HSST system development, and it would be foolish not to benefit from the major investments and experience of others in high-speed train and maglev systems technology.

**Safety Standards.** New federal track safety standards were recently promulgated to address today’s railroad operating environment and provide for future high-speed train operations. Similar revisions to safety standards for signaling and train control, vehicle structure, crashworthiness, braking systems, and other systems are also being developed to permit the implementation of HSR systems in the United States. The challenge is in the technology transfer of overseas HSR experience and ensuring that no degradation of safety or unmitigated environmental effects result from the deployment of this technology in North America. Frank Banko’s article, “Making Fast Trains Safe”, page 21 of this issue of PB Network, discusses the critical safety aspects that need to be considered in HSR trainsets.

**Advances in Materials Technology, Signaling & Communications.** Although the state of the art of intercity passenger rail systems is quite mature (having evolved over the course of the last 150 years), continuing improvements in HSR technology have been realized through developments in materials technology; advances in electronics, particularly with the advent of microelectronics and computer systems; and automation of manufacturing and assembly techniques. Ongoing advances in signaling and communications systems technology, in particular, are expected to have a dramatic effect on the future of passenger rail systems. Use of satellites, Global Positioning System (GPS), communications-based train control, and computer control of dispatching and real-time monitoring of vital and important non-vital systems and subsystems promise to enhance the safety, reliability, and performance, and possibly reduce the cost of HSR systems. As in other fields, technological developments have revolutionized the industry, and there is no end in sight for further advances.

**Integrated Vehicle-Track System Needed.** An objective of the design, construction, and subsequent maintenance of HSR systems is to achieve a fully integrated vehicle-track system. The track structure must be durable, stable, and able to withstand repetitive dynamic loading without excessive deformation in the track, its foundation, or adjacent structures. This is achieved by designing track to close geometric tolerances, maintaining a consistent track modulus (stiffness response to loading), designing and maintaining the wheel tread and rail head profiles to stay within close tolerances, and ensuring that the vehicle—track system as a whole performs as intended. Achieving a consistent track modulus can be extremely costly on existing rail lines. Research into ways of making existing infrastructure appear uniform to the vehicle may yield large dividends. Continued advances in the modeling and simulation of vehicle-track interaction should lead to better understanding of the system requirements and foster further improvements in practice.

Advances in materials, construction techniques, inspection methods, and maintenance practices have elevated the performance level, ride-comfort, and safety of HSR systems over the years and will continue to contribute to better infrastructure performance in years to come. The widespread use of continuous welded rail, concrete ties with resilient fastening systems, track geometry cars, and ultrasonic rail flaw detection techniques have all contributed to higher-quality and safer track. Nevertheless, interpretation of rail flaw detection tests remains difficult and inconsistent, and there is still no test for the base of the rail, where many of the failures in field welds occur.

**Implementation Challenges Discussion**

As touched upon briefly above, there are many political, institutional, financial, and other challenges to be overcome before the development of HSR in North America can be realized.

**Political Impediments.** Sustained political support and commitment over many years is essential. The relatively short terms of our elected officials compared to the decades-long implementation period from planning, through environmental approval, design, and construction, to testing and commissioning of a new HSR system have made it difficult to sustain HSR project initiatives in Florida and Texas, in particular. It will be necessary to build and maintain broad public and political support over many years to implement HSR in the US. Recent history has demonstrated the difficulties, the long lead times, the costs, and the institutional impediments to system deployment in the United States.

**Institutional Challenges.** The Federal Railroad Administration (FRA) was created in 1966 to promulgate and enforce rail safety regulations, conduct research and development in support of improved railroad safety and national rail transportation policy, and administer federal grants. As such, the FRA must approve the design, construction, and operation of any HSR system in the United States. As the rules and regulations for HSR are new and evolving, applicants seeking to secure regulatory approval of their system plans can experience schedule uncertainty in the review and approval process.

**Financial Challenges.** Beyond the absence of stable, long-term funding sources, HSR projects must overcome other economic and financing issues, including their size (some are in the $50 – $100 billion range); cost and ridership uncertainty; lengthy environmental review and approval processes; potentially costly regulatory requirements, including “Buy America” provisions that accompany use of federal funding; untested project delivery methods, such as very large
public-private partnerships or design, build, operate, maintain (and possibly finance) (DBOM/F) franchise agreements.

State- or region-wide HSR systems, like those operated in the Northeast Corridor and proposed in California and in the Midwest, have the potential to generate high levels of ridership and revenue and, at a minimum, to recover their operating costs; nevertheless, project proponents must make the case for a system’s ridership potential and economic viability to justify government support and to convince Wall Street and banks to invest in a project.

Other Challenges

Safety. Historically, HSR has been the safest mode of transportation. The Japanese Shinkansen system has an unblemished safety record, carrying 275 million passengers or more per year without a major accident in its 47-year history. The European high-speed rail network had a similarly remarkable safety record, with no deaths or serious injury during many years of service, until the InterCityExpress (ICE) train crash in Eschede, Germany, in 1998. This accident occurred on conventional intercity trackage, not high-speed infrastructure, a fact that raises concern that higher risks may be posed by operating on track not built specifically for high speed. In this particular case, however, a faulty wheel design was determined to be the primary cause of the accident.

The recent Chinese HSR rear-end collision near Wenzhou on July 22, 2011, killing 39 people, was apparently caused by design flaws in the signaling system. The Yongtaiwen Railway, which opened on September 28, 2009 between Ningbo and Wenzhou South, is designed for mixed traffic operation with a maximum speed of 250 km/h. It is equipped with wayside signals overlaid with CTCS-2 to provide automatic train protection. Until the accident investigation is complete, it is premature to speculate on the exact cause, but reportedly, a lightning strike disabled the signaling system, which apparently was not equipped with lightning protection. (Presumably corrective actions will be taken to avoid similar fatal mishaps on the Chinese HSR network in the future.)

Despite the 1998 and 2011 accidents described above, the overall safety record for high-speed rail is much better than that for any other mode. Nonetheless, safety can never be taken for granted, and ensuring the integrity of future high-speed rail systems in the United States will take a concerted effort throughout the planning, design, construction, and operation of these systems. (The FRA serves as the federal agency responsible for certifying the safety of new HSR systems.)

Right-of-Way Availability/Acquisition. The process of identifying, environmentally clearing, and acquiring needed land for new HSR systems, even when eminent domain procedures are employed, adds schedule and cost uncertainty and is subject to legal challenges. Not-in-my-backyard opponents can employ legal and other public-process tactics to delay or stall (and in some cases stop) projects from proceeding. The fact that HSR is being proposed in already densely urbanized corridors further compounds and complicates the identification and acquisition of suitable rights of way.

Project Delivery. The lack of HSR design and construction experience in the United States, and the daunting size and capabilities of new owner organizations needed to manage the implementation of mega-projects as large as most HSR projects, present additional challenges. Delivering such large projects involving new HSR technology will require developing and training a new generation of US railroad engineering design, construction, and operations professionals, railroad equipment and materials suppliers, and labor workforce.

Conclusion

Given the need for improved passenger system performance and significantly higher capacity in high-density intercity corridors throughout North America, HSR will probably be the mode of choice for many regional applications through the next century and beyond. High speed rail can be viewed as a critical link in seamless transportation, with connections to major airports and the urban rail systems of large regional cities.

There are many challenges to be overcome before the development of HSR in these corridors can be realized, however, most of these are not technological, but rather political, institutional, and/or financial. In particular, the absence of a long-term, dedicated funding source has been a major impediment to the implementation of HSR in North America. The new surface transportation reauthorization legislation currently being debated has the potential to play a major role in deciding whether HSR will have access to federal funding equal to that of its rival transportation modes over the next few years.

Ultimately, the most important development would be a successful implementation of HSR somewhere in the United States – something Americans could touch, feel and ride. The experience in Europe and Asia makes clear that once travelers experience HSR, they want it where they live. We need that “shiny new train” experience in the United States. If and when we can deploy high-speed rail in a major US corridor, development of HSR in the rest of North America may become easier.

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There has been an increasing amount of European rail regulation over the last twenty years. Although much of this has been aimed at financial and operational structures, a considerable amount has technical relevance. Much of this is enacted through directives, for which member states must create legislation that embodies their requirements.

The earliest impact on rail engineering practice was the Procurement Directive of 1990, which triggered the creation of European Standards (ENs) drawn up by the CEN/CENELEC organisations, and which supported the open market for rail equipment and components, by seeking to eliminate ‘barriers to trade’ caused by differing national technical standards.

Subsequently the European Directives on Interoperability, as supported by Technical Specifications for Interoperability (TSI) were introduced. The term Interoperability is often misunderstood. As with the Procurement Directive, the driver is essentially economic. The EU sees rail transport as fundamental to enhanced economic activity and lowering of carbon emissions, and wishes to facilitate lowering the costs of rail operations. The establishment of a set of common standards for rail allows manufacturers to achieve economies of scale by the use of a single (or at least limited) set of equipment standards and requirements across a much wider market. It is not to be confused with ‘interworking’.

UK Legislation

The provisions of the EU’s High Speed (1996/48/EC) and Conventional Rail (2001/16/EC) Directives have now both been ‘transposed’ into UK legislation, as the Railways (Interoperability) Regulations 2006. Their application in UK, and other countries, is based upon the Trans European Network (TEN) map (found in EU decision 1692/96/EC). The map (see weblink at end of this article) identifies the High Speed and Conventional lines (which for UK amounts to approximately 40% of Network Rail’s total track miles). Also shown on the map are other (domestic) lines to which the regulations do not (yet) apply, however the recast directive 2008/57/EC allows member states the facility to extend the application to these.

An often held misunderstanding is that the Technical Specifications for Interoperability apply to the routes. They do not, they apply only to projects undertaken on those routes, to each sub-system, and even then, only when the competent authority (Department for Transport in UK) determines that they shall apply.

A project can also include any major upgrade and renewal works to the infrastructure. Upgrade is defined as achieving performance enhancements. Renewal is replacing like for like. Additionally any new rolling stock capable of speed in excess of 250km/h built after the date of the Regulations must also comply.

Structure of the Interoperability Directives

The directives mandate essential requirements that must be met by the system, the subsystems and any interoperable constituents. There is a Technical Specification for Interoperability (TSI) for each of the following subsystems:

- infrastructure
- energy
- control and command and signalling
- rolling stock
- traffic operations and management
- maintenance (rolling stock)
- telematics applications for passenger and freight vehicles

Additionally, there are TSIs for two ‘transverse’ (i.e. applying to all subsystems) areas:

- Safety in railway tunnels (SRM)
- Persons of reduced mobility (PRM)

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1CEN, The European Committee for Standardization, and CENELEC, The European Committee for Electrotechnical Standardization
The Conventional rail directive divides telematics\(^2\) into separate TSIs for passenger and freight; rolling stock into locomotives, passenger and freight, with an additional TSI for rolling stock noise.

In areas where differences are known to exist across national rail systems, the TSIs make no provision and the requirements are achieved by the use of member states own national standards, known in this context as ‘Notified National Technical Rules’ (NNTRs).

**Compliance with TSI and the Role of Notified Bodies**

Under the Regulations, Contracting Entities (CEs) undertaking any upgrade on a High Speed or Conventional line falling into the scope are required to employ a **Notified Body**\(^3\) (NoBo) to certify compliance with the TSI and NNTRs for each subsystem affected by those works.

The NoBo undertakes an assessment of those works (design and implementation) to verify compliance and produces a Technical File (TF) and a Certificate of Compliance (CoC). The CE completes his own Declaration of Verification and submits this together with the TF and the CoC produced by the NoBo to the Supervisory Authority in order to obtain Authorisation for service.

The assessment format may be either a 100% design/construction compliance check or a Quality System (QS) audit together with a sampling of design/construction compliance. Where an internationally recognised QA qualification (e.g. ISO 9001) is held, only a relatively low level of QS auditing need occur.

Once a Letter of Authority has been received from the Supervisory Authority, the section of line or a particular class of rolling stock may be placed into service.

**Seeking Project Authorisation**

The Office of Rail Regulation (ORR) fulfils the role as the Supervisory Authority and is responsible for licensing NoBos within the UK against each of the subsystems.

Parsons Brinckerhoff staff’s experience of seeking authorisation for projects, and managing and undertaking NoBo activities has highlighted some issues.

For West Coast Route Modernisation (WCRM) project, where PB managed the authorisation process for Network Rail, a Staged Works Submission (SWS) process was found to be beneficial, such that:

- The project was divided into geographical areas or disciplines;
- The completed sections returned to operation before other parts in order not to stop the service;
- SWS allowed completed parts to be returned to operation in non-upgraded mode (i.e. no higher speed) prior to authorisation;
- Authorisation is only sought by CE when all parts are completed and NoBo-certified;
- When authorised, all completed parts may be operated in upgraded mode.

But problems were encountered with the Notified Body process:

- The screening process was too time consuming for ORR – they requested CE ‘self-screening’ wherever possible;
- Too many national standards were originally ‘notified’ – the NoBos felt they had to assess against far too many clauses;
- Network Rail’s internal verification processes were not always accepted by the NoBos;
- NoBos were viewed as an ‘expensive irrelevance’ by some project teams – co-operation was sometimes lacking.

Separately, the challenge for the NoBo carrying out assessments was to determine the detailed assessment criteria. At the time these projects were carried out, the TSIs were only recently introduced (and still evolving) and there were no established detailed assessment methods.

For WCRM electrification equipment, the approach agreed between the NoBo and the client was to carry out an assessment using a combination of requirements of TSI Energy and NNTRs. Design drawings and as-built records were reviewed to assess compliance of the built (and operational) electrification system. These routes had originally been electrified in 1958 – 1966 and the upgrade was carried out in 2001 – 2004. The TSI Energy was introduced when the upgrade design was largely complete, so it was unlikely that the design would comply with all of the TSI requirements, as most routes in the UK were not built to continental European (UIC)\(^4\) loading gauge and this upgrade did not include increasing structure clearances to UIC requirements. Consequently, the assessment was abandoned when the UK railway safety authority (ORR) decided that it would not be possible to achieve TSI certification for these routes.

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\(^2\) Telematics applications for passenger services include systems providing information before and during the journey, reservation and payment systems, luggage management and management of connections between trains and with other modes of transport; and for freight services, include real-time monitoring of freight and trains marshalling and allocation systems, reservation, payment and invoicing systems, management of connections with other modes of transport and production of electronic accompanying documents.

\(^3\) Notified Body is a common European term meaning a body responsible for assessing conformity with a European Directive

\(^4\) Union Internationale des Chemins de fer
Short History of HSR in the USA

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In the 19th and first half of the 20th centuries, the United States was linked together as a result of public policies and both public and private investments in a national intercity passenger rail network, effectively shrinking distances between cities and enabling extraordinary economic growth. Over the past fifty years, the United States invested heavily in highways and airports and, in general, has abandoned intercity passenger rail (IPR) service. Over this same period, by contrast, Europe and Asia have committed large sums of money to building extensive new high-speed rail (HSR) networks and have maintained and strengthened their intercity systems. The US launched a high-speed ground transportation initiative in the mid-1960s and abandoned it in the mid-1970s. Over the past 30 years, various state-sponsored initiatives have started and stopped, mostly because of inadequate funding and/or insufficient popular/political support necessary to sustain funding.

The Obama Administration’s support of high-speed and intercity passenger rail, through both the American Recovery and Reinvestment Act (ARRA) and the High Speed Intercity Passenger Rail (HSIPR) programs, has spurred new public interest in developing this mode of ground transportation. This nascent support for investing in the nation’s high-speed/passerger rail infrastructure is still somewhat tenuous in that it has emerged during an extraordinarily challenging economic and political climate resulting from a prolonged and deep recession and an era of massive and growing federal deficits. And because of delays in enacting federal reauthorization for surface transportation, there is not yet a dedicated program for HSIPR funding. As a result, HSIPR funding is, and will continue to be, caught up in debates over those who argue that the nation can’t afford these projects versus those who believe that this is exactly the type of infrastructure investment that will not only foster short-term employment to mitigate against the current recession, but also stimulate longer-term economic growth just as did the earlier investments discussed above.

HSR in the US

Forty-five years ago, Senator Claiborne Pell of Rhode Island, widely recognized as the father of high-speed rail in America, had a vision of convenient, comfortable, high-speed trains connecting cities of the Northeast Corridor (NEC) from Boston to Washington, D.C., providing a truly competitive alternative to automobile and airline travel in the “Bos-Wash” Corridor. The High-Speed Ground Transportation Act of 1965, which he sponsored, authorized the Metroliner and Turbo Train Demonstration programs, which were the beginning of a gradual long-term improvement in intercity passenger rail service in this populous region [Public Law 89-220, 89th Congress, S. 1588 9/30/1965]. Pell’s visionary book, Megalopolis Unbound, promoted high-speed trains before the rail company Amtrak or even the US Department of Transportation (USDOT) existed.

Through the intervening years, government support of passenger-rail improvements in this and other corridors has come and gone in fits and starts. In the late 1960s, USDOT embarked on an ambitious program of research, development, demonstration, and testing (RDD&T) of high-speed ground transportation (HSGT) equipment, based at a national test center built in Pueblo, Colorado. Yet in 1975, Congress voted to terminate all RDD&T of new HSGT equipment, and decided instead to focus on rehabilitating and upgrading existing railroad infrastructure. The government turned over the test center to the Association of American Railroads (AAR) to test rail freight and urban transit systems and equipment.

Starting in 1977, the Federal Railroad Administration (FRA) and the National Railroad Passenger Corporation (Amtrak) embarked on the Northeast Corridor Improvement Program (NECIP), a federally-funded $2.5 billion rehabilitation and upgrading of Amtrak’s mainline between Washington, D.C. and Boston, MA. Caught in the high-inflation years of 1978-80, the program ran out of money before completing some of the improvements needed to permit high-speed service, particularly in the north end of the corridor between New York and Boston. However, the Northend High-Speed Rail Improvements authorized under subsequent legislation funded completion of the NEC electrification in the late-1990s. After 35 years, the cumulative effect of continuing government investments and technological advances in passenger trains largely fulfilled Senator Pell’s vision.
In the 1990s, Section 1010 of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) [Public Law 102-240, 102d Congress, H.R. 2950 12/18/1991] provided modest but historic financial support to the development of high-speed rail in five designated corridors throughout the United States. The Clinton Administration’s High-Speed Rail Development Act of 1993 [H.R. 1919 4/28/93] authorized additional financial assistance to support the efforts of states and local governments and the private sector to develop HSR service in qualifying intercity corridors. In 2003, under the Bush Administration, the Passenger Rail Investment Reform Act (the PRIRA) [H.R. 1713] was proposed to Congress, but it was never passed. In October 2007, the Senate passed the Passenger Rail Improvement and Investment Act of 2007 [S.294] and, despite a veto threat by President Bush, a similar bill passed the House on June 11, 2008. The final bill, which was greatly driven by a rail collision in Southern California, was called the Rail Safety Improvement Act of 2008 [Public Law 110–432, 110th Congress, H.R. 2095 10/16/2008]. This bill provided $1.625 billion for rail safety investments and lost its original focus on supporting HSR projects.

Current Federal HSR Funding
Passage of the Passenger Rail Investment and Improvement Act of 2008 (PRIIA) heralded the start of a new era in intercity passenger rail investment in the US. In addition to reauthorizing Amtrak, PRIIA established three new federal competitive grant programs to fund IPR and HSR in cooperation with the states and other eligible recipients. But government investment in HSR, outside of the NEC, did not materialize until the Obama Administration’s recent national high-speed rail initiative. ARRA provided an unprecedented $8 billion for high-speed and intercity passenger rail projects nationwide. This $8 billion investment is considered a jumpstart to improve IPR across the country and to develop HSR in a few key corridors. The Obama Administration proposes to integrate HSR into the surface transportation program to ensure a sustained and effective commitment to a national high speed rail system over the next generation. The annual appropriation funding for Fiscal Year (FY) 2009 was combined with the ARRA funding and project selection. The $2.5 billion from FY2010 USDOT Appropriations Act grant funding was announced separately.

Federal Funding is Critical
As has been consistently demonstrated over the past 50 years, both in the US and abroad, high-speed and intercity passenger rail systems have not been developed without substantial federal financial assistance and support. The future of a range of robust HSR and intercity passenger rail corridors in the US depends on resolving a number of issues associated with its cost, funding sources, and implementation strategy. Nevertheless, there are a number of potential long-term benefits in implementing HSIPR. The challenge the U.S. faces is how effectively involve the federal government in the long-range planning and funding of HSIPR transportation infrastructure within the American economic system. Just as private industry faces unparalleled competition from government-supported industries abroad, so too our national transportation system is challenged to keep pace technologically with other national systems, which are typically planned and developed in a centrally-directed fashion as part of their national transportation policies.

As discussed above, federal involvement to date has been intermittent and, as a result, very few projects have been able to advance; certainly, no high-speed projects have. A sustained level of federal involvement and investment is absolutely critical for the program to be successful and for these projects to be implemented. And that will require having significant, predictable funding established as part of the next federal surface transportation bill just as has been done for the New Starts program, which provides federal matching funds for mass transit projects in major metropolitan areas. Because of the complexity of HSIPR projects, because of their magnitude, and because of the long timeframes associated with their construction, they require the certainty of a federal commitment. Those states committed to implementing HSIPR projects need the assurance of a federal partnership and the confidence that their investments will not only be matched with federal funds but in the timeframes necessary to construct the projects on a feasible schedule. To establish that federal commitment in the next federal
transportation authorization bill will require a broad and committed coalition of states and metropolitan areas that recognizes – and can clearly and compellingly articulate – how these projects will advance the nation’s transportation, economic, environmental and other policy goals.

John Harrison, a Parsons Brinckerhoff VP and Principal Project Manager, has devoted most of his 40-year career advocating for HSR in the US. In 2009-10 he served as Deputy Program Director of the California High-Speed Train Project in Sacramento, CA. Mr. Harrison holds a Masters Degree in the Management of Technology from the Massachusetts Institute of Technology (MIT). His 1983 MIT thesis was entitled: “An Assessment of U.S. High-Speed Ground Transportation Prospects.”

Sheila Dezarn, a Vice President and Director of Transport Strategy within Parsons Brinckerhoff’s Strategic Consulting Group, has spent her 22-year career helping major transportation projects develop funding and implementation strategies and securing federal funds for New Starts and high speed rail projects. She is currently serving as a strategic advisor to the California High-Speed Rail Authority on a range of issues including the development of its business plan.

Allison Dobbins, a Supervising Transportation Planner, has spent much of her 20-year career assisting state, regional and local governments and transit agencies in the areas of transportation planning, engineering and finance. Over the past two years, she assisted the California High-Speed Rail Authority in the preparation of several grant requests for federal High-Speed/Intercity Passenger Rail Program funds.

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Conclusion and Future Development

Although the directives are now law, as implemented by various national regulations, the supporting TSIs are in various states of completion or revision, with different TSIs referring to different dated versions of European Standards.

Additionally, the application of the directive/regulations and the TSIs is fraught with ambiguity, as the identification of high speed, conventional and domestic categories is on a route basis, and consideration has not yet been given to application of different lines (i.e. slow and fast lines) of a route.

Finally, as the TSIs are meant to ‘work together’, there is an issue with the advance implementation of a TSI on a single subsystem, well in advance of the rest of the rail infrastructure.

Consequently, seeking authorisation for a project, and managing the NoBo, requires a flexible approach and one which establishes at the outset a clarification of understanding as to which requirements will be applied to which parts of a project.

For the future, work has now started on redrafting the High Speed and Conventional Rail TSIs into a single document and, at the same time, extending the scope to include many of the previously excluded rail lines (i.e. the ‘domestic’ lines). Although the opportunity may well be taken to address some of the anomalies outlined above, there is also a concern that the inclusion of so many additional types of line in the scope will, of necessity, result in a much larger document, incorporating many compromise provisions.

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Related Web Sites
Making Fast Trains Safe
By Frank Banko, Newark, NJ, 1-973-565-4811, banko@pbworld.com

Parson Brinckerhoff’s (PB) California High Speed Train Program (CHSTP) Engineering Management Team (EMT) is focused on developing system requirements and performance specifications that will ultimately be used to support the procurement of the trainsets and core systems. As the rolling stock manager supporting the EMT, my team is evaluating best practices from the US and from high speed (HS) trainset manufacturers and operators worldwide to identify the critical safety attributes that must be addressed. Current US carbody strength and crashworthiness regulations, as codified in the Code of Federal Regulations (CFR) issued by the Federal Railroad Administration (FRA), are applicable for trains traveling at a maximum speed of 240 kilometers per hour (kph) or 150 miles per hour (mph). The operating plan for the CHSTP requires a trainset capable of traveling at 350 kph (220 mph). Therein lies the challenge.

As the recipient of the 2010 William Barclay Parsons (WBP) Fellowship, I have been completing research on my fellowship program entitled “Pioneering the Application of High Speed Rail Express Trainsets in the United States” and have been able to learn about best practices relative to designing, manufacturing, operating, and maintaining HS trainsets from countries such as France, Germany, Italy, Japan, Spain and, most recently, China and Korea.

A common philosophy recognized through this research is that a system-based approach should be implemented when developing a HS rail system. This system-based approach takes into account all of the attributes of the core systems (e.g., trainset, train control, traction power, communications, track, infrastructure, operations, and maintenance), and how these core systems contribute to the overall safety of the system. The second key lesson learned was that the trainsets need to be designed to be able to withstand the rigors of high speed operation, while preserving a lightweight structure. Static axle load, defined as the weight placed on the rail for all wheels that are mounted on a common axle, is a critical parameter. In Europe, for example, a maximum static axle load of 17 tonnes (18.7 tons) has been adopted.

European and Asian HS operators recognize that the US CFRs (e.g., 49 CFR Part 229) have traditionally focused on the specification of minimum compressive strength requirements for numerous structural elements incorporated into the design of a rail vehicle. Recent regulatory developments, as embodied in 49 CFR Part 238, have also focused on compressive strength requirements, with added emphasis on vehicle crashworthiness, and occupant protection standards. The CFRs have adopted significant requirements for compressive strength when compared to the strength requirements for European and Asian HS trainsets. As an example, 49 CFR Part 238.405 identifies a 9,341 Kilonewton (kN) [2,100,000 pound force (lbf)] requirement for longitudinal static compressive strength of the leading rail vehicle traveling up to 240 kph (150 mph). The European Technical Specifications for Interoperability (TSI) adopt a 1,500 kN (337,213 lbf) requirement for compressive strength, whereas Asian trainsets are being designed with compressive strengths of 980 kN (220,313 lbf). With the European and Asian trainset manufacturers designing to lower compressive strength requirements, static axle loads of 17 tonnes (18.7 tons), or less, are being realized. This axle load can be compared to the 22.7 tonnes (25 tons) axle load of the CFR compliant Amtrak Acela HS power car. Overall system efficiency improves with lighter weight trainsets as there is reduced wear on vehicle components, track and infrastructure; lower noise emissions; increased acceleration and operating speeds; and lower energy consumption.

The US CFRs (e.g., 49 CFR Part 229) have traditionally focused on the specification of minimum compressive strength requirements for numerous structural elements incorporated into the design of a rail vehicle. Recent regulatory developments, as embodied in 49 CFR Part 238, have also focused on compressive strength requirements, with added emphasis on vehicle crashworthiness, and occupant protection standards. The CFRs have adopted significant requirements for compressive strength when compared to the strength requirements for European and Asian HS trainsets. As an example, 49 CFR Part 238.405 identifies a 9,341 Kilonewton (kN) [2,100,000 pound force (lbf)] requirement for longitudinal static compressive strength of the leading rail vehicle traveling up to 240 kph (150 mph). The European Technical Specifications for Interoperability (TSI) adopt a 1,500 kN (337,213 lbf) requirement for compressive strength, whereas Asian trainsets are being designed with compressive strengths of 980 kN (220,313 lbf). With the European and Asian trainset manufacturers designing to lower compressive strength requirements, static axle loads of 17 tonnes (18.7 tons), or less, are being realized. This axle load can be compared to the 22.7 tonnes (25 tons) axle load of the CFR compliant Amtrak Acela HS power car. Overall system efficiency improves with lighter weight trainsets as there is reduced wear on vehicle components, track and infrastructure; lower noise emissions; increased acceleration and operating speeds; and lower energy consumption.
the core systems each contribute to the overall safety of a HS rail system, thereby embracing a philosophy of designing a system that focuses on collision avoidance rather than collision survivability. The FRA has recognized that the system-based approach is a viable approach to assuring safety, and has empowered the FRA Railroad Safety Advisory Committee (RSAC) Engineering Task Force (ETF) to produce guidelines that will include a set of technical evaluation criteria and procedures to evaluate passenger rail equipment built to alternative designs. As stated in the ETF’s charter, “The technical evaluation criteria and procedures would provide a means of establishing whether an alternative design would result in performance at least equal to the structural design standards set forth in the Passenger Equipment Safety Standards (i.e., 49 CFR Part 238).”

The establishment of the ETF, and the resulting development of criteria and procedures that will be used to evaluate passenger rail equipment built to alternative designs, represent a critical first step forward for true HS rail to be realized in the US. This process will provide the HS rail industry with a means to demonstrate to the FRA how trainsets designed and manufactured to international standards can provide equivalent levels of safety, when compared to traditional, CFR compliant rail vehicles. Furthermore, this approach provides an opportunity for HS trainsets to be interoperable with traditional CFR compliant rail vehicles, providing projects such as the CHSTP the option to share existing conventional rail tracks and corridors in high density urban centers.

The ETF’s initial focus has been on developing standards for rail vehicles operating at speeds less than 200 kph (125 mph). A guideline has been drafted that identifies collision scenarios, compressive strength requirements and crash energy management criteria that are comparable, in principle, to the requirements identified in the European TSI. Currently, the ETF is developing standards for trainsets operating at speeds up to 350 kph (220 mph).

At the October 2010 meeting of the ETF, the FRA presented the scope of the proceedings which included technical evaluations and discussions pertaining to crashworthiness, end-facing and side-facing glazing, emergency windows, emergency door releases, emergency lighting, passenger occupancy in lead cars, occupant protection (e.g., interior component attachment strength, and seating design), trainset occupancy in platform heights, ADA requirements, and luggage rack configuration. The FRA signaled its intent to re-define the Tier V classification of HS systems, as contained in the FRA’s High Speed Passenger Rail Safety Strategy document, by incorporating the requirement for interoperability of the high speed systems, with lower speed conventional (Tier I) systems. This resulted in a definition of Tier III which now includes the previously defined Tier IV and Tier V environments. The FRA has advised that the minimum crashworthiness standards developed for ETF Tier I environments need to be satisfied to provide a comparable level of safety. Currently, the HS trainset manufacturers are evaluating the potential weight, design and cost impacts that the specification of the ETF Tier I crashworthiness guidelines would have on International HS trainset designs. The manufacturers have presented their findings to the FRA in subsequent ETF meetings, and excellent progress is being made.

We anticipate that the approach that the FRA is taking with the ETF will result in new regulations and guidelines that will enable US HS rail projects to procure service proven HS trainsets with nominal modifications, thereby reaping the benefits associated with implementing safe, service proven technologies and trainset designs.

**Frank Banko** has been with Parsons Brinckerhoff for 13 years, and manages the rail vehicle division within the Transit and Rail TEC. In addition, he is the manager of rolling stock for the CHSTP, and has managed rail vehicle procurement and overhaul programs for NJ Transit, UTA, and Caltrain.
The European Train Control System (ETCS) – A Beginner’s Guide

by Richard Jackson, IVV GmbH, Berlin, Germany, +49 30 420808-28, Richard.Jackson@ivv-gmbh.de

This article aims to swiftly inform the interested reader about the European Train Control System (ETCS) with regard to system principles and some of the current issues concerning implementation worldwide.

IVV is Parsons Brinckerhoff’s rail engineering design company in Germany. In the past, IVV has performed detailed design work for the German high speed line projects: Cologne-Frankfurt, Nuremberg-Ingolstadt and Karlsruhe-Basel. We are currently training our signalling designers in ETCS design principles for future high speed projects.

What is ETCS?
ETCS is an ATP (Automatic Train Protection) system including cab signalling which arose from a European Union directive to promote interoperability. ETCS ATP equipment is fitted both lineside and onboard the trains.

Referral is often made to ERTMS (European Rail Traffic Management System). ERTMS is the combination of ETCS and GSM-R technology, the GSM mobile communications standard for railways.

What does Automatic Train Protection do?
An ATP system’s primary function is to make sure that a train obeys the decision of the ‘interlocking’ and stops at the right place, thus preventing trains from crashing.

The interlocking is the safety critical route setting equipment.

When a route is setup, checked and locked by the interlocking, the lineside signals then change their respective colours (known as ‘aspects’) and the ATP system translates the route into an MA (Movement Authority), which it then rigorously enforces. If necessary, the onboard ATP equipment will stop the train itself if the driver does not brake correctly.

Because trains can take a long time to stop, ATP systems are thus heavily involved with the supervision of, and intervention in, braking curves (see Figure 1).

Another use of ATP systems is to prevent trains from travelling too quickly and derailing.

All Train Protection systems can be grouped into two main categories, which we need to understand when learning about the ETCS system:
• Intermittent Train Protection systems – MA (Movement Authority) information is given to the train at fixed points only
• Continuous Train Protection systems – MA information is given to the train continuously

Both types of system are very safe, as they both fulfill the primary function of stopping the train at exactly the right place. However, Continuous Train Protection systems offer the advantage of immediately allowing a train to speed up as soon as the route ahead has been set.

With an Intermittent Train Protection system, the train has to continue braking until the next fixed point has been reached. This disadvantage is particularly great when approaching signals, and is why ‘infill’ systems are sometimes used. An infill system gives Continuous Train Protection information to the train over a limited length of track.

Numerous types of Train Protection systems are in use across Europe, using widely differing technologies, and each different system requires a different system onboard the train.

This is why Europe’s goal of interoperability made a single European system necessary.

ETCS – the ‘Levels’
On the track, an ETCS system can be implemented with different basic system designs. These are known as the ETCS Levels.

ETCS Level 0
ETCS Level 0 is not really ETCS at all. It is represents an ETCS train travelling over a line which isn’t fitted out with
ETCS. The train’s equipment may, however, be used to supervise line speed.

An example of a train running in ETCS Level 0 is the TGV shown in Figure 6 a). As it effectively has no Train Protection system, its running speed has been reduced to 40 km/h which is enforced by its onboard ETCS equipment. The driver has sole responsibility for stopping the TGV before it reaches signal number 12.

**ETCS Level STM (Specific Transmission Module)**

This is used to represent an ETCS train travelling over a line which isn’t fitted out with ETCS, but accepting Train Protection Commands from a Class B national system.

The onboard ETCS equipment has a supplementary module fitted for the Class B System, acting as a slave to the EVC (European Vital Computer).

STM usage can be found on Spanish high speed trains of type AVE S102 and S103. (See Figure 2.)

**ETCS Level 1**

With ETCS Level 1, the train receives its MAs (Movement Authorities) from ‘Controlled Data Eurobalises’. Thus it is an Intermittent Train Protection system.

Eurobalises are magnetic transponders placed in the track. They obtain the information for their MAs from the adjacent signals and / or the interlocking via an LEU (Lineside Electronic Unit). However, it is actually the passing trains which activate and power the Eurobalises by sending a 27.1MHz power signal down from the onboard antenna. When activated, a Eurobalise sends its MA data up to the train in the form of a telegram at 565 Kbit/s via a 4.2MHz signal (see Figure 3).

Eurobalises have been tested up to 512 km/h (318 mph).

The EVC (European Vital Computer) on board the train supervises the train speed and position, controls the DMI (Driver Machine Interface, for cab signalling) and activates the brakes if necessary.

Uses of ETCS Level 1:
- To provide an ATP system on an existing line with no existing Train Protection system e.g. in Saudi Arabia
- General replacement for an older train protection system (Class B System) e.g. in Belgium, Luxembourg. The gain to the railway is an increase in safety
- Installation on specific Pan European corridors to enable through freight traffic (mixed signalling ETCS and Class B System) e.g. in Slovakia, France

With such uses, maximum train speed is generally restricted to the maximum speed for safely observing the signals. In continental Europe this is generally 160 km/h (100 mph).

An example of a train running in ETCS Level 1 at 120 km/h is the international freight train shown in Figure 6 b). The ETCS system ensures that it cannot run into the RE train ahead.

Increasing speed to greater than 160 km/h is theoretically possible. An important issue with speed increase is that the Eurobalise requires route information from much further down the track (faster trains take longer to stop!). Even without speed increase, the cab signalling requires route in-
formation not directly available from the signal.

High speed uses of ETCS Level 1:
- as a backup to ETCS Level 2 for increased system diversity and availability e.g. Belgium high speed corridors
- on any type of new line, high speed or not e.g. in Spain, Korea, China. Current usage up to 300 km/h (186 mph)

It is important to remember that ETCS Level 1, because of its cab signalling, can function perfectly well without any lineside signals at all. In this configuration, route information for the MAs is taken from the interlocking itself. Marker boards at the lineside provide the driver with visual information about where the ends of the sections are.

It is also important to know that although there is no necessity for signals, train detection equipment still has to be installed along the track so that the interlocking can know where the train is, and when the track is free of trains.

An example of a train running in ETCS Level 1 at high speed is the AVE train shown in Figure 6 c). In this example, a limited number of signals are installed to allow occasional trains to be run without ETCS. Infill is provided via Euroloops on the approach to the marker boards.

ETCS Level 1LS (Limited Supervision)
ETCS Level 1 LS aims to avoid the problem of the cab signalling requiring extra route information which is not available from the signal. Therefore, the Eurobalise is only supplied with that route information for its MA which can be obtained from the adjacent signal. When running on a line equipped with ETCS Level 1LS, the driver must still observe the lineside signals and the cab signalling equipment is not used.

Uses of ETCS Level 1LS:
- as a cost effective overlay system (mixed ETCS and Class B signalling) providing ETCS functionality on specific Pan European corridors e.g. planned for Germany, on lines with max 160 km/h running where the ‘Indusi’ Train Protection system is already fitted

ETCS Level 2
With ETCS Level 2, the train receives its MAs via a constantly available GSM-R radio link from the RBC (Radio Block Centre). Thus it is a Continuous Train Protection system (see Figure 4).

As the MAs are received by radio, the amount of lineside cabling is significantly reduced. The only Eurobalisises required for ETCS Level 2 are ‘Fixed Data Eurobalises’. The main function of Fixed Data Eurobalisises is to tell the train exactly where it is so that odometry errors can be corrected.

As with Level 1, ETCS Level 2 can be implemented with or without signals. When used without signals, or with signals only as a back up, the nature of the system design means that very short section lengths can be implemented.

Short section lengths lead to near optimum line throughput.

With less lineside cabling, ETCS Level 2 systems could even be cheaper than Level 1 systems.

It is important to remember that lineside train detection equipment is still required for ETCS Level 2.

Uses of ETCS Level 2:
- ETCS and Class B mixed signalling on specific Pan European corridors to enable through freight traffic at 160 km/h (100 mph) e.g. Czech Republic
- ETCS and Class B mixed signalling on specific Pan European high speed routes [e.g. France, Germany]
- on any type of new line, high speed or not [e.g. Germany, Spain, Switzerland, Italy, China]

An example of a train running in ETCS Level 2 at high speed is the Thalys train shown in Figure 6 d). A limited number of signals allow occasional trains to be run without ETCS. MAs are issued by the RBC and received via the train’s antenna using GSM-R radio.

ETCS Level 3
ETCS Level 3 is the Holy Grail of ETCS.

The difference to Level 2 is that lineside train detection equipment is no longer required. Rather than the tracks determining if trains are present, this task is passed to the train. The interlocking no longer has any sensors connected to the track, instead receiving track occupancy information via the RBC. It can be compared to an air traffic control switching its radar off and relying on the planes to radio in when necessary (see Figure 5).

The main advantage is significantly reduced lineside costs, with very little lineside infrastructure.

Also, because of the continuous nature of the system, optimum line throughput can be achieved (trains following each other at braking distance, known as ‘Moving Block’).

An example of a train running in ETCS level 3 at high speed is the future Eurostar train shown in Figure 6 e). MAs are issued by the RBC. Track position and train integrity are relayed from the train to the interlocking via the RBC.

In the CBTC system (Communications Based Train
Train Control Systems and Safety Technologies for High Speed Rail

SEPTEMBER 2011

Figure 5. The principle of ETCS Level 3

Control), some Metros already use this form of track occupancy reporting. The difficulty in achieving Level 3 for heavy rail is in implementing a safe ‘train integrity’ system. This is particularly challenging for freight trains. If a train coupling breaks, the train must always be able to recognise this. Should it fail to, the interlocking will receive incorrect information and the following train will crash into the part of the leading train which was forgotten about.

Current issues regarding ETCS implementation

Migration Policy

Migration Policy is the term used to describe a country’s policy regarding changeover from Class B to ETCS Train Protection equipment, both lineside and onboard trains.

For new or existing rail lines, in countries where Train Protection systems were previously not in use, the case for installing ETCS is good. Reliability levels on systems already installed around the world are high [2].

Where the existing Class B system only offered limited protection, a changeover to ETCS makes sense in safety terms. With regard to high speed travel, high speed lines are a relatively recent phenomenon in some countries. Again, the installation of ETCS on these new lines makes sense.

However, some countries in Europe do not see many advantages in the installation of ETCS. This is especially the case where the Class B Train Protection systems work well. Complete replacement of these systems would be enormously expensive. With regard to onboard equipment, many local train operators do not aspire to international operation and thus there is little reason to modify existing train stock. In these countries, limited ETCS implementation using mixed signalling is usually the solution, providing ETCS along defined corridors such as the ‘TEN-T’ Trans-European Transport Networks. When such countries construct new lines, difficult decisions may need to be made.

Specification Level and Interoperability

The ETCS system is still evolving.

ETCS system standards are defined in UNISIG’s

true interoperability is promised by baseline 3 ETCS, which should be ready and approved by 2012 or 2013.

Conclusion

ETCS systems are reliable and safe. They may be installed as the sole system on new rail lines or mixed in with existing signalling systems on existing lines. Both Level 1 and Level 2 ETCS can be used with or without lineside signals, and for conventional or high speed running. ETCS Level 3 promises to realise a cheap signalling and Train Protection

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Control & Safety Technology for HSR in Germany
Case Study: Cologne - Rhine/Main Line

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History of High-speed Rail in Germany

In Germany, specific plans for the nation-wide introduction of high-speed rail date back as far as the early 1970s. Germany defines high-speed rail as any railway capable of reaching speeds of $V_{\text{max}} > 230$ kph (143 mph).

The first two high-speed railways to debut in public were the Hannover to Würzburg and Mannheim to Stuttgart lines in May 1991, simultaneously with the debut of the country’s first high-speed trains named ICE 1 (class 401).

Ever since, Germany’s network of high-speed railways has steadily increased with the commissioning of additional rail specifically designed for that purpose.

Figure 1: High-speed railway ICE 1 on the Fuldatal Bridge, Solms near Niederaula (1,628 m) – Hannover - Würzburg line

Figure 2: Three high-speed railways – ICE 1 (at rear), ICE 3 (center) and ICE-T (in front) – at Munich central train station

Figure 3: High-speed rail lines in Germany
Control and Safety Systems

The development of high-speed rail required certain conditions to be met in order to deal with vastly increased speeds and the resulting increase in dynamic loads as compared to regular rail.

In Germany, demands for raising the standard in control and safety equipment continue to run abreast of the maximum speeds permitted on the country’s individual rail lines.

Even as the first high-speed (locomotive-pulled) trains went into operation in the late 1960s, it became evident that the old stationary signaling system, with distant signals placed as far as 1,500 m apart, was no longer adequate in providing train drivers with the clear advance directions they needed to ensure safe deceleration within defined distances under any conditions.

To address this problem, Germany introduced a continuous train control system called “Linienförmige Zugbeeinflussung” (LZB) in 1976. Designed as an overlay system, LZB enhances local stationary signal systems by continuously keeping train drivers up-to-date about track occupancy several track segments ahead. As a result, all railways capable of surpassing 160 kph in speed are now required by law to have LZB systems present and active.

That same decade, Deutsche Bahn made it standard to equip all track expansions with LZB systems for 200 kph of maximum speed. Equally, LZB comes standard on the new high-speed railways as well.

Most of Germany’s high-speed railways today are controlled by means of electronic signal boxes (ESTW). Furthermore, all tracks are laid out for two-way traffic, meaning all tracks can equally handle both directions of traffic.

In addition to the automatic train control systems (LZB), all of Germany’s high-speed railways in operation today rely on local stationary signals and other exclusively national safety systems. Further facilitating railway operations are standard systems like train number indication (ZN) and train routing (ZL). Railways equipped with ESTW are primarily managed from operation centers (BZ) with a host of backup control systems at their disposal.

As high-speed rail lines are rarely open to trains not equipped with automatic train control, the use of local fixed signals is now mostly limited to railroad junctions and stations.

Case Study: Cologne – Rhine/Main High-speed Line

Line Management and Significance

The Cologne – Rhine/Main high-speed railway opened in August 2002, capping approximately seven years of construction.

Roughly 180 km, this railway links the cities of Cologne and Frankfurt. New routes were built to further link the railway to Cologne Bonn Airport and to the cities of Wiesbaden and Mainz. Added to that was the construction or redevelopment of long-distance train stations for high-speed rail at the sites of Siegburg, Montabaur, Limburg-Süd, and Frankfurt Int’l Airport.

Between Cologne’s central train station and the town of Siegburg, the railway first follows the old route into the Siegtal countryside until track kilometer 25, where it veers southeast and basically runs parallel to Autobahn A 3, one of Germany’s federal highways. At track kilometer 152, the rail-

<table>
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<th>Class</th>
<th>Type</th>
<th>Length (m)</th>
<th>Engine</th>
<th>Train Length</th>
<th>Train Engine</th>
<th>Train Type</th>
<th>Track Type</th>
<th>Operating Conditions</th>
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<tr>
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<td>400</td>
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<td>x</td>
<td>x</td>
<td>x</td>
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<td>15 km, 16.7 Hz</td>
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<tr>
<td>ICE 3</td>
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<td>250</td>
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<td>x</td>
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<tr>
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<td>x</td>
<td>x</td>
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<td>15 km, 16.7 Hz</td>
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<tr>
<td>ICE T</td>
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</tr>
<tr>
<td>ICE-TD</td>
<td>606</td>
<td>230</td>
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<td>x</td>
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</tbody>
</table>

Table 1: High Speed Trains (ICEs) in Germany – German producers designed and built the above train series by individually adapting them to local track and operating conditions.
way branches off to Wiesbaden and the Rhine-Main Region. At track kilometer 169, it arrives at the new long-distance railway station of Frankfurt Airport, it’s just 4 km to the two-way junction where the railway meets the Riedbahn (Frankfurt – Mannheim line).

When it comes to cutting travel time between Germany’s two most densely populated areas – the Rhine-Main Region and the Ruhrgebiet – the new railway surpasses previous Rhine railways by about one hour.

Given the unusual track layout, with a longitudinal tilt of more than 40 per mille, this railway is only open for passenger traffic. Only multiple units of the ICE 3 type train, which is specifically designed to handle steep inclines, can use the Cologne – Rhine/Main high-speed railway as regular service.

Planning Services Rendered by IVV GmbH

IVV GmbH won the bid for construction planning for the Cologne Rhine/Main high-speed line and, in particular, the north section from Cologne Central Railway Station (Hbf) to Siegburg/Bonn. Across an area of roughly 26 km, plus the Cologne Airport Loop, this planning section encompassed both the new line and the original Wiesbaden (East Rhine Railway) and Siegen (Siegi Railway) lines running parallel thereto. The fact that this section serves the combined use of S-Bahn commuter rail, local passenger service, high-speed rail, and freight traffic produced a vast network of junctions and branch-off points, which made planning particularly complex and challenging.

The most daunting part of the project, however, was in repositioning the existing rail sections (affecting freight traffic from Cologne to Niederlahnstein and passenger traffic from Cologne to Siegen) on the outer edge of the overall rail line in order to clear the center for the two high-speed lines. The result was a splintering of all the major transport networks. Since all construction had to take place without interrupting railway operations, IVV GmbH planned for at least 100 intermediate construction phases to complete the project step by step from beginning to end.

These intermediate construction phases included everything from minor modifications on mechanical signal boxes, construction process integration, and one of the most vast refitting projects to date involving an electronic signal box. Interlocking technology upgrades were required for signal boxes which ranged from pre-World War I mechanical, 1930s electro-mechanical, and 1960s track diagram types, all the way to present-day ESTW.

Another significant challenge was the narrow timeline set aside for the intermediate construction phases. Planning engineers had as little as four weeks to produce the documentation necessary to keep up with the finished stages of the project.

Planning by IVV GmbH included the sectors of control & safety technology, telecommunication facilities, underground construction for cable lines, as well as cable planning and routing for said sectors.

The contract award comprised service-rendering phases (Lph.) 3 through 7 and 9 of the German Fee Structure for Architects and Engineers (HOAI). They delineate the production process for preliminary design and approval planning, implementation planning, preparing and assisting in distribution thereof, and the documentation process including production of revision plans.

With regard to sub-contractors hired for the project, IVV was commissioned to assist client teams in the coordination of construction measures pertaining to control & safety technology as well as telecommunication facilities (project management services), and to render construction supervision services pertaining to same (Lph. 8).

The planning period for the project lasted from 1994 to 2003. Rendering planning services involved the formation of a solid team consisting of 3 engineers for control & safety planning, 1 engineer for telecommunication planning, 1 engineer for underground construction, 2 technical draftsmen, as well as project assistants. Engineers for control & safety planning were all firmly assigned to individual areas of planning (e.g., operational units at railway stations), performing planning services as assigned in each case. Another point of immense value was the in-house proximity between the technical equipment engineers and the engineer for underground construction. It never failed to ensure swift reaction to sudden changes.

Planning for all sectors was facilitated by ProSig®, a planning tool developed by IVV based on AutoCAD.
It really took the stress out of CAD jobs. The following parameters describe the extent of planning services rendered by IVV:

- 5 electronic signal boxes (incl. 1 sub-center (UZ) at Troisdorf)
- LZB center (at Troisdorf)
- Integration into operation center (BZ) Duisburg
- Approx. 400 signals
- Approx. 170 turnouts, incl. branch turnouts for V = 160 kph
- Replacement of outdated technology to adapt multiple line blocks to their connecting or branching lines

Carsten Scharf is a senior project manager for electronic interlocking systems (ESTW), signalling and multidisciplinary projects at IVV GmbH in Braunschweig. He started there as design engineer for signalling projects in 1994. He completed his studies at the University of Braunschweig in 1996 with a degree as a mechanical engineer.

References
[1] DB Guideline 800 (Design of Network Infrastructure Technology)

continued from page 26

system in the future. The migration over to ETCS can be especially challenging for countries with good existing Train Protection systems.

Richard Jackson was trained as a Railway Signalling Engineer in the UK in Newcastle and York. After working in the field of Signalling Maintenance and Technical Support on the West Coast Main Line, he moved to Germany in the year 2000. He has been with IVV since 2002, working on a variety of signalling projects, with his primary expertise in the implementation of new electronic interlockings.

References:
Selecting the Train Control System for the California High Speed Train Project

By Ed Mortlock, San Francisco, CA, 1-415-243-4780, mortlock@pbworld.com

Parsons Brinckerhoff, as the Program Management consultant for the California High Speed Train Project (CHSTP), is currently conducting the planning and engineering for the 800 mile route high speed rail project linking the major cities of California. High speed passenger rail requires the deployment of an Automatic Train Control (ATC) system to meet the safety and performance criteria. ATC must deliver the functions of Automatic Train Protection (ATP), Automatic Train Operation (ATO), and Automatic Train Supervision (ATS).

A prime requirement for all CHSTP systems is that they must comprise technology with a proven track record at or near 220 mph on at least one high speed passenger railway. This requirement arises from a need to minimize project risk. Another key requirement is that they must comply with the regulatory requirements from authorities such as the Federal Railroad Administration (FRA), the Federal Communications Commission (FCC), and the California Public Utilities Commission (CPUC). Meeting those requirements requires changes to the proven system(s) to achieve regulatory certification.

This article provides a description of ATC system concept and highlights how the changes to the candidate proven systems are being managed to meet both the regulatory requirements and to minimize technical and project risk.

The ATC System Description

The CHSTP requires an ATC system that supports the goals of the project including maximum speeds, trip times, headway, and safety thresholds. The ATC system is divided into the following functional sets:

- **Automatic Train Protection (ATP)**
  ATP is responsible for the safety-critical functions including those of interlocking (ensuring security of routes through switches), train detection, signal aspects, broken rail detection, hazard detectors that are linked to the ATC, and movement authorities (these are the sets of instructions passed to trains allowing them to safely proceed up to a defined point on the track) that are sent to the train and acted upon by the on-board train control subsystem. Positive Train Control (PTC) functions are contained within ATP.

- **Automatic Train Operation (ATO)**
  The functional set is responsible for automatic operation of throttle and brake, moving trains between stations and signalled stops within the safety constraints imposed by the ATP functional set. Some high speed systems have included partial ATO (such as Taiwan) in order to make station stops more reliable and avoid excessive caution approaching platforms as well as overrunning. Full ATO between station stops, with the Engineer overlooking the throttle and brake application by the on-board computer, will enable consistent and minimum run times to be achieved thereby increasing on-time performance. ATO will not prevent the Engineer from taking control if necessary and regular manual driving runs will be required to keep the Engineer’s skills honed.

- **Automatic Train Supervision (ATS)**
  This functional set is responsible for the centralized supervision and control of train movements. ATS monitors train positions, adjusts the performance of individual trains to maintain schedules, and provides data to adjust service to minimize inconveniences otherwise caused by irregularities. ATS also provides automatic and manual route setting at interlockings and the identification and tracking of trains, the display of alarms and events, and logging of events. The automation of many functions, including the

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1 In October 2008, as a direct consequence of the Chatsworth California train accident in which 25 people died, Congress passed the Railway Safety Improvement Act of 2008 that mandates the deployment of Positive Train Control (PTC) on all passenger and the majority of freight railroads across the country to ensure that trains operate within safe speed limits and obey stop signals independent of the actions of the Engineer. PTC requirements are detailed in the Code of Federal Regulations (49 CFR Part 236 Subpart i); CHSTP’s ATC must comply with these requirements. PTC as described by the Law and by the CFRs is being installed on many railroads as an overlay system that enforces an existing conventional signal system that uses wayside color light signals, or in some cases, signals transmitted into the locomotive cab and displayed to the Engineer in the cab. Key PTC functions require the enforcement of speed restrictions and also prevent the train from overrunning stop signals. In the case of CHSTP, the PTC functions will be integrated into the ATC system.
setting of routes and adjustment of train speeds in order to regulate train schedules, will also improve reliability of the service and on-time performance.

All three functional sets are essential for a safe and effective ATC system. Put simply, an ATC system is needed in order to meet two key goals; the first is to ensure safe operation of trains. In the case of high speed rail this is at speeds exceeding 200 mph. The second is to enable efficient use of very expensive infrastructure, including bridges, viaducts and tunnels, by running trains as close together as safety allows and to run as close to the civil speed limits (again as safety allows) so as to minimize the trip times between stations.

Safety considerations are paramount. The ATP set contains the majority of safety functions although there are also a number of safety related functions in the ATS subset, including the setting of temporary speed restrictions and the provision of safety blocks to prevent trains entering unsafe areas of track and for protecting track workers.

It is worthwhile pausing here to consider that for the first 100 or so years of the signaling and train control industry, practices were reactive in terms of safety. Systems were developed and modified in response to experience, especially accidents that led to injury and fatalities. Over the past 25 years, the industry has become proactive with safety; sophisticated practices are now standardized in order to anticipate hazards that might occur, not just ones experienced in the past. Quantification of hazard probability is also determined. The ATC design process has identified the optimum processes and standards that are being followed by the Parsons Brinckerhoff team in their conceptual design and that must be followed by the system supplier who will undertake the design, manufacture, installation, testing and placing in service of not only the ATC, but the complete high speed rail system.

The functional sets will be implemented through groups of hardware and software located on-board the train, at the wayside in rooms and cases, on the track itself, and in central control facilities. Equipment is interconnected by direct cables, by local networks, and by a high capacity fiber optic backbone connecting all high speed rail facilities.

In addition to ATC for safe operations on the main lines, a simpler signal system will be installed to control train movements within the various storage and maintenance yards and depots.

The Development of the Design
The European Technical Specifications for Interoperability (TSIs) provided the framework for the development of design for all project elements. The TSIs were developed to ensure interoperability between rolling stock and the railroad systems of all countries within the European Union. From the TSIs, a set of high level System Requirements (SRs) were prepared. The SRs were packaged and submitted to the FRA for review. With FRA feedback incorporated, the SRs are used to generate the content of a Rule of Particular Applicability (RPA) that will be used for the regulation of CHSTP high speed operations at the 250 mph design speed. Current legislation only covers speeds up to 150 mph, RPAs are required to be developed and issued by the FRA for rail operations not covered by existing legislation. This is Parsons Brinckerhoff’s opportunity to help craft legislation (in the form of the RPA) for true high speed rail operation that can be expanded to cover high speed rail systems across the country.

The ATC system is being specified at a functional and performance (design-build) level, and is being kept open to multiple technologies. These specifications essentially describe what the ATC system must do and how well it must do it. A functional requirement is that the system must ensure that trains do not exceed civil speed limits at any point on the track; a performance requirement is that it must be available 99.99% of the time. The number of candidate systems that have proven high speed operational experience is limited and consists essentially of the European Rail Traffic Management System (ERTMS), the Chinese Train Control System (CTCS) (which is very similar to ERTMS), and the Japanese Shinkansen (Bullet Train) technology. The first two systems use radios to communicate safety critical information and commands to the trains, the latter uses inductive coupling between the running rails and truck mounted antennas.

As part of Parsons Brinckerhoff’s scope, a study was conducted in 2009 that identified the candidate technologies. In mid 2010, a Request for Information (RFI) was sent to train control suppliers worldwide, including Japanese, European (ERTMS), and domestic U.S. The RFI provided excellent input to the specification development process and validated design assumptions.

A detailed review of the candidate technologies indicates that they will require minimum modifications to satisfy the Code of Federal Regulations (CFR) requirements. The biggest impact of needed modifications is the availability of radio frequencies required for ERTMS or CTCS. Both use Global System for Mobile Communications - Railway (GSM-R) which incorporates frequencies in the high 800 and low 900 MHz range. GSM-R has been specifically assigned for railway use (hence the R in the acronym) throughout Europe and has recently been adopted in China for the same purpose. These same bands are unavailable within the U.S. as they are used for public cell phone and data use. Service providers in these bands have paid high-ly for their spectrum and invested heavily in equipment. The availability of alternative bands is being examined for
the project and the FCC is being approached for support. Figure 1 illustrates the concept ATC overall system architecture. Figure 2 illustrates the ATC on-board subsystem architecture that will be installed on passenger trainsets.

**Conclusions**

The impacts of federal legislation (CFRs governing train control) are likely to be minimal. Of greater impact is the availability (or lack thereof) of radio spectrum to support the implementation of the proven radio-based ATC technologies. Modifying the radio portions of the system to alternate frequencies, perhaps having to divide the frequencies used (bandwidth) into small parcels in different portions of the radio spectrum, will be a major technical risk for the project. The technology assessments identified those systems with potential to comfortably meet functional and performance requirements. The industry responses to the RFI validated the conclusions of that study and also provided the opportunity to seek supplier counsel on the problems of radio spectrum. This project has placed Parsons Brinckerhoff in the forefront of high speed rail and high speed train control in the U.S. The adaptation of proven technologies to work within the U.S legislative framework is cutting edge and could be of significant value to high speed rail projects in other states.

Detailed functional and performance specifications are now being prepared with construction of the first segment of civil works scheduled to start in 2012 in the Central Valley.

*Ed. Mortlock* has over 30 years experience in transit and railroad signaling and train control applications, focusing on advanced technology systems. He began his career with London Underground’s signal engineering department and worked on several signal modernizations schemes across the network, predominantly with signal system testing and commissioning. He has subsequently worked in management of operations and maintenance. Since moving to the United States in 1990, Mr. Mortlock has worked on a wide variety of conventional and new-technology train control projects in the U.S. and worldwide on light rail, metro, and heavy rail technical environments. He is currently managing the design activities for train control systems for the California High Speed Rail Project.
A Database to Support the Development of a CHSTP Rule of Particular Applicability

By Matthew Petty, San Francisco, CA, 1- 415-243-4614, pettym@pbworld.com

The CFR and the RPA

The US Code of Federal Regulations (CFR) describes safety requirements for railways up to 150 mph. The California High Speed Train Program (CHSTP) has a much higher design speed, so a Rule of Particular Applicability (RPA) - an extra rule which applies particularly to a specific project - was necessary.

The RPA process requires a Basis of Equivalency – a statement that the proposed new code will be as safe as, or safer than, the existing code. The CHSTP System Requirements (SRs) were created to track the CHSTP disposition and record the Basis of Equivalency to each relevant part of the CFR. The most efficient way to do this was in a relational database developed in Microsoft Access.

Developing the SR database

The CFR is freely available online at the Government Printing Office. A batch script downloaded the relevant sections to text files, stripped unnecessary text, and imported them to the SR database. The CFR changes annually, causing considerable effort to update the local copy, so it was later replaced by a hyperlink to the relevant section of the official online source.

The initial SRs were based on the European Technical Standards for Interoperability (TSI). The table of contents of the TSI subsystem documents was extracted and imported into the SR database to create a proposed list of SR titles.

The database was used as the data source for a mail merge operation which created a set of Microsoft Word SR forms, with areas for the subsystem engineers to complete their requirement information based on knowledge, regulations, standards, and the CHSTP Basis of Design Policy. Space was also provided for the engineers to state which CFR sections were addressed (or superseded) by the SR, along with a detailed Basis of Equivalency.

The SR forms were held in the project’s document control system, ProjectSolve. After peer review, they were considered “50% complete”, and after subsystem manager review, “75% complete”. They were then gathered into about 50 topic-based packages, and reviewed in meetings with FRA representatives, after which they were classified as “95% complete”. The SRs were then manually copied into the SR database, and archived.

Using the database

The SR database holds all the information related to the SRs, CFRs, TSIs, and the complex relationships between them. One SR could address many CFR sections, and one CFR section could be addressed by many SRs. SRs could also link to each other to track interfaces, and to standards to track compliance.

Database outputs included:

- Substance of the Rule - suggested RPA wording based on the SR text.
- CFR disposition - correlation between SRs and CFR sections, including Basis of Equivalency.
- SR lists with varying detail.

The SR database is fully auditable, and documents a holistic approach for preparing the applicable federal and state regulations, HSR design requirements, design criteria and standards, progress tracking and standards compliance reports, and interface management.

Lessons Learned

Create a Requirements Management Plan, incorporating a specification for an off-the-shelf requirements management software package. A small investment at the start can greatly reduce migration and re-engineering later.

Don’t store locally what is freely available online from an official source.

Systems Engineering is widespread in other industries, such as software development, aerospace and defense, but not as much in transportation or civil engineering. It is hoped that this large and prestigious multi-disciplinary project will aid the growth of Parsons Brinckerhoff’s Systems Engineering capability.

Matthew Petty has been with Parsons Brinckerhoff for over 11 years, during which time he has worked on prominent transportation projects in the UK and US, as well as large-scale telemetry projects, applying his data collection and analysis skills to streamline the configuration management and assurance processes. He has a background in localized and wide area control systems, and is currently using his experience to grow PB’s Systems Engineering capability by engaging with the International Council on Systems Engineering (INCOSE).
The German Unity Transport Projects (VDE\footnote{Verkehrsprojekte Deutsche Einheit}) were approved by the German government in 1991 following the country’s reunification, with 13 billion euros slated for expansion of the Munich – Berlin corridor.

VDE 8 high-capacity rail is designed to meet the present and future demands of passenger traffic and freight traffic in an eco-friendly manner. Part of the North–South corridor is in eastern Germany, and it is joined by the expanded and new rail section between Nuremberg, Ingolstadt and Munich to the South. As such, it forms a vital link within the trans-European traffic network that stretches from northern Italy across Austria, Munich, Berlin, and as far as Scandinavia.

VDE 8 is divided into the following sectors:

- **VDE 8.1 Expanded rail section (scheduled to open in 2017)**, 83 km, Nuremberg – Ebensfeld, including S-Bahn commuter rail Nuremberg – Forchheim
- **VDE 8.1 New rail section (scheduled to open in 2017)**, 107 km, Ebensfeld – Erfurt
- **HUB at Erfurt**, 5 km
- **VDE 8.2 New rail section (scheduled to open in 2015)**, 123 km, Erfurt – Leipzig/Halle (23 km in operation since June 2003)
- **VDE 8.3 Expanded rail section (open since May 2006)**, 187 km, Leipzig/Halle – Berlin

**VDE 8.2 New Rail Section between Erfurt and Leipzig / Halle**

At a length of 123 kilometers, this section is laid out as double-track rail for mixed traffic (passenger and freight trains). It is designed for a top speed of 300 kph and runs through the states of Thuringia, Saxony-Anhalt and Saxony.

Starting at Erfurt central railway station, the new rail section runs parallel to existing track before crossing the Saale – Elster – Aue valley on the viaduct south of Halle and continuing east to Leipzig. On the Saale-Elster viaduct, the connection veers north toward Halle to join the existing Weißenfels–Halle railway. Incorporating this branch turnout with the viaduct presents engineering at its finest in that it connects the track leading to and from Halle to the main transit traffic without traversing various areas. The viaduct spans approximately 6.5 km in length, while the branch turnout to Halle runs approximately 2.1 km in length. The gateway at Halle was completely rebuilt to accommodate two new sets of track. Construction involved applying the conventional interlocking technology (electromechanical signal or NX towers) available on location and adapting them to the control points nearby. Construction was completed in Summer 2006 for the commissioning of ESTW-A Halle-Ammendorf, the southern link to Halle, paving the way for the completion or near-completion of other projects to reach the final stage and incorporate the new rail section.

Going to Leipzig, the rail section runs through the Saal district community of Gröbers where it joins the existing Halle-Leipzig railway. Upon entering the train station at Gröbers, all freight traffic transfers from the new rail section to the existing rail toward Leipzig for subsequent connection to the airfreight service, freight village and the container terminal at Leipzig-Wahren. Passenger traffic entering the station switches to the new 23-km rail section between Gröbers and Leipzig, completed in 2003. Gröbers is also where non-ballasted track turns ballasted, reducing speeds to 250 kph.

From Gröbers, the rail section continues on to cross the highway intersection at Schkeuditzer Kreuz (federal high-
ways A9 Nuremberg–Berlin and A14 Magdeburg–Dresden, running parallel to A14 via the train stations of Leipzig/Halle Airport and Messe Leipzig before merging with the existing Berlin–Leipzig railway on its way to Leipzig’s central railway station.

**Planning Services Provided by IVV GmbH for Sector VDE 8.2**

With offices in the cities of Braunschweig and Leipzig, IVV GmbH has been actively contributing its planning services to the aforementioned sector since 1993. These services include everything from preliminary planning for telecommunications and signal technology, draft planning and final planning documentation. All planning stages required detailed coordination with planners of physical and engineering structures as well as material planners. Add to that requests filed with the German Federal Railway Authority for the financial resources necessary for the facilities that IVV GmbH took into account in its draft planning.

Producing the construction documentation for the three electronic signal towers in the Gröbers – Leipzig sector was the task of the IVV GmbH office in Braunschweig. In addition to part 1 of the planning stage, their documentation comprised the planning for the train number log and guidance systems. The latter involved a combination signal system with speed signaling using speed indicators and speed pre-indicators. Axle counter technology, based on a bus system, serves to monitor block occupancy. The sector is currently used at speeds of 160 kph. Beginning in 2012, Gröbers station will undergo further construction to accommodate the new rail section.

The sector is scheduled for a pilot run between Erfurt central railway station and Gröbers to take place in approximately 2014 as it is planned to open 2015. An intrinsic part of the sector is the European Train Control System (ETCS) Level 2 without fallback level. The only exception here is the Gröbers – Leipzig section, which retains the use of its existing signals as a fallback level. Along with the mobile radio standard GSM-R, the ETCS system is the blueprint for the European Rail Traffic Management System (ERTMS).

**ETCS Level 2 Migration Strategy:**

- Recommended for new high-speed rail
- Significant increase in train density
- Line equipment directly available with ETCS Level 2 systems
- Complex wiring, e.g. in automatic train control (ATC), is made obsolete
- Optional wayside signals are not installed or, if present, kept dark
- ETCS Level 2 is implemented within corridors; i.e. cross-border traffic

The Radio Block Center (RBC) is an automatic control system for ETCS traffic in Level 2. The RBC serves as the interface between interlocking and movement authority management via GSM-R. A Radio Block Center controls a defined track section based on the management subsystem range of an electronic signal tower. The primary functions of the RBC are to:

- Analyze electronic interlocking data and manage movement authorities for ETCS vehicles
- Transmit standard control information (movement authorities, train stops, etc.) to ETCS vehicles via a Europe-specified EURORADIO protocol using GSM-R
- Record location data via GSM-R
- Monitor the safe separation and speed of trains within a given block.

Once planning concludes for the southern link to Halle (ESTW-A Halle-Ammendorf) and for building construction at Gröbers train station, the stage is set for generating the construction documentation for control and safety technology in the Erfurt – Gröbers section.

Planning for the telecommunication systems comprises, among others, equipping the section with hot-box locators and supplying the signal towers with burglar and fire alarms plus the required transmission technology. It further comprises the installation of copper and optical fiber cables necessary for GSM-R and the bus connections to function in the signal towers.

All aforesaid services are rendered directly on behalf of DB ProjektBau GmbH.

Participation in bidding consortia resulted in contract awards for other services as well, such as the construction documentation for overhead lines and electro-technical equipment. The Finne and Bibra Tunnels are two examples of the latter.

Contracts for ETCS planning are awarded via call for proposals to the appropriate vendors. Given its long history of comprehensive service to the project, it is the goal of IVV GmbH to receive the contract for ETCS planning services as subcontractor of the signal technology provider. Customer satisfaction, adherence to timeframes and carefully planned budgets, along with maintaining high quality standards, are crucial to continued involvement in any measures regarding sector VDE 8.2 and beyond.

**Holger Taschowsky** has a master’s degree in railway signalling engineering from the Techni-cal School for Traffic System in Dresden (Fachschule für Verkehrswesen Dresden). After 6 years working as planning engineer for signalling and control systems, he joined IVV in 1998 and is currently a design engineer and senior project manager in the Leipzig branch office.

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2 Global System for Mobile Communications - Railway
Overview of HSR in China with a Focus on the Overhead Contact Line System for the Wuhan Guangzhou HSR, the Fastest Railway in the World

By Gerhard Zimmert, Balfour Beatty Rail, Beijing, People’s Republic of China, +86 (0)10 6590 0610/11, gerhard.zimmert@bbrail.com

The People’s Republic of China is consistently implementing its ambitious programme for the expansion of railway infrastructure, and electrification of the high-performance lines is crucial to this.

A particular technical challenge is the realisation of a high-speed network for passenger traffic (Passenger Dedicated Lines), providing operating speeds of 250-350 km/h (155-217 mph). By 2020 this network is to comprise about 17,000 km of track. The magnitude of this task becomes all the more clear when you consider that only ten years ago operating speeds of 120-160 km/h were only possible on a handful of main lines.

The objectives for 2020 have meanwhile become even more ambitious, in that by 2020 the total railway network is to grow to 120,000 km, over 70,000 km of which is to consist of electrified lines.

For over ten years Balfour Beatty has been the strong partner supporting the Ministry of Railways’ electrification plans, and during this time it has realised over 15 major projects in China, having been directly involved in about 8,000 km of line.

Development of the high-speed network

As early as in 2004 the new Qinhuangdao-Shenyang line opened in northeast China. This was the first line intended exclusively for passenger traffic. The project involved extensive attempts to realise speeds of over 200 km/h, and in particular drew on the experiences of Japanese, French and German railways for every aspect, e.g. track, signalling technology, rolling stock and, of course, electrification. In parallel with this, every opportunity was grasped to raise the speed on important main lines in the existing network. A speed increase to 200 km/h was undertaken on some important lines in 2007. These lines were already equipped with modern overhead contact line systems, which in terms of system parameters largely correspond to Germany’s Re 250 overhead contact lines.

At the same time, work started on planning and building new lines for speeds of 250-350 km/h and, by 2010, there were already 3,500 km of these so-called Passenger Dedicated Lines or PDLs.

From the very start German industry and, in particular, Balfour Beatty helped Chinese Railways with technology transfer, formation of powerful joint ventures, deliveries, engineering and consultancy. This assistance applies to lines such as:

- Beijing-Tianjin (length approx. 115 km, operating speed 300 km/h). This line was equipped by Siemens AG, and came into operation for the 2008 Olympic Games.
- Wuhan-Hefei-Nanjing (length approx. 550 km, operating speed 250 km/h).
- Wuhan-Guangzhou (length 969 km, operating speed 300 km/h).
- Zhengzhou-Xian (length approx. 425 km, operating speed 300 km/h).
- Beijing-Zhengzhou-Wuhan (length approx. 1200 km, operating speed 300 km). The line will come into operation at the end of 2011.

An overview of the high-speed network and the important lines under construction are shown in Figure 1.

The electrification project Wuhan-Guangzhou

The Passenger Dedicated Line, Wuhan-Guangzhou, constitutes the first major section of the high-speed line Beijing-Zhengzhou-Wuhan-Hong Kong (Figure 2).

Important data on lines and operation:

- Total length: 969 km of new line, including 75 bridges and viaducts (410 km)
33 tunnels (167 km)
18 stations
• Target speed: Design speed and collection speed – 350 km/h
  Operating speed – 300 km/h
• Minimum succession of trains: 3-minute frequency of multiple units (8 waggon and 2x8-waggon units)
• Energy supply system: multivoltage system with autotransformers 2 AC 50/25 kV 50 Hz

Since 26 December 2009 scheduled multiple units have been operating on the Wuhan-Guangzhou line using single and double traction (1xEMU (Electrical Multiple Unit) / 2xEMU) at a cruising speed of 320-330 km/h (198-205 mph), making it the fastest railway line in the world. A top speed of 394.2 km/h (244 mph) was achieved on 9 December 2009 using 2 regular EMUs (Figure 3).

Balfour Beatty Rail’s main tasks in the project were:
• Drawing up the basic design for a high-speed overhead contact line together with the Chinese planning institutes (the concept for the overhead contact line system was based on experiences from the German Re 330 overhead contact line design);
• Supervision of design, installation and commissioning, which will involve over 20 German experts;
• Delivery of overhead contact line components; and
• Delivery of dynamic and optical measuring technology for inspection and approval of the overhead contact line.

Assumption of responsibility for the high-speed overhead contact line (350 km/h) involved these tasks.
The overhead contact line system for the Wuhan-Guangzhou line

For the overhead contact line concept Balfour Beatty Rail has built on the technical experiences in electrification of the Nuremberg-Ingolstadt line using the Re 330 design and of the new Spanish line, Madrid-Lerida, using the EAC 350 design.

The following are being used for the overhead contact line:

- Magnesium-alloy copper wires with a cross section of 150 mm$^2$ (CTMH 150) and a tractive effort of 30 kN
- Bronze messenger wires with a cross section of 120 mm$^2$ (JTMH 120) and a tractive effort of 21 kN
- Stitch wires with a cross section of 35 mm$^2$ and a tractive effort of 3.5 kN
- A consistent aluminium design was chosen for construction of the cantilevers (Figure 4).

The dynamic properties of the overhead contact line system for the Wuhan-Guangzhou line (a comparison)

As a result of the close cooperation between Chinese Railways with German industry – especially Balfour Beatty Rail – a new standard for overhead contact line systems has gradually developed in China over the past 10 years, to a great extent based on German experiences.

Figure 5 shows the system parameters for the lines currently in operation using speeds >300 km/h.

It is to be recognised that for all systems the theoretically expected wave-propagation and operating speeds as a result of the high tractive effort in the contact wires are over 350 km/h. On the Beijing-Tianjin line no stitch wire was used, at the request of the customer, but the Ministry of Railways (MOR) later recognised that the positive effect of the stitch wire on the dynamics (behaviour of pantograph and contact wire) should be used in the high-speed area.

In addition to the theoretical wave-propagation speed, the elasticity of the overhead contact line is crucial to good pantograph current collection from the contact wire. The elasticity is the uplift of the contact wire with a defined load (measured in mm/Newton). The elasticity should be very low (for high speed lines <0.5 mm/N) and very even between the support points (overhead contact line masts).

Figure 6 shows the comparison between elasticities in the three Chinese systems.

It is clear that elasticity is naturally highest between the support points. At the same time one can see that the stitch wires at the support point make elasticity in the stitch-wire area even and thus give reason to expect more favourable conditions than for the overhead contact line without stitch wire. In comparison with this, the elasticities for the high speed overhead contact lines Re 250 and Re 330 in Germany are shown.

During the commissioning phase all theoretically gained values were to be demonstrated through...
practical measurements. For this purpose a Type CRH2 EMU was equipped with Deutsche Bahn’s measuring technology (force measurement and contact-free geometric measuring technology) (Figure 7).

In particular, the contact force between pantograph and contact wire is crucial. It should stay low within a given range, but should not go below zero, as the pantograph then loses contact. In the European specification TSI (Technical Specification for Interoperability), subsystem Energy Expenditure 2008, the relevant requirements are in place, but they only extend to a speed range of 320 km/h (see Figure 8).

The tests on the Wuhan-Guangzhou line went up to a speed of 360 km/h (223 mph), and the emphasis was on measurement of contact force.
Typical contact-force results are represented in Figure 8 for the pantograph during lateral and knee movement. The results lie within the expected average range for contact force, but are significantly lower than the requirements for the maximum values and significantly greater than the minimum requirements.

**Final comments**

After a total construction period of only 4½ years, at the end of December 2009, the approx. 1,000 km new line between Wuhan and Guangzhou in the People’s Republic of China commenced scheduled services. With a cruising speed of approx. 320-340 km/h (198-211 mph) it is the fastest railway connection in the world, and the dynamic behaviour of the overhead contact line and the pantograph increasingly determines the maximum speed of the overall system. Globally there is little experience of dynamic behaviour in this speed range. Balfour Beatty Rail developed the basic design for this line, was crucially involved in realisation and was thus also responsible for establishing the quality of the overhead contact line. A number of trips to measure the geometry and the contact power behaviour verified the suitability of the system.

Chinese Railways will now be using the experiences gained on this line to further develop its high-speed technology.

**Professor Gerhard Zimmert:** Study of electric railways at Dresden’s ‘Friedrich List’ College of Transport until 1971; until 1992 Head of Electrification Department at Deutsche Reichsbahn’s Testing and Development Works; from 1992 work for AEG, Adtranz and Balfour Beatty Rail as Project Manager Converter Works Jübek, Head of Technology; since 1999 work in China: Overall Project Manager for the Balfour Beatty Rail/Siemens consortium for electrification of the Harbin-Dalian line in Shenyang; 2002-2007 Head of Balfour Beatty Rail’s Representational Office Beijing; 2007-2010 Project Manager Balfour Beatty Rail for the Wuhan-Guangzhou electrification project in Wuhan; since 2010 Chief Engineer Balfour Beatty China in Beijing; Honorary Professor at Darmstadt Technical University.

**Figure 8:** Required and measured contact forces between pantograph and contact wire
Italy’s High Speed Rail Network

By Paolo Steffanini, Balfour Beatty Rail, Milan, Italy, +39 0289536100, paolo.steffanini@bbrail.com

Part of the European Master Plan, proposed by the EU in the mid-1980’s for a network of new high speed lines across Europe, is the 300 km/h (186.41 mph) Italian high speed network. The Italian entity of the Balfour Beatty Group, as a member of the Saturno Consortium, was commissioned by the Italian State Railways (RFI SpA) to design and construct the power and electrification systems for the 4 main sections (about 600 km - double track) of the high speed rail plan. These sections are: Turin – Milan, Milan – Bologna, Bologna – Florence and Rome – Naples.

The scope of work for each section included 132/150 kV HV transmission lines (overhead and underground), 2x25 kV AC overhead contact lines, 132/25 AC and 132/3 kV DC substations, 2x25 kV AC autotransformer station, LV power supply and the remote control system. This high speed rail project was particularly challenging in terms of geography, environment and impact on communities, thus enabling Balfour Beatty Rail (BBR) to develop unique technological and sustainable solutions.

The Italian HS network links the major cities of Italy in an east-west, north-south direction (see Figure 1). Corridor 5 of the Trans European Transport Network (from Lisbon to Kiev) runs through Turin, Milan and Venice to the Slovenian border. The section which crosses central Italy is encompassed in Corridor 1 (Berlin – Palermo axis) and runs southwards through Milan, Bologna, Florence, Rome and Naples. It requires crossing complex geographical conformation of the territory, environmentally sensitive areas, population centres, natural barriers such as the Apennine mountains and the “fiume Po”, the longest river in Italy.

Underground electrical sub-station in Florence

In the Appenine area, 93% of the rail section between Bologna and Florence runs in tunnels (Figure 2), posing many restraints and thus leading to the development of new systems and methods of construction. An example is the underground electrical sub-station (ESS) built in Florence. To comply with the technical specifications and the configuration required by RFI (the Italian State Railways) for the Italian high speed rail and due to the many tunnels along its route, it was necessary to locate an ESS.
in a highly sensitive area in terms of environment and population. The solution was to design and build a completely underground 132kV ESS, thus solving both technical issues and mitigating impact on local communities in a historical and archaeological area, preserving Tuscany’s hilly landscape as well. Construction itself was very challenging because all equipment, including 2 60MVA transformers, had to be lowered 60m underground. Other fixed installations (including ventilation systems, fire detection and suppression systems, automatic partition and closure systems for fumes in case of an emergency) had to be specifically designed and put in place for this underground environment. In the Italian rail sector, this ESS is the largest and most unique.

MATS system for high speed Bologna-Florence section

The safety requirements were considerable. To ensure the highest safety level in the event of failures inside a tunnel, BBR designed and developed an automatic earthing (grounding) system for the contact line (MATS) which is controlled, monitored and managed both locally and from the central control room (DOTE). The system was installed in all tunnel accesses.

The Italian Ministry for Transport and Infrastructure passed a law in 2005 for safety in the rail tunnels (Law Decree 28.10.2005) and the European Technical Specifications for Interoperability (TSI) (UE 2008/163/CE) defined the minimum distance between electrical line sectioning points and safety guidelines for installation in a rail tunnel. Because of this, the contact line increased the line sectioning (with additional disconnectors) and every tunnel access needs an earthing switch. The automatic earthing system for the contact line that BBR designed and developed has the following components:

- 25kVca (1 pole or 2 pole) disconnector (2,000 Ampere interruption power)
- 25kVca (1 pole or 2 pole) earthing switch (16kA electricity short) - optical wire for connection
- PLC for controlling, monitoring and communication (type safety PLC XPS-MF40)

Figure 3 shows the typical installations in every tunnel of high speed Bologna-Florence section.

If a problem occurs in the tunnel, the emergency team pushes the button near the access of the tunnel; this action activates an automatic sequence from the central control room (DOTE) to ensure that the contact line is disconnected and all the lines are safe (without electricity). After this, the emergency team can enter the tunnel.

Special care was taken for the safety and health of the people working in tunnels. Interface between the local health unit, the hospital, the general contractor and the other partners guaranteed the safe evacuation of an injured worker in less than 15 minutes in tunnels up to 20km long. A dedicated GSM emergency telecommunication network and an emergency rail-road ambulance service with lights for the emergency routes were also provided as well as fire extinguishers and anti-gas kits for

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2 Automatic Earthing System – Messa a Terra in Sicurezza
Green solution along the Turin-Milan high speed section

We were able to minimize the environmental impact of the railway infrastructure by designing transmission line towers which featured a double-circuit line and two pile-based towers instead of the traditional four piles. The design led to a notable reduction of impact to the ground area on farmland and industrial property. The local community was fully engaged and this led to moving the line from zones designated for a future housing development and the grounding of cable in urbanized areas. Phasing of construction activities took into consideration local agricultural activity. Also, to minimize the impact on bird fauna, transmission lines were placed parallel to existing lines in feeding and nesting habitats, such as the Ticino River. Electromagnetic fields were reduced through the inversion of the transmission phases.

Design of contact line and innovative regulation system for the cantilevers

The 25kV system has been implemented for the first time in Italy with the high speed network. With our client (RFI SpA), we developed and designed solutions for power and electrification.

The contact wire suspension was expressly designed for high speed lines, with the purpose of simplifying assembly and maintenance. All the structural parts are aluminum and the length can be adjusted on site by means of pins, thereby minimizing the time of erection and eliminating the necessity of performing measurements. In Figure 4 we can view the new concept of cantilevers.

The contact line was designed by using a program that could simulate the interaction between pantograph and the catenary. The result of this study led to a contact line having the following characteristics:

**Required specifications**

- Running speed 300 km/h
- Reliability (failure rate per km) 7.97 x 10^-7
- Pantograph separation <1:200 sec
- Contact force Fcm -3σ ≥ 30N

Note: Fcm = contact force mean value
σ = standard deviation

**Environment and line characteristics**

- Running speed 300 km/h
- Track gauge 1435 mm
- Distance between tracks 5 m
- Minimum radius 5450 m
- Maximum wind speed for operation 100 km/h

Contact wire section 150 sqmm and 20 kN tension
Messenger wire section 120 sqmm and 16,25 KN tension
Droppers 9 droppers per span
(length of standard span 60 m)

A prototype of the contact line was then built on the “Direttissima Florence-Rome” line, in order to test the theoretical calculation; the experimental data successfully validated the simulation. A value of about 50 N was found for both the first and the second pantograph and no contact loss was recorded. The contact line was designed to ensure a failure rate (MTBF) of 1,250,000 hours per km of line or a reliability of 0.994; this result was achieved by means of an accurate selection of the catenary components and the reduction in maintenance need.

A further innovation was introduced in an experimental section along the Turin-Milan line with a special contact wire made up of a copper/magnesium compound which is more resistant, improves performance and life cycle, and makes the collection of current by the pantograph more efficient.

Conclusion

The rail line has met all expectations and, while doing test runs between Bologna and Florence, the Frecciarossa train set a new Italian high-speed record of 362km/h (224.9 mph), and reached the world high-speed ‘indoor’ record inside the 9km (5.6mi) long Monte Bibele tunnel.

The whole network was completely opened for commercial service in December 2009 and was welcomed successfully by the wider community and the media. In this time it has proved to be competitive with air traffic (especially along the Milan-Rome route) and car traffic and has been likened to

*continued on page 47*
New and Expanded Karlsruhe–Basel Rail Line

By Detlef Fischer, IVV GmbH, Leipzig, Germany, +49 341 6964223, detlef.fischer@ivv-gmbh.de

The new and expanded rail line from Karlsruhe, Germany to Basel, Switzerland is high-priority under Germany’s Federal Railway Infrastructure Development Act (BSchWAG). The double track of the Rheintalbahn (Rhine Valley Line or Rtb) is undergoing expansion into four tracks to boost its capacity.

As a rule, the expansion involves placing two new sets of track adjacent and parallel to the existing double track. Plans call for each set of track to serve as a separate line (new line: Line 4280; Rtb line: Line 4000). The new line is laid out for $v_e = 250$ kph (155 mph) and the Rtb line for $v_e = 160$ kph (99 mph). In rail sections where the track layout of existing routes prevents the conceptualized speed of $v_e > 160$ kph, the parallel track layout between the new line and the Rtb line is discarded in favor of a separate track layout for the new line.

The objectives of Deutsche Bahn (DB) are to include the rail lines of the Karlsruhe – Basel corridor in its priority network, to separate the fast-moving and slow-moving traffic and ultimately to maintain a performance-based and cost-efficient railway service. In its designation as “Corridor 17”, the new-expanded Karlsruhe – Basel line forms part of the Trans European Network (TEN) corridor of Rotterdam-Genoa. DB’s strategy, called Network 21, pursues restructuring measures, standardization, separation/harmonization, elimination of bottlenecks, deployment of new technologies and full use of opportunities in transportation with the ultimate goal of boosting railway traffic. In other words:

- Allocation of sufficient capacities on an as-needed basis
- Competitive travel time
- High availability of installations
- Massive reduction of network operating costs

Network 21 presents overall strategy based on a set of three intertwined and interdependent “packages”:

**Package 1**
- Optimization of existing network
- Increase in replacement investments
- Separation and harmonization of traffic networks

**Package 2**
- Modernization of control and signaling technology

**Package 3**
- New and expanded rail lines for maximum net effect

The expansion of this rail line corridor was further concerted in an agreement between the Federal Republic of Germany and the Swiss Confederation in 1996. The agreement establishes the Rheintal line expansion as the continuation line connecting to Switzerland’s New Railway Link through the Alps, NRLA (Neue Eisenbahn-Alpentransversale, NEAT), in step with traffic demand and synchronized with each other.

Planning Services Rendered by IVV GmbH

The Karlsruhe-Basel project is arranged into nine sections. IVV GmbH was awarded the contract for overall structural and equipment planning in Section 9 of the new and expanded Karlsruhe-Basel line, between Buggingen and Basel Badisch-Baden.
er Bahnhof station (approx. 40 km in track length, 5 stations). The section includes the Katzenberg railway tunnel, with 9.6 kilometers of double track (see Figure 2).

The contract involves the planning and design of the following structures and equipment:
- Control and signaling technology (interlocking systems)
- Telecommunication and signaling facilities
- Catenary systems and traction power supply
- Electrical systems (50 Hz)

**Control and Signaling Technology**

The planning and design of control and signaling technology involves the construction of new signaling systems as well as adjustments/upgrades to existing signaling systems.

The train stations of Müllheim, Schliengen, Haltingen, Weil am Rhein and Basel Badischer Bahnhof face significant changes to their track layouts. This requires various construction plans for their signaling systems. At the train stations of Müllheim and Schliengen, these plans include the replacement of existing relay interlocking technology with ESTW\(^1\) technology. The train stations of Haltingen and Weil am Rhein will be left with existing relay interlocking technology and will be fitted with a FL90 remote control for connection to the newly built electronic interlocking at Basel. The same interlocking will also serve Basel Badischer Bahnhof station.

With regard to the junction at Buggingen, the control and signaling concept of the construction project calls for the construction of an ESTW subordinal control center (UZ). The ESTW subordinal control center at Buggingen will be unmanned and controlled via the operations control center at Karlsruhe. It will be connected to the Karlsruhe operations control center in redundant fashion via an open network (TCP/IP).

The ESTW subordinal control center commands the new signaling systems in the southern section of the Rheintalbahn between the towns of Heistersheim and Rheinweiler, the freight bypass and new section between the towns of Teningen and Haltingen, as well as the trackside computers at Buggingen, Müllheim, Schliengen stations and Lehen crossover.

An intrinsic part of planning remains the conformity of the line installations to the Technical Specification for Interoperability (TSI). In terms of control and signaling technology, this entails European Train Control System (ETCS) Level II equipment. The current automatic train control system (LZB) of the rail line will extend to the new section. This is necessary to allow a transition period for mixed traffic, including trains not equipped with ETCS. Further planning components include systems for train number indication and train routing.

**Telecommunication and Signaling Facilities**

Core elements in planning the telecommunication facilities include equipping the rail section with hot-box detection systems and outfitting the modular structures of the signal towers, as well as the control facilities of the Katzenberg tunnel, with burglar and fire alarm systems.

**Catenary Systems and Traction Power Supply**

Construction on the new rail section involves the installation of an Re 250-type catenary system in single-pole design. The Katzenberg tunnel section will have an Re catenary system.
330-type catenary system installed. Planning for the traction power supply of the new rail section comprises extensions and up-grades in the existing substations at Müllheim and Haltingen, along with the required rewiring of feed and return cables.

An additional component planned for the catenary systems is remote control technology. This entails a complete redesign of the local control equipment. Once in place, the new equipment will be connected with both existing and redesigned switches.

**Electrical Systems (50 Hz)**
Planning the electrical systems comprises the power supply of the Katzenbergtunnel, its equipment facilities (including signal towers), operating facilities, platform lighting, emergency lighting and switch heating systems.

The new and expanded Karlsruhe-Basel Line, a very complex design project, is an outstanding opportunity for IVV GmbH. The unique challenge lies in combining modern high-speed line equipment with existing technology. It demonstrates our special competence in planning and designing future high-speed railway projects.

**Detlef Fischer** has a Master’s Degree in electrical engineering from the Technical University Dresden, Germany, 1994. He was planning engineer for control and signaling systems at IVV GmbH in Leipzig since 1994. Currently he is senior project manager for the Karlsruhe-Basel line planning project.

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a huge national metro linking cities rapidly and efficiently.

BBR owes much to the Italian high speed project. Because of the client’s recognition of the value of the work done, they are currently reviewing and modifying the specifications for all MATS-like projects and there is an opportunity for our companies to explore together the potential implementation of MATS in all national tunnels. It has been a tremendous experience in all safety related issues. Building under the Appenines presented extreme conditions and led to both exceptional safety measures and a change of attitude in workers who started to take action with a “make safety personal” approach.

To conclude with a look to the near future: “The challenge for BBR is making infrastructure more and more sustainable in business, social and environmental terms; and in motivating customers, suppliers and decision makers towards this vision with the harmonious aim of modernizing the infrastructure, improving quality of life and preserving the country’s unique beauty”.

**Reference publications**
2. Connect, issue 3, spring 2009, # 4-11 http://www.bbrail.com/Media-Library
7. University lecture: “La sottostazione elettrica sotterranea di Firenze Castello per l’alimentazione della tratta ferroviaria dell’alta velocità Firenze Bologna” – available only in Italian

**Paolo Steffanini** has been working for Balfour Beatty Rail Spa since March 1991 (then within ABB Sae Sadelmi). He was appointed head of project management Italy in Balfour Beatty Rail Spa in 2008. He has a degree in mechanical engineering and extensive field experience. Mr. Steffanini has been active in the project management of overhead transmission line projects in Europe and Africa and of rehabilitation of electrical power plants in Lebanon, El Salvador and Italy. His most challenging and relevant experiences are his involvement in the construction of the Marco Polo airport in Venice and the High Speed Rail Project in Italy.
The traction power supply system (TPS) is the railway electrical distribution network used to provide energy to high-speed electric trains and comprises three types of traction power facilities (TPF), namely, traction power substations (SS), switching stations (SWS) and paralleling stations (PS), in addition to connections to the overhead contact system (OCS) and the traction return and grounding system. A 2x25 kV autotransformer feed configuration was selected for the California High-Speed Train Project (CHSTP) after the following considerations:

- This system addresses the voltage drop and inductive interference encountered in the simple single-phase system; and
- It is a safer system compared to the single-phase system because less return current flows in the running rails closest to the SS.

Electric power will be drawn at high-voltage (generally 115 kV or 230 kV) from the power supply utility network, stepped down to 2x25 kV at the SS, and fed to the catenary and negative feeders to supply power for the high-speed trains. The SS will be located along the CHSTP route alignment, generally at uniform spacing, and close to the utility high voltage (HV) network.

Ideally, TPF for high-speed rail are spaced uniformly along the alignment. The spacing depends upon train operation plans, train sizes (e.g., 8-car or 16-car trains) and frequencies, rolling stock parameters, track alignment, and the capacity of transformers/autotransformers at these facilities. Traction power load flow studies were conducted for representative sections of CHSTP and the capacity of the transformers and normal spacing of the TPF established.

However, it is not feasible to provide uniform spacing of TPF at all locations because the track alignment passes through different types of terrain including level ground and stretches of mild to steep gradients. Additionally, HV utility feeding points are not at uniform distances along the alignment. This necessitates non-uniform spacing of these facilities. At the time of carrying out the preliminary design, this flexibility in spacing/configuration of TPF was quantitatively ascertained on the basis of load flow studies for different ‘what-if’ scenarios of track alignment. Based on the results of these studies empirical rules were developed as guidelines for locating TPF under the constraints mentioned above.

### Traction Power Supply Configuration

The proposed TPS configuration for CHSTP, which has been validated for a representative level section using standard load flow simulation software, is as follows:

- Traction power substations (SS) spaced 30 miles apart, each having two 60-MVA transformers designed to power its normal ‘feed section’.  
  - If one transformer is out of service, the other will be capable of powering both the ‘feed sections’;
- Switching stations (SWS) located midway between two adjoining SS will each have two autotransformers of 20 MVA;
- Paralleling stations (PS) located five miles apart between SS and SWS will each have one 20-MVA capacity autotransformer. (The sequence of the facilities will be SS – PS – PS – PS – SWS – PS.)

### Different Track Alignment Situations

Because of the difficulty locating TPF uniformly along various alignment options, power load flow simulation software was used to assess the situation:

#### Continuously Graded Sections

A portion of the alignment passes through mountainous terrain with gradients that, in some sections, are steep (up to 3~3.5%) for a 15~20 mile stretch. In some areas a full ‘feed section’ might be located on a gradient. Load flow simulations were used to verify if the TPS would be
able to operate on the scheduled timetable over these continuously graded sections.

**Longer Electrical Sections**

In some sections it may not be feasible to locate these TPF exactly five miles apart because of alignment constraints, and their spacing may be increased or decreased. Additionally, it may not be feasible to have a high-voltage feeding point of supply utilities every 30 miles along the alignment. This will necessitate locating SS at uneven spacing, thereby resulting in ‘feed sections’ of non-uniform lengths. The options are either to alter the spacing of adjacent TPF with distances being as much as 6 to 7 miles, or to provide an additional PS in a long ‘feed section’ to maintain TPF spacing close to 5 miles. The feasibility of operating scheduled train services on these sections with non-uniform spacing of TPF or with long ‘feed sections’ having three PS was tested using traction power simulations.

**Base Case for Simulation**

The simulation study was done using TOM (Train Operations Model) for a typical 15-mile long two-track section with an SS at one end, an SWS at the other, and two PS in between.

The following are the major features of the typical section chosen (‘the base case’) and the train operations plan:

- 15 mile-long section, starting from SWS (northernmost point) to SS, 15 miles away, with two paralleling stations PS1 and PS2 located 5 miles and 10 miles away from the SWS. The sequence of the TPF is SWS – PS1 – PS2 – SS
- the main transformers at SS are 60 MVA capacity, and all the autotransformers at SWS, PS1 and PS2 are 20 MVA capacity
- no station stops, curves, gradients, and speed restrictions in the section
- maximum permissible speed: 220 mph
- trains enter the section at 220 mph, and can leave it at the maximum permissible speed subject to the constraints of gradient (considered in later scenarios)
- twelve 16-car, modern high-speed trains run in the section in each direction during the peak hour

**Model Output and Analysis of the Results**

The model output was analyzed to calculate the following system parameters: minimum voltage anywhere in the section, maximum current in the OCS conductors, maximum apparent power (MVA) in the main transformer and all the autotransformers, average speed of trains, and energy consumed by each train.

**Impact of Change in Gradient**

- The high-speed train is able to maintain its initial speed (220 mph) on level sections and also on down gradient sections but not on sections with rising gradients. It slows down (by up to 50% of its initial speed in the case of 3.5% gradient) and takes a longer time to cover the section. For train speeds above 100 mph, the tractive effort required/available to maintain its cruising speed is inversely proportional to speed; therefore, power available to,

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Gradient from SWS to SS</th>
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<tbody>
<tr>
<td>1</td>
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<tr>
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<tr>
<td>5</td>
<td>Rising 3%</td>
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<td>6</td>
<td>Rising 3.5%</td>
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</tbody>
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**Table 2 - Impact of Longer Electrical Section (Seven scenarios were performed)**

2 With a configuration of SS-PS-PS-PS-SWS

3 A commercially available, standard system simulation software
and consumed by the train, is roughly equal to the maximum power it is capable of drawing. When the train is traveling on a rising gradient, a portion of the available tractive effort is consumed in overcoming gravity, hence, less tractive effort is available to accelerate the train, and the speed of the train decreases though it is drawing full power. In all the scenarios where trains are negotiating rising gradients, they are unable to sustain the maximum speed. Because of the reduction in speed, the train remains in the ‘feed section’ for a longer period drawing power for a longer duration, thereby consuming more energy. The trains running along declining grades consume less power because gravity helps them in running.

- There is a greater decrease in energy consumption while travelling down the gradient than the corresponding increase when travelling up the gradient, thereby reducing the combined energy consumption for one northbound (NB) and one southbound (SB) train as compared to their corresponding run over level sections. Therefore the combined energy consumed for one NB and one SB trains is reduced in a section with a 1% gradient as compared to the energy consumed over a level section, and is the lowest in the section with 2% gradient for the combination of the TPS configuration and the chosen rolling stock characteristics. If the gradient is increased further, the combined energy consumption for the train-pair increases, and is the highest for the section with 3.5% gradient, but still remains below the energy consumed over level sections. A similar trend is observed for the figures of energy consumption per car-mile, the maximum currents in catenary and NF wires, and MVA of main transformer\autotransformers.
- The minimum voltage anywhere in the section, the currents in the conductors and the MVA load on all transformers remain very much within permissible limits.
- There is a slight increase (about 4%) in the 1-hour MVA load on the main transformer as the length of the ‘feed section’ increases from 15 miles to 18 miles.
- When the ‘feed section’ is longer than 17 miles, provision of one additional PS brings the traction power parameters within acceptable limits.

Conclusions
The following conclusions for different alignment options are based upon the above analysis:
- The basic TPS configuration is satisfactory and will support train operations on continuously graded sections as well as on longer ‘feed sections’, i.e., 16~17 miles long.
- Under exceptional circumstances 6-mile spacing of TPF may be acceptable.
- For ‘feed sections’ 18 miles long, it may be preferable to provide an additional PS so as to bring inter-TPF spacing to 5 miles or less.

Impact of Longer Electrical Section
- The minimum voltage anywhere in the section reduces gradually as the length of the ‘feed section’ is increased from 15 miles to 18 miles (Table 2 scenarios #1 ~4). The voltage profile improves as an additional PS (PS-3) is introduced in the system (Table 2 scenarios #5 and 6). The minimum voltage remains within permissible limits.
- The currents in the conductors and the MVA loading of the autotransformers remain within permissible limits.
- There is a slight increase (about 4%) in the 1-hour MVA load on the main transformer as the length of the ‘feed section’ increases from 15 miles to 18 miles.
- When the ‘feed section’ is longer than 17 miles, provision of one additional PS brings the traction power parameters within acceptable limits.

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Vinod Sibal has over 30 years experience in planning, design, and O&M of railroad systems/project and is presently working as Traction Power Lead Engineer, California High-Speed Train Project, CA.

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Tunnel Configurations for the California High Speed Train Project

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On the 925 km (500 mile) long first phase of the California High-Speed Train Project (CHSTP) between San Francisco and Los Angeles, there are an estimated 25 bored or mined high speed train tunnels totaling about 50 miles length through three mountain ranges. These tunnels represent a significant proportion of the total cost of the project.

Parsons Brinckerhoff (PB) is providing the project and engineering management teams for the client, California High Speed Rail Authority.

This article describes the design approach used for determining preliminary tunnel sizes and suitable tunnel configurations in order to limit the magnitude of transient pressure waves which are developed and travel along the tunnels when high speed trains enter the tunnels.

Transient Pressure Variations
Since the 1970’s, it has been known that when passenger trains enter tunnels at high speed, transient pressure waves are induced and travel in the tunnels. The pressure variations which result can affect passenger comfort because the human ear has difficulty adjusting to rapid changes in pressure and, in extreme conditions, they can cause pain to passengers, especially those with pre-existing aural medical conditions. These pressure variations can be either instantaneous, or develop and repeat over time (pressure pulses).

Instantaneous pressure variations could occur if the sealing system of a passenger compartment suddenly failed (for example, a window breakage). The European Technical Specifications for Interoperability (TSI) require that pressure variations along the train in the tunnel shall not exceed 10KPa (1.45psi) for high speed trains at the maximum operating speed. These criteria are known as the “Medical Health Criteria” and apply to both sealed and unsealed trains.

Pressure variations also occur inside the train which are time dependent and can cause less severe but repetitive passenger discomfort. These are regulated at the national level and vary from country to country. They are referred to as “Aural Comfort Criteria and apply only to unsealed trains.

The magnitude of pressure changes can be limited by:
• providing adequately sized tunnels (sufficient free cross sectional area);
• aerodynamic design of rolling stock;
• sealing of rolling stock; and
• applying speed restrictions.

As mentioned previously, this article addresses limiting the adverse effects of pressure changes through design of the tunnels.

Sizing and Configuration of Tunnels
The topography of the three mountain crossings on CHSTP varies considerably with abrupt changes in elevation in many locations. The 25 individual bored or mined tunnels vary in length from less than 300 meters (1000 feet) to approximately 14.5km (9 miles), and approach structures include high viaducts and embankments, and deep cut slopes.

The purpose of preliminary sizing and configuring mined and bored tunnels for preliminary design is to:
• establish a sufficiently wide corridor for environmental assessment;
• prepare quantities for costs estimates;
• provide directive drawings to the regional teams preparing the preliminary design alignment and associated design reports and drawings; and
• provide input to the project fire/ life safety strategy.

Three basic tunnel configurations were selected for analysis. All configurations have a walkway for each track:
• Twin tunnels with a single track in each tunnel, and track centers of 20 meters (66 feet).
• A single tunnel with a central separation wall and two tracks at a spacing of 7.6 meters (25 feet).
• A single tunnel without a separation wall containing two tracks at 4.9 meters (16 feet) spacing. This type of tunnel configuration requires a different approach to the tunnel fire/ life safety strategy including escape of passengers to a place of safety.
Methodology

International Union of Railways (UIC) Guideline 779-11 details the methodology and provides two sets of data curves which can be used to determine the necessary tunnel free cross sectional area\(^1\) required for compliance with Medical Health Criteria and Aural Comfort Criteria. The curves have been developed using computational fluid dynamics modeled by UIC software. Theory and methods of aerodynamic analyses are detailed in EN 14067 Railway Aerodynamics. The results have been validated by full scale field testing. The effects of rapid pressure changes on human volunteers have been studied with the use of decompression chambers.

A preliminary assessment of the required free tunnel cross sectional areas for different train speeds and tunnel lengths were established from data provided in UIC 779-11 R.

For each tunnel configuration, the free tunnel cross sectional area was calculated for each train type, various operational speeds and tunnel lengths. A spreadsheet was developed to establish the tunnel dimensions based on the required free tunnel cross sectional areas.

The formula for calculating the free tunnel cross sectional area in UIC 779-11 is as follows:

\[
\text{Tunnel free cross sectional area} = \frac{\text{Train cross sectional area}}{\text{Blockage Ratio}}
\]

As the size or length of rolling stock for the project has not yet been selected, calculations were carried out on various single and bi-level trains having cross sectional areas of between 10m\(^2\) (108ft\(^2\)) and 14m\(^2\) (150ft\(^2\)), and lengths of both 200m (660 feet) and 400m (1312 feet). Allowances were made for continuous fixed equipment and construction tolerances.

For the purpose of the analyses it was assumed that:

- A trainset with an equivalent cross sectional area could be developed that can achieve the design speed of 400km/h (250mph) even though the design speed of some of the rolling stock considered is less than 320km/h (200mph). Very few existing high speed rail systems worldwide currently operate a revenue service where trains travel at speeds of greater than 300km/h (190mph) in tunnels.
- As the CHSR rolling stock will be specified to have excellent sealing characteristics similar to Shinkansen (Japan) and the ICE-3 (Germany) rolling stock, the tunnels will be sized to comply with the Medical Health Criteria only and the Aural Comfort Criteria will not apply.
- Trains will be travelling at a minimum headway of 3 minutes in each direction. Typically only one train will be travelling in each direction within the same tunnel or adjacent twin tunnel.
- For the twin tunnels and single tunnel with separation wall, doors to adjacent tracks are assumed to be sealed so that pressure cannot be transferred to the other tunnel or trackway.

Summary of Results

A selection of the results are presented in Table 1.

Notes:
1. Train cross-sectional area = 14m\(^2\) (150ft\(^2\))
2. Tunnel length of 960 meters (3150 feet) to 3.2km (2 miles) = critical case
3. Single track tunnel
4. 350km/h (220mph) speed
5. 400m (1312ft) train length

Figure 1 shows the variation of tunnel span at different speeds for the critical tunnel length. Figures 2, 3 and 4 show the variation of the above parameters with tunnel length.

Conclusions

The following conclusions are based on the TSI Medical Health Criteria, UIC guidelines and assumptions:

<table>
<thead>
<tr>
<th>Speed km/h (mph)</th>
<th>Tunnel Diameter meters (feet)</th>
<th>Conditions for Analyses (see notes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>320 (205)</td>
<td>8.5 (28)</td>
<td>1, 2, 3, 5</td>
</tr>
<tr>
<td>350 (220)</td>
<td>9.0 (29.5)</td>
<td></td>
</tr>
<tr>
<td>400 (250)</td>
<td>10 (33)</td>
<td></td>
</tr>
<tr>
<td>Train Length (meters)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 (660)</td>
<td>8.5 (28.5)</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>400 (1312)</td>
<td>9.0 (29.5)</td>
<td></td>
</tr>
<tr>
<td>Tunnel Configuration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Tunnel without Separation Wall</td>
<td>15.7 (51.5)</td>
<td>1, 2, 4, 5</td>
</tr>
<tr>
<td>Single Tunnel with Separation Wall</td>
<td>14.6 (48)</td>
<td></td>
</tr>
<tr>
<td>Train Cross-sectional Area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shinkansen Bi-Level 14m* (150 ft*)</td>
<td>9.0 (29.5)</td>
<td>2, 3, 4, 5</td>
</tr>
<tr>
<td>Shinkansen Single Level 11m* (118 ft*)</td>
<td>8.0 (26.5)</td>
<td></td>
</tr>
</tbody>
</table>

Table 1

---

\(^1\) The tunnel free cross-sectional area is the internal space in the tunnel not occupied by any structure or continuous fixed equipment.

\(^2\) In this equation, the train cross sectional area is calculated as the projected frontal area above mid axle of the leading vehicle and the blockage ratio is obtained from the data curves in UIC 779-11 R. The blockage ratio can be determined for a given tunnel length and for various operational train speeds.
**Single Track Twin Tunnels**
- The twin tunnels can be economically sized to comply with an operating speed of 350km/h (220mph) or less.
- It is unlikely to be economical to size twin tunnels less than 9.6km (6 miles) in length for a design speed of 400km/h (250mph) because of the large increase in tunnel size compared with tunnel sizes for 350km/h (220mph).

**Twin Track, Single Mined Tunnel (with separation wall)**
- It is unlikely to be economical to size the single tunnel with separation wall for speeds of 320km/h (205mph) or more because of the large increase in tunnel span. The UIC curves do not provide data for speeds of less than 320km/h (205mph) but it may be an economical tunnel configuration at lower speeds.

**Twin Track, Single Mined Tunnel (without separation wall)**
- The single tunnel without a separation wall (and trains travelling in opposite directions in the tunnel at the same time) appears to be economical only for an operating speed of up to 300km/h (185mph) and for tunnel lengths of 960 meters (3150ft) to 2km (1.2 miles). However this configuration may also be economical for relatively short shallow tunnels, if mitigation measures can be provided such as pressure relief shafts to the surface.

**All Tunnel Configurations**
- It may be cost effective to optimize tunnel diameter or span according to the specific length of each tunnel if this is appropriate to the tunneling methodology.
- The difference in cross sectional area between the Shink-
Figure 2 - Variation in Single Track Tunnel Diameter with Tunnel Length for different train speeds

Figure 3 - Variation in Twin Track Mined Tunnel (without separation wall) Span with Tunnel Length for different train speeds
ansen bi-level and single-level trains is large and significantly impacts the required tunnel size.

- The required tunnel free cross sectional area is less sensitive to train length than train cross sectional area.

As a result of the above conclusions, the twin tunnel configuration with a single track in each tunnel and track centers of 20 meters (66 feet) was selected for all bored and mined tunnels on CHSTP for preliminary design.

The preliminary internal tunnel diameter was selected to be 9 meters (29.5 feet) based on a maximum operating speed of 350km/h (220mph). When rolling stock dimensions and aerodynamic performance are more precisely defined, it may be possible to reduce the tunnel diameter during detailed design.

This configuration also provides the widest/most conservative footprint for the environmental assessment and preliminary alignment.

Construction contracts will likely be design/build and, depending on the procurement/contracting strategy, the final choice for tunnel configuration may be left to the design builder to select. The method of tunnel construction will likely be the choice of the design/builder.

Jimmy Thompson specializes in design and construction of large underground infrastructure projects. Notable projects include the Channel Tunnel, Lesotho Highlands Water Project, Hong Kong Airport Railway and BART Extension to San Jose.

Nao Otsubo is a Tunnel Engineer with six years of detailed design and construction supervision experience including numerous deep shafts in London. He recently transferred from Parsons Brinckerhoff Godalming to join the CHSTP Team in Parsons Brinckerhoff San Francisco.
The Gotthard Base Tunnel (GBT) forms part of the New Railway Link through the Alps (NRLA) and is a vital element in the European high-speed rail network. Its flat-track rail links economic centers on both sides of the Alps and its expansion will bring these economic centers closer together by shrinking travel time.

At a length of 57 kilometers (35.4 miles), the Gotthard Base Tunnel is slated to become the world’s longest rail-road tunnel upon its completion in late 2016. It consists of two tubes linked together by a system of cross passages, connecting tunnels and two crossovers. Both tubes are laid out with continuous track and overhead catenaries designed for travel speeds of up to 250 kph (155 mph).

Its builder-owner is AlpTransit Gotthard AG (ATG), a wholly owned subsidiary of Swiss Federal Railways (SBB). On May 4th, 2007, Transtec Gotthard won the bid to become the prime contractor for the installation of railroad technology in the Gotthard Base Tunnel. Transtec Gotthard is a consortium of enterprises which includes Alpiq, Alcatel-Lucent/Thales, Alpine-Bau and Balfour Beatty Rail.

The railroad technology comprises the track layout, power supply with 50 Hz, cable systems, railway traction power supply with 16.7 Hz, telecommunication networks (fixed and radio) and safety installations. While the project was still in its proposal phase, the engineers of Munich-based Balfour Beatty Rail and Zurich-based Kummler+Matter AG had already produced an R 250 GBT catenary system in joint development. Designed for both tunnel and outdoor routes, their system meets the special requirements posed by the GBT which a typical catenary system would not satisfy.

R 250 GBT Catenary System at a Glance

The R 250 GBT type of catenary system is currently in approval procedure in Switzerland and meets requirements mandated by the Technical Specifications for Interoperability regarding sub-systems and directives. ¹

Laid out for speeds of 250 kph, the Gotthard Base Tunnel line, with its connections to the SBB main lines to the north and south, is considered to be Line Category I based on 2008/57/EC. According to Directive 2001/16/EC Annex I, Article 1 (TSI Energy), the line is ranked in the category of lines designated for mixed traffic (passenger and freight trains). The maximum speed for passenger trains is up to 250 kph and 120 to 160 kph for freight trains.

Requirements

The Gotthard Base Tunnel comes with enormous requirements to the catenary system planned for installation inside. Here is a brief overview of the conditions to which the catenary will be exposed:

• Limited cross-section of tunnel
• High mechanical loads on structural elements due to dynamic pressures of up to 7000 N/m²
• Special climatic conditions including up to 40 °C in ambient temperature and humidity as high as 70%
• High risk of corrosion due to aggressive saline environment and effects from brake dust, concrete dust and soot particles
• High demands to availability
• Short-circuit currents as high as 40 kA

Electrical Data

The R 250 GBT underwent a series of comprehensive load analyses verifying its dimensioning and compliance with GBT parameters. Based on these parameters, analyses of the R 250 GBT produced a peak value of 2.220 A over a period of 15 minutes. Said parameters called for equipping the catenary system with parallel feeder cable (4 x Cu 95 mm²) in the tunnel.

Load analyses took into account the most special conditions. These included extreme temperatures, low wind speeds, conservative estimates of catenary impedance, high and consistent wear on contact wire and tracks as well as maximum traffic load. They were performed us-

The following is an overview of the analytical outcome:

- Nominal voltage/frequency: 15 kV / 16.7 Hz (EN 50163)
- Continuous current in catenary (30% wear on contact wire, ambient temperature at 40°C and wind speed at 1 m/s): 2390 A
- Short-circuit strength: 40 kA / tKS ≤ 100 ms (EN 50388)
- Insulation level: 36 kV (EN 60694)

Usability
In order to examine the current collection properties of the R 250 GBT catenary system, engineers applied the CATMOS® simulation program to create two simulations of each catenary section. One focused on maximum longitudinal spans, the other on sectioning and tensioning. As reference for the collectors, engineers relied on mechanical models and on the technical data of the collector types DSA380F, DSA200.07 and WBL85KCRC. Said collector types are used on German Type 406 traction vehicles (ICE3) as well as on Swiss Type 460 and Type 482 traction vehicles.

Simulations for verifying conformity with TSI Energy involved the use of a second, TSI-conforming collector of the SSS400+ type. Simulations based on EN 50318 were created using different collector configurations and travel speeds. The results of these simulations were analyzed using limit values based on EN 50119.

Corrosion Protection
The special climatic and environmental conditions prevailing inside the Gotthard Base Tunnel necessitate the use of special protection measures against corrosion. To this end, the Swiss Federal Laboratories for Materials Testing and Research (EMPA) conducted a number of comprehensive material tests, including salt spray and storage tests. Their test results have shown that it takes elements made of sufficiently hot-galvanized steel to weather these conditions, whereas elements made from aluminum and aluminum alloys fail to meet the demands. Screw joints and safety-relevant fixtures will be made of high-grade stainless steel.

Installations along the outdoor lines receive standard SBB/DB materials.

Components
Catenary System
The R 250 GBT catenary system consists of RIS 120 mm² contact wire and BZ II 70 mm² bearer cable. Tensile forces are 17 kN in the contact wire and 15 kN in the bearer cable.

Both the contact wire and bearer cable have separate independent retensioning systems for retensioning. Both come as flexible retensioning systems. This dual flexible retensioning system requires a fixed point for fixing the catenary system in position and handling its load in case the contact wire were to snap.

A fixed point cancels out if retensioning is at half-length, in which case full retensioning is applied instead. Retensioning systems are planned as parallel-running catenaries with space for transition. Electrical separation follows parallel to them in the form of contact wire insulators installed in the transition spaces, tolerating the occasional grinding caused by contact wire uplift.

Owing to the limited tunnel cross-section, the catenaries of the R 250 GBT system are laid out at a contact wire height of 5.20 m and a system height of 0.90 m within...
the tunnel. This contact wire height complies with TSI requirements. The low system height of 0.90 m leaves no room for stitch wire in the tunnel. However, the system layout (relatively low longitudinal spans, tensioning forces of contact wire and bearer cable) leaves plenty of room for flexibility nonetheless.

**Retensioning Devices**
The flexible retensioning devices in the tunnel come with a 1:1 transmission ratio. They involve the same retensioning systems already utilized by SBB in the tunnels of its new Mattstetten - Rothrist line. Corrosion protection requirements entailed adjustments to material and corrosion protection in both cases.

The retensioning devices meet the following parameters:
- Maximum permissible retensioning length from fixed point \( L = 700 \text{ m} \)
- Maximum permissible temperature range: \(-20 \text{ to } +100^\circ \text{C} (T_{\text{per}} = 120^\circ \text{K} / \text{incl. tunnel mouth})\)
- Weight migration range: 1,430 mm, with \( \geq 170 \text{ mm tolerance for assembly purposes} \)

**Cantilevers**
The cantilevers in the tunnels correspond to Figure 1. Each cantilever is made up of a rotary support for mounting the insulator and cantilever tube. The cantilever tube holds the turning clamp for the bearer cable as well as an anchor arm connection with a special band clamp.

The steady arm connection holds the steady arm for lateral support. Steady arms for lateral support involve Furier+Frey products of the corrosion-resistant kind, which are also widely used by SBB. An uplift of 120 mm, the maximum permissible under TSI, can cause anchor arms to slant approximately 15°. Dispensing with the use of uplift stops, the design of these anchor arms instead accommodates a contact wire uplift of 2 x 120 mm to stay within TSI Energy limits.

Holding the cantilevers in place are truss posts mounted along the tunnel wall. The truss posts also include fixtures for the parallel-running earth wire. Movable parts like the rotary support are hooked up to earth wire.

**Supporting Structure / Drop Tube**
The truss posts are made up of square, heat-produced hollow profiles RRW 120x120x5. The mounting plate needed for mounting them in the tunnel uses three or four shear connectors for that purpose, depending on load and inclination of the plate. A ground clip serves to connect it to the ground wire.

**Supporting Structure / Feeder Supports**
The feeder supporting structure serves as conduit for four feeder cables (4 x 95 mm2 Cu) and two return wires (2 x 150 mm2 Cu). The feeder supporting structures are basically laid out along the same kilometric positions facing the supporting structures of the tunnel. Intermediate supports midway in between are only necessary for the smallest cross-sections with minimum existing tolerance. This helps reduce the effects of cable slack enough to maintain the necessary clearance gauge.

**Insulators**
The R 250 GBT catenary system required the design of special insulators. Providing the basis for this design were the silicon compound insulators manufactured by SEFAG Pfisterer for the Lötschbergtunnel of the BLS railway in Switzerland. The design of these special insulators included an increase in the dimensions of the glass fiber reinforced plastic structure and a change in the material of the insulator caps from aluminum to cast iron.

The advantage of silicon compound insulators is their high pollution resistance owing to the lotus effect of their surfaces. Like their counterparts in the Lötschberg-tunnel, these new insulators are designed for a minimum creepage distance of 1,250 mm, which is a must when considering the degree of pollution involved. They also eliminate the need for repeatedly cleaning insulators during operation. Unlike outdoor lines, tunnels cannot depend on rain or snow to keep them clean.

Further information is available upon request.

Robert Walz, after having completed his university education in mechanical engineering in Frankfurt/Main (Germany) in 1993, worked as a project engineer with the company Siemens AG in Frankfurt. From 1998 to 2002 he was the project manager of design at the high speed line “NBS Köln-Rhein/Main”. In 2002, Mr. Walz joined Balfour Beatty as a design engineer for railway catenary systems. Since 2004, he has been a design engineer for railway catenary systems for IVV in Offenbach where he manages national and international projects e.g. Gotthard Base Tunnel in Switzerland, electrification project Dash Dublin in Ireland and rehabilitation project Fetesti-Constanta in Romania.
Ventilation Analysis for High Speed Tunnels (Channel Tunnel Rail Link – UK)

by Kate Hunt, Godalming, UK, +44(0)1483-52-8966, huntk@pbworld.com and John Morris, Newcastle upon Tyne, UK, +44(0)191-226-2646, morrisj@pbworld.com

Background

High Speed 1 (HS1), originally known as the Channel Tunnel Rail Link (CTRL), is a 108 kilometre (67 mile) high-speed railway running from St Pancras railway station in central London, through the County of Kent to the British end of the Channel Tunnel near Folkestone. It operates at speeds up to 300 km/h (188 mph) and cost £7 billion ($10.5b) to build. After passing under the Channel, the line connects with high speed lines in Northern France, Belgium, Holland and Germany.

The first portion of the line to be built (Section 1), the 74 km section from the Channel Tunnel to Southfleet, was opened in 2003, and trains initially completed their journey to London Waterloo station over congested conventional rail lines. Subsequently the more difficult to construct 39 km section (Section 2) into St Pancras station was opened in 2009. In common with many high speed rail projects across the world, the environmental concerns associated with a new line, as well as noise and visual intrusion, required that a significant amount of the line be in tunnels. In all, tunnels account for 26km (25%) of HS1. Section 2 of HS1 includes three tunnels in London and under the Thames River, totalling 19 km (11.8 miles). These tunnels are twin bore, single track, with cross-passages at regular intervals. Trains travel through these tunnels at speeds up to 230 km/h (144 mph).

Parson Brinckerhoff’s involvement

Construction contracts for Section 2 of CTRL were let in 2005, and the mechanical and electrical design and construction work was awarded to EMCOR Limited with Parsons Brinckerhoff (PB) providing engineering services support.

Safety in the high speed tunnels was a primary consideration, particularly the ability to evacuate passengers in the event of fire, and EMCOR’s main task was to provide smoke control ventilation and a pressurised ‘safe haven’ in the adjacent tunnel bore (reached through the cross-passages). The ventilation system needed to provide pressurisation of the non-incident running tunnel to deliver the safe haven to a high Safety Integrity Level1 (SIL3), and longitudinal smoke control with safe haven to a lower Safety Integrity Level (SIL2).

The design of the ventilation equipment and control system allowed the operator to select fan operations to move smoke in either direction for any possible fire incident, but the decision on preferred direction for smoke control is always a difficult one for the operator to make; moving smoke forwards (in direction of train travel) makes best use of the prevailing air flow within the tunnel, but means that passengers must escape by walking back towards following trains, which may still be moving. Forcing smoke to move in the reverse direction requires the tunnel air flow to be reversed, but the stranded train provides protection to escaping passengers (against being hit by a moving train) and is closer to most operators’ instructions for detaining passengers away from stations. Other operational factors include the position of the fire along the length of the train and the location of the train with respect to the nearest evacuation point. The preferred (and default) direction for smoke control for the three London Tunnels was in the direction of train travel at the time of the incident, with reverse direction also being available.

All mechanical and electrical installations required an Application Specific Safety Case2 and a Reliability, Availability and Maintainability (RAM) Analysis, to be assessed by the Safety Review Panel (SRP) of the client, Rail Link Engineering (RLE).

Parsons Brinckerhoff’s team was made up of tunnel ventilation analysis experts, M&E design engineers and systems engineering and assurance specialists. They were integrated into EMCOR’s design team, co-located in the client’s...
HSR Tunnel Design and Technologies

project offices, and delivered a tunnel ventilation system to a performance specification. Parsons Brinckerhoff provided the following services: ventilation analysis for smoke control; development of control strategies and mode tables; ventilation designs; acoustic calculations; review of fan selections; cooling and heating load calculations; building services design; pumping and drainage design and testing, commissioning and handover support. Fault Tree Analysis (FTA) and Failure Modes, Effects and Criticality Analysis (FMECA) supported the Safety Case, which needed to be approved by RLE before the ventilation system (and railway) could be brought into revenue service.

Ventilation Analysis
The primary purpose of the ventilation system was to provide a smoke-free safe haven to a high Safety Integrity Level (SIL) and smoke control to a lower SIL. The performance specification included three key criteria that, under certain situations and conditions, could conflict with each other:

- Ensure the non-incident tunnel remained smoke free at all times by providing a higher pressure than in the incident tunnel and a minimum air speed through open cross-passages;
- Provide longitudinal smoke management in the tunnels by means of critical velocity; and
- Ensure the pressure differential between the two tunnels remained low enough to allow the opening of any cross-passage door.

Meeting the three criteria with varying fire locations, train positions and number of open cross-passage doors was a massive challenge. In addition, the SIL level required that all the scenarios be repeated with key equipment removed from service to give secondary, and in some cases tertiary, ventilation responses.

In all, over 1350 incident scenarios were simulated, using version 2000 of Parsons Brinckerhoff’s Subway Environment Simulation (SES) program. This allowed the development of mode tables, consisting of a matrix of all the required operating conditions of fans and dampers, and their combinations for ventilation control system commands. Thus, a single command would instruct fans at one shaft to operate in supply with a particular damper configuration, while simultaneously instructing fans at the next shaft to operate in extract with another damper configuration. Should any equipment fail to operate, the control system would automatically initiate a second configuration achieving the same overall effect.

Ventilation Design
Parsons Brinckerhoff designed the ventilation system, selecting equipment and laying out equipment spaces within the ventilation shafts. Civil structures design was already complete at this time, so the team was challenged to fit the ventilation equipment within the civil envelopes available. Whenever possible, equipment was standardised and modularised to give a flexible, cost effective solution and to minimise spares holding by the maintainer. FTA and FMECA required that quantitative reliability data for individual pieces of equipment be acquired from manufacturers and suppliers.

The ventilation system eventually proposed consisted of seven fan shafts with a combined airflow capacity of 2,591 m³/s (5.5 million cfm), 48 jet fans and four Saccardo nozzles.

Commissioning phase
It was not practical to test every possible ventilation response during commissioning, so it was agreed that testing selected key design parameters and an agreed scenario response would confirm the correct operation in all other cases. The key parameters to be confirmed were:

- Supply/extract capacity from each ventilation shaft in all operating configurations;
- Cross-passage resistance;
- Train resistance; and
- Tunnel friction factor.

The commissioning tests confirmed that the installed ventilation capacities were as required, and that design assumptions for tunnel friction factor and train friction factor were appropriate, but that the cross-passages had a lower than expected resistance. The commissioning (undertaken by others) revealed a non-uniform air flow profile in the tunnel, preliminary analysis of which gave rise to concerns regarding the tunnel friction factor. However, detailed analysis of the measurements confirmed a skewed velocity profile at the measure-
Civil Design and Overhead Power Line Systems in the Finnetunnel and Bibratunnel

By Michael Lammert, IVV GmbH, Offenbach, Germany, +49 (0) 69 30859/205, michael.lammert@ivv-gmbh.de and Wolfgang Porsch, IVV GmbH, Offenbach, Germany, +49 (0) 69 30859/211, wolf-gang.porsch@ivv-gmbh.de

Following the reunification of Germany, the federal government approved a series of construction projects to improve the transportation infrastructure between East and West Germany; i.e., programs to upgrade the nation’s roads, railroads and waterways. One of these is the rail connection VDE 8 (German: Verkehrsprojekte Deutsche Einheit = German Unity Transport Projects) between Berlin and Nuremberg.

VDE 8 is made up of three sectors. The Sector VDE 8.2, including both the Finne- and Bibratunnels (described in more detail below), constitutes the new section between the cities of Erfurt and Leipzig/Halle (Saale), to be completed in the year 2016.

VDE 8 runs about 500 km in overall length. This high-capacity railway is the centerpiece of the topmost trans-European transport project, which stretches from northern Italy to Scandinavia.

Throughout the planning stage for this project, IVV GmbH was contracted to provide numerous planning services. In sector VDE 8.2, between Erfurt and Leipzig/Halle (Saale), these included, among others, the planning of technical equipment for the Finnetunnel and the Bibratunnel. Like the overall sector itself, requirements called for the overhead line systems in both tunnels to be designed for and equipped with the standard Re 330 type overhead lines ($V_{max} = 330$kph or 205mph). Further services included detailed drafts for the earthing (grounding) system of the two tunnels.

The Finnetunnel

As part of the new section between Erfurt and Leipzig/Halle (Saale), the Finnetunnel will emerge 25 kilometers north of the town of Weimar. It covers a section of eight kilometers and comprises two tunnel tubes, each measuring 6,886 meters in length. A system of rescue adits and sluices serves to connect them to each other every 500 meters.

Both tunnel tubes are created by means of two tunnel-boring machines running parallel. Measuring 10.50 m in diameter each, the two tunnel tubes are each lined with one ring of tubing partitioned into $6^{1/2}$ sections, each of which is 45 cm thick. As such, this ring design consists of 6 complete sections and a keystone half the size of the other sections. Each ring section measures 2.00 m in width. Prior to the planned drift phase, the tunnel sections are converted into open cutting within a ‘sonic boom’ environment. This is essential in minimizing dynamic pressure and controlling airflow. In short, the idea is to enhance the tunnel by supplying it with side air chambers.

Following their open-cutting assembly, the tunnel tubes are equipped with Re330 overhead lines. At this point, the tunnel rings receive mounting anchors at the overhead line installation sites. This is done by embedding the anchors in the concrete of the ring sections during the tubing production process.

The purpose of overhead line planning is to provide specifications essential to the tunnel construction such as positioning and mounting instructions for mounting anchors.
and screw anchors. Here the overhead planning requires compliance with the Technical Specification for Interoperability (TSI) of the trans-European high-speed rail system.

The construction documentation specifies the exact positioning of the overhead line supports. The supports are suspended from trusses using the mounting anchors already embedded in the tubing, likewise the indispensable catenary supports, fixed-suspension retaining elements and return wires running parallel to the catenary. The catenary features flexible pre-stressed contact wire. The Re 330 has not been applied to its maximum permissible pull-in limit (between the two anchor points) of 1,250 m in order to keep a certain amount of tolerance for possible adjustments.

The Bibratunnel

The Bibratunnel is situated along the new rail section connecting Erfurt, Halle and Leipzig, measuring 6,466 meters in length between the Saubachtal Bridge near the village of Bad Bibra and the Unstruttal Bridge near the district of Karsdorf Wennungen.

The Bibratunnel consists of two single-track tunnel tubes built with shotcrete technology. Its exterior shell is constructed using standard concrete, while its interior shell is made of waterproof concrete with embedded mounting anchors. The two shells are separated by a sliding layer in the main tunnel and by synthetic sheeting in and around the cross passages. Adjoining both tunnel tubes at their ends by the tunnel entrances are the double-track portals put in place to minimize the effect of ‘sound boom’. Both tubes of the Bibratunnel essentially run in parallel. The tunnel track has a minimum radius of 5,800 m.

Planning for the preliminary stages of installing the overhead power line system in the Bibratunnel involved compiling data sheets for the mounting anchors, anchor positioning and earthing (grounding) intrinsic to tunnel construction. Core planning involved the sectorization of the Bibratunnel’s...
interior shell. Choosing the proper mounting anchors for these sectors involves knowing the sector types. Return wires, for example, can only be suspended from their extended mounting anchors in sectors equipped for overhead power line support.

Plans for the Bibratunnel call for installing an overhead power line type Re 330 (tunnels). This type is founded on the standard cross-section of a three-centered arch tunnel for slab track systems based on assembly drawings in accordance to Ril. 853.9001.

The fact that the Bibratunnel differs from the standard cross-section necessitated a technical feasibility study of the overhead power line type Re 330 (tunnels) for use in the Bibratunnel. The study was done under application of loading gauge GC acc. to Ril. 800.0130, Fig.1, and pantograph clearance for rail-ways with ve ≥200 kph acc. to Ril. 800.0130, Fig.5. Furthermore, the study solely focused on standard Re 330 units, excluding special design versions. The deviation from the current drawings of overhead power line type Re 330 (tunnels) is the distance gap of 1.20 m for the standard supports in the parallel field and 1.50 m for this tunnel.

Earthing (Grounding) Activities in the Finnetunnel and Bibratunnels

The electro-technical equipment at both the Finnetunnel and Bibratunnels is subject to a universal earthing concept created in line with DB Guideline 997.0223. As such, it provides general guidelines to detailed planning for all engineering divisions.

One basic rule concerns the function of return wires. In the context of rails, return wires are the same as rail ground in that they function as earthing busbars for any parts requiring earthing. In the Bibratunnel, the primary earthing element of each concrete block machine is its thimble joint, a mandatory part of its equipment. If a concrete block machine has overhead power line supports, the short circuit proof connection between its thimble joint and the return wire is formed by the extended mounting anchor of the machine. If it does not have overhead power line supports, the same connection forms through the suspended return wire.

Due to the fault level of the two adjoining substations at Saubachtal and Dörstewitz, overhead line ratings include short circuit currents of ≤ 25 kA. Earthing components embedded in concrete are laid out for short circuit currents of > 25 kA, since their location in the concrete makes it hard to increase their diagrams to counter subsequent short circuit currents.

Conclusion

The complex planning of the overhead power line and earthing systems in the two tunnels presented a great challenge to everyone involved. Because of the different types of tunnels there were various problems to be solved, both at the construction of overhead power lines and at the earthing (grounding) of the tunnels.

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Wolfgang Porsch has a Master’s Degree in electrical engineering from the University of Technology, Munich, Germany, 1978. He was technical project manager for rotary converter substations – traction power supplies at AEG in Munich and Frankfurt, Germany until 1986, planning engineer of energy supply systems for the Transrapid maglev system until 2000, planning engineer for overhead power line systems at Balfour Beatty Rail in Frankfurt, Germany, and is planning engineer for overhead power line systems at IVV GmbH in Offenbach, Germany since 2004. He was Senior Consultant for Greece’s railways (Ergose) in 2006/2007.
Simulation Tools for Analyzing Underground High Speed Railway Projects

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High speed railways (HSR) are likely to be the trend of future mass transport for long distance travel. They have been implemented in many countries such as Japan, Germany, France, and China. China currently has the world’s longest high speed rail network and more will be constructed in the coming years. To reduce environmental and visual impact, some of the lines are built underground instead of being elevated or at grade level. With the increasing speed of trains due to advances in technology, there are more aerodynamic issues in underground high speed railway design. Parsons Brinckerhoff has been involved in studying and resolving various pressure transient and sonic boom issues for high speed railway projects in Taiwan, The People’s Republic of China and Hong Kong. This article discusses the application of two major simulation methods used in the analysis of these projects.

Parsons Brinckerhoff Project Experience
Parsons Brinckerhoff has used different kinds of approaches and simulation tools in various high speed railway projects. Table 1 summarizes some of PB’s experience in the aerodynamic analysis for various high speed railway projects.

Aerodynamic Issues of Underground High Speed Railways
Due to compressibility of air, a train running at high speed generates compression pressure waves when it enters the tunnel portal (Figure 1). The pressure waves propagate along the tunnel and may affect human comfort for passengers on the train or inside that underground station, or the stability of the equipment at the station. Therefore, a good design of the HSR system should include an appropriate prediction of air pressures and velocities caused by trains in tunnels and a study of the pressure wave characteristics.

Application of Analysis Tools
To determine the appropriate design and the mitigation measures to resolve the aerodynamic problems in a HSR project, 3-D computational fluid dynamics (CFD) simulation is usually used for the prediction of air pressures and ve-
inside the tunnel generated by the high-speed trains with a very quick simulation time and little computer resources compared to the 3-D CFD simulation.

1-D Analysis of a Typical Aerodynamic Problem
Simulations by ThermoTUN have been done to compare the measured and the predicted magnitude of the pressure fluctuation of a train entering the tunnel portal and passing through a station.

Using the data of an experiment from the Institute of Advanced Aerospace Technology (IAAT) of Korea, a simulation model by ThermoTUN was created. The IAAT’s experiment was a scaled-down version of a high-speed train running into a tunnel portal at 300kph. The parameters of the experiment are summarized in Table 2.

<table>
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<tr>
<th>Parameter</th>
<th>Value</th>
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<td>Train Speed</td>
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</tr>
<tr>
<td>Train Length</td>
<td>2340mm</td>
</tr>
<tr>
<td>Blockage Ratio</td>
<td>8.1%</td>
</tr>
<tr>
<td>Tunnel Length</td>
<td>7.6m</td>
</tr>
</tbody>
</table>

Table 2. Parameters Used in the IAAT Experiment

The setup for the analysis is shown in Figure 4. A high speed train model runs through the tunnel at 300kph and the pressure fluctuation is measured at a point close to the entry portal of the tunnel.

Figure 5 illustrates the predicted value by ThermoTUN and the measured value in the experiment. ThermoTUN’s prediction proved to be highly accurate. The pressure fluctuation pattern and the magnitude are close to the measured result. It can be concluded that ThermoTUN has the capability to analyze typical aerodynamic problems related to the HSRs.
1-D Analysis of a Complicated Problem

For a complicated problem, such as the prediction of pressure fluctuation inside a station area when a high speed train is passing through, 1-D analysis may not be the best approach. This is because the 1-D model cannot capture features of the actual geometry such as bends, abrupt changes of area, dead ends, staircase/escalator openings, etc. These features would have significant effect on the pressure wave patterns because they contribute to the reflection or dissipation of the pressure waves.

To study the suitability of using 1-D analysis for the above mentioned situation, 1-D analysis was carried out using ThermoTUN with reference to the information obtained from Taoyuen station of the Taiwan High Speed Rail project. The ThermoTUN model is illustrated in Figure 6. The model consists of a 94m² cross-sectional area 2-track tunnels at both ends and a 198m² cross-sectional area 4-track tunnel at the station area with dividing wall to isolate the local tracks at the side and express tracks in the middle. A high speed train is passing through the station on the express track at 300kph and the pressure wave generated at the tunnel portal was transmitted to the station. In the Taoyuan Station project, PB performed a 3-D analysis and measured the actual pressure level at the platform. A measurement point was located at the platform end to measure the pressure fluctuation for a cross comparison with the simulation results. Figure 7 shows the fast response data acquisition system used for capturing the pressure variations.

Figure 8 compared the results predicted by 3-D CFD simulation, 1-D simulation by ThermoTUN and 2 sets of actual measurement data [3]. It should be noted that both sets of measurement data show a high degree of consistency, which indicate that the site measurement was highly reliable and the influence from other possible factors, such as weather, station ECS operation model, etc., is negligible.

The results show that the 1-D analysis obtains a similar pressure pattern and magnitude to the 3-D CFD analysis in the beginning. However, it starts to lose its accuracy a few seconds later, while the 3-D CFD simulation was still able to capture the actual pressure fluctuation pattern. The reason for this is the lack of information in the 1-D model for reflection and other corresponding effects. When the pressure wave is transmitted into the station, a very complicated wave transformation occurs due to the reflection and other corresponding effects by these station features. 1-D analysis cannot capture this effect caused by the features and so it loses its accuracy at the later time in the simulation. On the other hand, the 3-D CFD simulation appears to be over-estimated. From further analysis, this is due to the slightly large train cross-section used.

Recommendations

To improve the efficiency and quality of the analysis on the pressure transient for HSR projects, different kinds of simulation approaches should be used carefully. 1-D analysis has a very quick simulation time and requires less computer resources compared to the 3-D CFD analysis. Based on project experience, 3-D CFD analysis required several weeks to complete an analysis while the 1-D simulation just took a few days to complete the analysis. However, with consideration for the limitations of 1-D analysis, it is recommended that 1-D analysis may be applied to the tunnel network assessment. It can also be used for the initial assessment of the pressure fluctuation for identifying potential problems and mitigation measures for a project. On the other hand, 3-D analysis should be applied for detailed and complicated problems, such as determining the pressure fluctuation at a specific lo-
cation inside a station, pressure which causes false ceiling to move and difficulties in closing doors, etc.

References
[1] www.thermotun.com

Dr. Dicken Wu, technical director with Parsons Brinckerhoff for 19 years, is a specialist in Computational Fluid Dynamics (CFD) simulation applications in various types of engineering systems, including railway system, high-speed rail tunnel aerodynamics, pressure transient analysis for subway system, special HVAC system design, façade design, building energy analysis, wind engineering for buildings, environmental flow, fire engineering, etc.

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Kate Hunt is a principal engineer and is the Senior Delivery Manager leading the UK Tunnel Ventilation Team. She has 20 years’ experience in the engineering analysis and design of ventilation systems for road, rail, metro and cable tunnels including, but not limited to fluid dynamics calculations and analyses, analysis of control software algorithms, pollution dispersion analyses, developing equipment layouts and production of specifications, operating and control strategies.

John Morris is Technical and Assurance Director for Parsons Brinckerhoff Rail & Transit business in the UK, based in Newcastle. He has been involved in European standards development for over 15 years, and is a member of UK TSI mirror group for Energy.

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John Morris is Technical and Assurance Director for Parsons Brinckerhoff Rail & Transit business in the UK, based in Newcastle. He has been involved in European standards development for over 15 years, and is a member of UK TSI mirror group for Energy.
Despite decades of underinvestment, resulting in a multi-billion dollar state of good repair backlog, ridership on the Northeast Corridor (NEC) is reaching record levels. With 13 million annual intercity passengers and 250 million commuters, the NEC is one of the busiest and most complex rail corridors in the world. The combination of record ridership and underinvestment in the underlying infrastructure, however, causes stress throughout the system, particularly at major choke points located in urban areas throughout the Northeast Megaregion.

Capacity constraints are particularly acute at the major stations along the corridor located in Washington DC, Philadelphia, New York, and Boston. Three of these cities (Washington, New York, and Boston) are either undergoing or will soon initiate major studies to plan for future operations at the terminals. While there is emerging interest in high-performance high-speed rail (Next-Gen HSR) for the Northeast, the planning for such a system is still in the early stages and lags far behind the planning at the major stations. Parsons Brinckerhoff (PB) is leading the planning effort for the Washington Union Terminal Master Plan and is in a supporting role for the design phase of Moynihan Station in New York. As we work with our clients to plan these station improvements, we will need to account not just for the short and medium term improvements that are critical to maintain and grow existing service over the next two decades, but to plan for these improvements in such a way that does not preclude the introduction of a future system whose service plan or infrastructure demands we do not yet know.

Northeast Corridor (NEC) Planning

The NEC Master Infrastructure Plan, published in spring 2010, represents the first coordinated planning effort for the NEC in more than a decade. The plan lays out a $50 billion, 20 year investment program that would bring the corridor to a state of good repair and incrementally improve trip time and capacity, allowing for a doubling of intercity ridership and a 60 percent increase in commuter ridership. Although the plan’s scope included all the physical assets on the corridor, it largely left the details of stations to the subsequent planning efforts in which we are now engaged. Although a fulfilled Master Plan would result in a corridor that is in a state of good repair, the corridor would still be operating at or near capacity with only marginally improved trip times.

Two more recent plans for the corridor envision a high-performance high-speed rail system on primarily dedicated tracks with a price tag more than double that of the Master Plan. While their exact alignment may differ, the two plans share common goals and ambition. Both plans would reduce trip times dramatically to approximately 90 minutes between New York - Washington and New York - Boston; but these plans, perhaps more importantly than trip time reduction, would create a step change in capacity, which the Master Plan does not provide. This is where corridor and station planning intersect. While we do not know what the ultimate capacity demands at major terminals along the corridor will be for a Next Gen HSR system, we do know that it is greater than the outlined scope of any of these terminal projects, which were largely envisioned to accommodate the capacity levels outlined in the Master Plan. Parsons Brinckerhoff, as we develop our recommendations for our clients, will need to craft a program of improvements for these terminals while remaining cognizant of the uncertainty regarding future service levels. This means that, although we may not recommend short or medium term improvements which allocate specific slots and terminal capacity to these systems, the improvement program we recommend must not preclude future Next Gen systems from accessing these terminals.

“A Vision for High Speed Rail in the Northeast Corridor,” Amtrak (September 2010).
http://www.amtrak.com/servlet/ContentServer/Page/1248542787937/1237405732517
Major NEC Terminal Planning
New York Penn/Moynihan Station

Of the three major terminals, Penn Station is the most complex, serving more than half a million commuter and intercity passengers per day. It is the most capacity constrained, located beneath midtown Manhattan and accessible to the Northeast Corridor only by rail tunnels under the East and Hudson Rivers. It is also in the most advanced stages of planning. The planning for Moynihan Station, the expansion of Penn Station to the west into the Farley Post Office complex, dates back nearly two decades. However, due to an infusion of federal funding in 2010, the project has entered final design on phase I. Improvements in this initial phase include the expansion of an underground concourse on the western edge of the existing station as well as two new street entrances on the west side of Eighth Avenue. This will lay the groundwork for a new, grand train hall (to come in phase II) that will occupy the interior space of the Farley Complex. Parsons Brinckerhoff is currently working in a design support role for final design on pedestrian circulation and lead for the design of the platform ventilation system.

Additional vertical circulation capacity and waiting areas for Amtrak, Long Island Railroad, and New Jersey Transit will be created, and the completed complex will be capable of accommodating the levels of traffic assumed in the Master Plan. These improvements in the underground circulation system, the new below ground concourse, and train hall need to be completed to accommodate medium term growth. While the plans as they exist now could not accommodate Next Gen HSR, there are steps that can be taken in these initial phases that would make it easier to accommodate this service in the future. In particular, the configuration of the southern expansion of the below ground concourse west of Eighth Avenue could be designed to allow further expansion through the south wall of the complex below 31st Street. Even if designed as a stub end terminal for commuter operations, this southern expansion could impact the ability for future run-through service for HSR on the existing middle platforms. Parsons Brinckerhoff is currently working with Amtrak on alternative alignments through New York for their Next Gen system.

Washington Union Terminal
Washington Union Station sits at the intersection of the Northeast and Southeast Corridors. It is the southern terminus for Amtrak’s high-speed Acela service and many of its Northeast Regional trains. It is also the southern terminus of MARC (Maryland Area Regional Commuter) commuter service from Maryland and the northern terminus of VRE (Virginia Railway Express) commuter service from Virginia. All three railroads are either at or approaching record ridership, and volume during the peak period at the station exceeds the level that the facility was designed for, limiting growth for all three. Parsons Brinckerhoff is currently leading the master planning effort for Washington Union Terminal. The goals of this Master Plan include more platform capacity, increased pedestrian circulation capacity, greater track capacity and flexibility, and expanded storage and maintenance yards. Each of the railroads have particular needs for platform height and power supply which results in a complex set of issues as we plan for future passengers levels on existing services as outlined in the Master Plan and the commuter growth plans. More challenging, however, is meeting the short and medium term needs of the three railroads while allowing for the introduction of high-performance high-speed rail at some future date.

Unlike designing for high-speed run-through service in Philadelphia and New York, Next Gen HSR service will terminate in Washington DC in the south and Boston in the north during the initial phases of the plan. This requires sufficient storage and layover capacity at or near the station to reduce deadhead (non revenue) train movements. Although initially terminating in Washington, future extension to the south should not be precluded in the initial planning of terminal location and design.

Lateral expansion of the station footprint is unlikely given the land use immediately surrounding the station and the proposed station area and neighborhood development. Reinstallation of two to three terminal tracks on the western edge of the complex is possible and will likely be needed to accommodate commuter growth. These additional tracks on the west side of the facility could also provide the operational flexibility required to remove several tracks in the center of the facility for a purpose built high-speed rail terminal at an elevation several levels below the existing tracks and platforms. This new lower level terminal would allow for future extension to the south through a new tunnel below the existing historic station while providing direct pedestrian connections to the existing Amtrak concourse, Metro station, and any future concourses recommended in the Master Plan.

Boston – South Station
In October 2010, the FRA awarded MassDOT a $32.5 million grant to fund an environmental study and preliminary engineering for the South Station expansion in Boston. Many of the issues that face Washington Union Terminal are relevant in Boston as well. The increase in both intercity and commuter traffic has caused capacity constraints in the terminal. Future commuter extensions to New Bedford, MA and Fall River, MA will further stress terminal operations at South Station. The current plan is to expand into an eight acre site owned by the United States Postal Service (USPS) located adjacent to the station to the east. This would add seven new terminal tracks to increase the total number of slots from 13 to 20.
Again, this expansion is being designed to support the volume levels associated with the 2030 Master Plan and does not account for future high-speed operations or allow for run-through service, which might be a prerequisite to attain the capacity at the station necessary to accommodate Next Gen service. It is early enough in the design and environmental process to expand the scope of this study to account for a scenario that includes these future conditions.

Conclusion

With decisions about Next Gen HSR occurring well after the planning processes at these major terminals have concluded, we cannot wait to learn what type of service will be operated to plan the terminals. We will need to plan these terminals with specific short and medium term interventions to handle the anticipated incremental growth in intercity and commuter rail networks over the next 10-20 years. However, the plans must have the flexibility built into the long term recommendations to allow for entirely new systems to access these critical terminal destinations. How we resolve these issues at the major terminals will ultimately dictate the total capacity of any future rail system. The investments required to construct a Next Gen HSR system in the Northeast will be considerable. We cannot afford to let capacity constraints at our major terminals limit the utility of these investments.

Yoav Hagler joined Parsons Brinckerhoff in the Transit and Rail Systems group in the fall of 2010. As a member of the Operations Planning Division, he is currently the deputy project manager for the Washington Union Terminal Master Plan. Prior to joining PB, Mr. Hagler worked for Regional Plan Association in New York as an Associate Planner for the America 2050 project. In this capacity Mr. Hagler’s research efforts included developing a criteria-based ranking system to identify priority corridors for high-speed rail, as well as developing methodologies for predicted air-rail diversion in the Northeast Megaregion. Mr. Hagler also acted as coordinator of the Business Alliance for Northeast Mobility, a coalition of more than thirty civic and business groups from Maine to Virginia dedicated to improving the transportation networks in the Northeast Megaregion, specifically intercity rail. Mr. Hagler holds a B.A. in economics from Wesleyan University and a M.A. in Urban Planning from Columbia University.
Airline passengers today are generally pretty savvy travelers; no matter whether we’re flying from Anchorage or Ankara, we can make a pretty good guess where to check in, check bags, pass security, buy a coffee, and wait for the flight. There’s a sequence of decisions with which we have become familiar that makes terminal-side air travel almost instinctive. Will passengers on California’s High-Speed Rail fare as well?

Parson Brinckerhoff’s (PB) Program Management Team for the California High-Speed Train Project (CHSTP) has been similarly seeking to define the essence of station design for the first truly high-speed rail system in the nation. We recognize that in order for the future system to be successful, passengers will need to feel a similar kind of familiarity and comfort in CHST stations that we expect at airports (security screening controversy aside). To that end, Parson Brinckerhoff’s architects have been establishing planning guidelines and design principles which will guide regional consultant teams toward functional commonality among California’s twenty-four unique HST stations.

High-Speed Train Precedents

Facility design for travelers has always required extensive front-end planning. In the 1950’s when commercial flying began to “take off”, the earliest commercial airport designers had few precedents from which to plan airline passenger handling facilities; each terminal had to generate a program of space needs for a new breed: the air traveler. Generations earlier, tremendous forethought went into the planning of nineteenth century railway stations to evolve them from whistle stops on the prairie to efficient edifices showcasing the greatest of American architects.

Today, unlike the eras of the early airports or railway stations, we are not without HST station precedents; hundreds exist in Asia and Europe from which we can observe high-speed passenger handling functions. But are Asian or European precedents suited to the needs of California travelers?

A HST station is a close cousin to a mass rapid transit (MRT) station: both move large volumes of passengers via fixed-guideway electrified vehicles. Yet in many respects a HST station bears more similarities to an airport. So what characteristics set a high-speed train station apart from other passenger handling facilities as a new and unique breed? Consider the following station elements:

**Station Location**

Accommodating a tangent (straight) 1,400’ HST platform length presents challenges unfamiliar to designers of MRT stations where platforms are one-third to one-half of this length. But in the same way that MRT stations are integrated into neighborhoods, HST stations will complement community connectivity; access may be via foot or bicycle as well as vehicular modes. The HST station will enliven and activate the neighborhood and be a magnet for community growth.

**Platforms**

The long HST platforms offer a hidden benefit: passengers are distributed over a larger area, significantly reducing passenger density. Train capacity is relatively low; comfortable HST trains will seat no more than 1,000 passengers so the long platforms will provide ample space for boarding and alighting. By contrast, a typical MRT vehicle may squeeze 3,000 to 4,000 passengers into a vehicle less than half the HST length. Side platform configuration, most commonly employed for CHST stations, provides clear separation of northbound and southbound passengers on platforms, further contributing to passenger comfort.

**Vertical Circulation**

Platform occupant load, normally a critical design factor in MRT station planning (ensuring quick evacuation of large passenger loads), is seldom a concern in lower-density HST stations. Provision of adequate escalators, stairs and elevators (vertical circulation elements or VCEs) between platform and concourse is simplified; the long platform of-
fers many opportunities for VCE placement. The controlling factor that typically dictates placement of HST VCEs is the maximum allowable distance to a platform exit (325') rather than a need to move great volumes of passengers.

### Passenger Safety
Without precedent in America, HST stations will no doubt cause some consternation amongst our local building officials and fire marshals who have never reviewed plans for this new breed of transportation facility. Parson Brinckerhoff’s architects are basing station life-safety provisions on the well-tested National Fire Protection Association (NFPA) 130 as well as the 2010 California Building Code which has added new references to high-speed rail. Although both HST and MRT stations serve fixed-guideway vehicles, fundamental operational differences diminish the applicability of NFPA 130 for HST. NFPA addresses high-density platform loadings, frequent trains, missed headways, concurrent multi-train emergencies, etc., none of which typically apply to HST. Nevertheless, we are relying on this document until a more appropriate national HST document is developed.

### Fare Collection
Whereas airline travel generally requires advance ticket purchase and MRT travel allows for stored value or single-ride ticketing, HST ticketing will fall somewhere between the two; reserved-seat tickets will be available either online or inside the stations. Entrance into the station paid zone will be permitted through the familiar electronic fare collection gate rather than being collected by an agent.

### Public Amenities
HST passengers will likely expect station amenities akin to those of airports. Trains may depart hourly or more frequently at major stations. Due to significant trip distances, passengers will likely arrive at the HST station in advance of their ticketed departure time and will expect amenities to pass the waiting time. These amenities may include comfortable, airport-style seating both inside and outside the paid areas, TV monitors, public restrooms, magazine and sundries kiosks, coffee shops, travelers’ assistance, rental car kiosks, etc., amenities unnecessary at MRT stations where trains often depart every two minutes.

### Architectural Image
Like airport terminals, which often become signature architectural statements by which communities put themselves “on the map”, dramatic high-speed rail stations, as we’ve seen in France, Germany, Belgium, China and elsewhere, can become destinations unto themselves. The combination of sleek, aircraft-like vehicles and soaring metallic station volumes often combine to attract passengers to stations simply to gaze at the architecture. CHST station designers will seek to collaborate with each community to generate planning and architectural goals for their station, whether that may mean understated simplicity or iconic drama.

### Conclusion
Having cut my transit teeth on designs of dozens of MRT stations, I initially assumed HST stations would be “super-sized” MRT stations. But this will not be the case; HST stations will have unique identities. They will be large but still pedestrian-friendly, catering to the needs of long-distance travelers while complementing the community. Travelers’ pace (ironically) will be more leisurely, unfettered by crowds, security lines or baggage carousels. Stations will have the potential to invoke a similar kind of fascination as the sleek trains that quietly roll into and out of platforms. Traveling can once again become a pleasure rather than a pain.

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**Gary Newgard, AIA**, joined Parsons Brinckerhoff in January 2010 as Senior Supervising Architect for the Program Management Team of the California High-Speed Train Project. He brings more than a decade of station design and management experience to the project, primarily on Mass Rapid Transit projects in Taiwan and Hong Kong.
Background
Taiwan is an island of a little more than 36,000 km² and a population of 23 million. It is approximately 400 km north to south, and 140 km east to west at its widest. The island is at the edge of two tectonic plates and is characterized by a range of mountains running north-south on the eastern side, which is consequently sparsely populated. The west coast is relatively flat and is the economic and population backbone of Taiwan. Over 95% of Taiwan’s population live and work along the western corridor which includes Taiwan’s major centres of government, industry, commerce and culture. To relieve the heavy congestion and boost the economy, the Taiwan government decided to implement a plan to build a north-south high-speed rail line that would provide easy access to 90% of the island for the entire population. Delivery was to be on a Build Operate Transfer (BOT) basis. The private sector was invited to submit proposals and two groups did so. The Taiwan High Speed Rail Consortium was selected as the preferred bidder. The Taiwan High Speed Rail Corporation (THSRC) was formed by five local and two foreign companies and registered in May 1998 and, following negotiations, Government awarded the BOT concession to THSRC in July 1998. The concession required THSRC to build and operate the railway for a period of 35 years. It also granted THSRC the right to undertake property development around station precincts for a period of 50 years.

THSRC assembled a multinational team to manage the delivery of the project, engaging personnel from world-wide prominent consulting and contracting organizations with high speed rail and associated experience. One of the key service providers was Parsons Brinckerhoff, drawing on their global resources and expertise and as part of their professional services, they seconded personnel to key leading roles in the Construction Management Division of THSRC.

With a US$16 billion price tag, including infrastructure, rolling stock and systems, the 345 km long mega project was one of the most challenging infrastructure projects in the world. Designed for 300 kph operation, the system provides a 90 minute service between Taipei in the north and Kaohsiung in the south. Construction commenced in 2000 and was mostly completed in 2006, a truly remarkable achievement for a mega scale project of this complexity. The railway commenced revenue service in 2007. (Refer to Figure 1).

THSR Maintenance Facilities
THSR system maintenance facilities comprise a main workshop and five depots/maintenance bases. At the start of revenue service in 2007 the Yanchao Main Workshop, Tsoying Depot, Wujih Depot and the Liuchia Maintenance Base were operational. Hsichih Depot and Taipao Maintenance Base will be constructed at a later date as the fleet grows.
and service needs expand. All the facilities were design-bid-build projects with Parsons Brinckerhoff, in joint venture with Sinotech, a major Taiwan consulting company, providing the design and technical support services during construction. The construction contracts were awarded to consortia of local and mostly Japanese companies.

Yanchao Main Workshop

The Yanchao Main Workshop, sited near the south end of the line, is the primary overhaul facility for THSR trains (Figures 2 and 3). It occupies approximately 35 hectares and includes the main workshop, an administration building and all the related facilities necessary for the scheduled inspection and overhaul of the trainsets and the unscheduled heavy maintenance and repair of the fleet cars. All overhaul, inspection and repair functions are undertaken under one roof in the 50,000m² main workshop. The work includes general inspection and overhaul, bogie repairs, wheel re-profiling, unscheduled heavy maintenance, and component repairs of the train sets, as well as maintenance of permanent way equipment and the assembly of new trainsets. Overhaul of train sets requires car bogies, traction motors and bodies to be totally broken down, refurbished, repainted and reassembled. The facility also includes a 1.2 km low-speed test track for the testing of trainsets after overhauls.

Most of the major buildings are piled using 16m long precast friction piles that were driven into a moderately dense, alluvial, silt-clay material. With the exception of the administration building and water tower, all other buildings are steel-framed structures using rigid portal-frame construction with metal panel roofing and siding and are designed for the seismic conditions prevalent in Taiwan. All building roofs are curved with a built-up, double-skin, insulated, standing seam roofs and insulated steel-sandwich panel siding. A special feature of the 140m wide main workshop is the seamless roof construction that was achieved by continuous forming of the 140m long roof sheets on site from pre-coated sheet steel coil stock.

All shops within the main workshop are naturally ventilated via high-level skylights with louvers that can also be augmented by fans during extreme temperature conditions; air conditioning is only provided as spot cooling in specific areas of the workshop. Offices and other special areas are all fully air conditioned. Fire safety was given a high priority and all buildings are equipped with multiple fire detection and prevention systems including smoke detectors and alarms, sprinklers, fire extinguishers, automatic smoke relief windows, FM200 gas flooding in electrical, control and similar spaces, foam sprinkler protection in workshops used for repair of diesel-powered vehicles and, where needed in large facilities, fire shutters to control spread of smoke.

Workshop Equipment

The main workshop has a wide variety of specialized maintenance equipment, some of which is specific to the Shink-
ansen (Japanese Bullet Train) cars and was provided by the core system supplier. All shop equipment was procured under separate equipment contracts.

With the exception of the inspection tracks, all other tracks in various workshops are not electrified for flexibility and safety reasons.

**Tsuying Depot**

Tsuying Depot is one of the two inspection and stabling depots for the THSR project (Figures 4 and 5). The Depot is situated on a 4 km long site and occupies approximately 38 hectares. It comprises an inspection shop with 5 through tracks for the 12-car train sets, stabling tracks for 13 revenue train sets, a wheel truing shop with a double-head wheel lathe, an unscheduled repair shop with a drop table for bogie exchange, and a train washing plant, among other facilities. Administrative staff is located in a separate administration building. Construction of Tsuying Depot buildings is similar to that of the Yanchao Main Workshop.

**Wujih Depot**

Wujih Depot is the second of the two inspection and stabling depots for the THSR. It occupies a site of approximately 20 hectares. Similar to Tsuying Depot, but on a smaller scale, its main functions are trainset stabling, inspection and cleaning, unscheduled maintenance and trainset washing; it also houses the permanent way (PW) maintenance facility. Administrative staff is located in a separate administration building.

**Liuchia Depot**

Liuchia Depot is a PW maintenance base for storing materials, equipment and work trains to maintain the THSR permanent way subsystems including traction power, communications and civil infrastructure. It occupies approximately 7 hectares.

Its main function is to provide a convenient point for maintenance of the northern half of the THSR permanent way.

**The Challenges Faced in Delivery**

This exciting mega-project presented many challenges to the design, procurement and construction delivery teams, too numerous to fully address in this article. Some of the particular challenges that took up an inordinate amount of time, energy and patience while trying to maintain programme were:

- Management of multi-cultural teams of engineers and technicians across a wide range of disciplines with diverse backgrounds, and expectations.
- Language barriers, knowledge transfer and long meetings
- Interface issues and coordination
- The procurement process and the huge volume of tender and contract documentation and drawings
- Addressing design and construction reviews by independent verification and validation teams
- Construction quality issues

The first and second of these, of necessity, led to lengthy group meetings, sometimes taking 8 or more hours, individual counseling sessions, and much mentoring which, though quite demanding at times of extreme work pressure, was highly valued by both mentor and mentee. It was a great inter-cultural experience.

Projects of this nature involve a multitude of design and construction interfaces. Managing these while trying to maintain schedule was the single biggest challenge on the project. One early and greatest interface challenge was the fact that the systems supplier (Shinkansen) contract was awarded very late so that the design information lagged the civil/M&E design by 6 to 9 months and caused extensive delays.
delays that had to be made up in other ways. For example, the civil/M&E designer received only the preliminary design information (from the systems/equipment supplier) at the start of final civil design phase - the result of this can be easily imagined. Early design proceeded on the basis of assumptions (with allowances for later modification), the design period had to be extended, much work had to redone, the tendering period had to be shortened, and so on. Coping with these issues tested all parties, including the owner, the designer and the systems supplier.

The procurement of consultancy services, construction contractors and equipment suppliers followed a process that met strict requirements of international standards of probity and transparency. Expressions of interest were invited on a world-wide scale, companies were shortlisted as pre-qualified to tender, and subsequently invited to tender. Many international companies were successful, always in joint venture with Taiwanese companies. This process, combined with the sheer volume of documentation, at times was overwhelming for the small dedicated team managing and administering this process. Allowance for this process should not be underestimated in resources, time and cost.

Reviews by the independent review consultants were frequent and often time consuming, and this added to the challenge of maintaining schedule. The outcome of all such reviews though was immensely valuable both in the design and construction phases. Independent review should always be allowed for in complex major multi-disciplinary projects.

Construction variation and quality issues occurred in several of the depots, not unexpected in a fast paced complex construction environment of this type. Providing full-time technical support on site by members of the design team helped to overcome many of these issues and assisted in ensuring the design intent was carried through to construction delivery.

The authors would like to acknowledge and thank the Taiwan High Speed Rail Corporation (THSRC) for their kind permission to have this article published.

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Emil Siranovic, a former Parsons Brinckerhoff employee, is now retired and living in Asia. He was a director in THSRC Construction Management Division, and led the maintenance depot design and later provided on-site technical supervision. His experience includes rail projects in Thailand, Taiwan, Singapore and Hong Kong, and in the United States.
California High-Speed Rail: A Uniform Approach for Obtaining Needed Environmental Approvals and Permits

By Bryan Porter, Sacramento, CA, 1-916-384-9522, porter@pbworld.com and Ann L. Koby, Austin, TX, 1-512-347-3525, koby@pbworld.com

As the Program Management Team (PMT) providing support to the California High-Speed Rail Authority (Authority), Parsons Brinckerhoff (PB) is managing the preparation and approval of the environmental documents required for constructing the 800-mile long high-speed train (HST) system. To manage this effort, the proposed system has been divided into nine HST sections. Each requires preparing a project-level environmental document that complies with the California Environmental Quality Act (CEQA), the National Environmental Policy Act (NEPA), and other applicable state and federal regulatory requirements. To complete this effort successfully, the Authority, Federal Railroad Administration (FRA), and PMT have implemented strategies that require consistency in approach, ongoing coordination with regulatory agencies, and proactively applying “lessons learned” from one section to the others.

Approach to Environmental Work

Early in project development, the Authority, FRA, and PMT recognized that the regional consultants the Authority had retained for each of the nine sections needed a common, consistent approach for preparing the engineering plans and environmental analyses required to obtain needed project approvals and the environmental permits. For the environmental work, the PMT developed the following guidelines and documents:

- **Environmental Analysis Guidelines.** These methodology guidelines outline the requirements for preparing technical reports and studies needed for the Environmental Impact Report/Environmental Impact Statement (EIR/EIS). The guidelines address 19 topics: safety and security; transportation; air quality and climate change; noise and vibration; electromagnetic fields-electromagnetic interference (EMF-EMI); public utilities and energy; biological resources and wetlands; hydrology and water resources; geology and soils; hazardous wastes and materials; socioeconomics, communities, and environmental justice; station planning, land use, and development; agriculture and forest lands; parks, recreation, and open space; aesthetics and visual impacts; cultural resources; regional growth, cumulative impacts; and Sections 4(f) and 6(f).

To facilitate the agency review process, the guidelines were reviewed with the resource agencies prior to being used by the regional consultant teams.

- **Environmental Document Requirements.** These are document outlines for preparing the EIR/EIS and 11 technical studies, environmental section templates, a formatting style guide, and requirements for establishing and maintaining an Administrative Record. (An Administrative Record is a collection of documents which form the basis for an agency’s decision, in our case, the project.)

- **Coordination Plans.** Since ongoing coordination is key to educating project stakeholders, the regional consultant teams prepared individual plans for coordinating with public agencies, Native American tribal organizations, and minority and economically disadvantaged community groups. Recognizing California’s diverse population, the Authority prepared guidelines for multi-lingual outreach activities by the regional teams.

- **NEPA/Section 404/408 Integration MOU.** To facilitate compliance under NEPA, the Clean Water Act Section 404, and the River and Harbors Act Section 408, a Memorandum of Understanding (MOU) was prepared that specifies concurrence checkpoints regarding the project Purpose and Need, Range of Alternatives, and Identification of the Least Environmentally Damaging Practicable Alternative (LEPDA). The MOU is unique in that it also incorporates procedural steps for U.S. Army Corps of Engineers (USACE) concurrence under Section 408 of the Rivers and Harbors Act concerning alterations/modifications to USACE flood control and related projects. Figure 1 illustrates how three different sets of statutory and regulatory requirements have been blended into a single review and concurrence process.
**Alternatives Analysis Guidelines.** To help identify a feasible and practicable set of alternatives for evaluation in the environmental document, a protocol for conducting an Alternatives Analysis (AA) was developed. While similar to the Federal Transit Administration procedures, these guidelines require consultation with the U.S. Environmental Protection Agency (US EPA) and the USACE consistent with a project-level NEPA/Section 404/408 Integration MOU adopted for the project. Figure 2 shows how the AA is incorporated into the overall environmental process.

**Statewide HST Approach for Environmental Approvals and Permits.** This draft document outlines the procedures for the environmental approvals required prior to advertising for design-builders for the various HST segments. The goal is to facilitate project delivery by identifying required environmental approvals and permits, fostering timely coordination with resource agencies and outlining key steps for approvals. Potential permits and approvals may include air quality conformity; Endangered Species Act consultation; Coastal Development permits; Section 4(f) and Section 6(f) evaluations; a Section 106 evaluation; Clean Water Act permits; Lake and Streambed Alteration agreements; plus Rivers and Harbors Act approvals.

**Section 106 Programmatic Agreement.** Working with the California Office of Historic Preservation and the Advisory Council on Historic Preservation, the Authority and FRA are implementing the Section 106 Programmatic Agreement (PA) that will govern compliance with requirements under the National Historic Preservation Act and other related federal statutes. Recognizing the importance of tribal and Native American participation, the PA includes specific requirements for participation and review of Authority cultural resource documents. Figure 3 shows the steps the Authority and FRA will follow in complying with Section 106.

It is important to note that these documents are updated as required to incorporate any changes made to the process as a result of the work completed or in-progress by the regional consultant teams, changes in regulations, etc. In addition to preparing guidelines, the PMT is responsible for the overall quality of the documents.
Environmental Quality Control

In response to the fast-paced preparation of the environmental documents and a need to continue reviewing the documents and associated reports, each HST section has an environmental manager and an assistant. Several people have been identified as reviewers for each environmental component. For example, a Parsons Brinckerhoff technical expert reviews the air quality and global climate change analysis results, technical reports, and EIR/EIS sections. ProjectSolve is used as the repository for all documents and comments. PMT reviewers post their comments and revisions in the documents. This expedites the Authority, FRA, and CA Attorney reviews since they have the benefit of viewing the PMT’s comments. In addition, the PMT and regional consultant teams discuss the comments and revisions prior to discussions with the Authority, FRA, and CA Attorney General. All team members have benefitted from these discussions because everyone hears the discussions related to the specific environmental components.

Figure 2– CA High-Speed Rail Environmental Process

Compliance with Section 106 of the National Historic Preservation Act for the California High Speed Train System

Figure 3 – Section 106 Compliance Process
Lessons Learned

One can imagine the complications arising from a project of this magnitude. The Parsons Brinckerhoff environmental team is learning every day what works and what does not work. The teams are very different, employ different perspectives, and have different solutions. It is in everyone’s best interest to garner that knowledge for the good of the client and project. Here are some insights:

- The regional consultant’s budget does not equate to a good job. The PMT reviewers are constantly checking and rechecking reports, etc. to ensure that they follow the guidelines, address comments, are politically sensitive, and adhere to NEPA and CEQA.
- Communication with the Authority, FRA, and CA Attorney General has to be continuous and may take several iterations before an agreed upon path forward is determined. Weekly status meetings are not always enough.
- During the Authority, FRA, and CA Attorney General initial reviews of the EIR/EIS sections, we did not include the regional consultant team members and they could have benefited from the discussions.
- Include the Program Management Oversight representative in discussions so that they understand the background information, nuances, and the “whys” behind the decisions; this alleviates time spent responding to their monthly reports.
- Prepare and keep current a master schedule that the regional teams have to comply with and manage their schedule accordingly.
- If the resource agencies are targeted to receive funding to dedicate resources to the project, start the agreement, scope, schedule, and budget process early. Make sure that you understand the client and agency approval processes.
- Hold a kick-off meeting with the resource agencies to discuss their expectations, data needs, and deliverables. This saves time and helps avoid submittal of documents that do not fully address the agencies’ needs.

Environmental Status Update

For the Authority to remain eligible for American Recovery and Reinvestment Act (ARRA) funding, steady, deliberate progress is needed to complete seven of HST section EIR/EIS documents over the next several years. Adherence to the guidelines and procedures described above will enable the Authority, FRA, and PMT to achieve these goals.

In 2012, the Authority intends to complete environmental documents for two Central Valley HST sections, one for Merced to Fresno, the other for Fresno to Bakersfield. The release of environmental documents for the remainder of the Phase 1 sections will be based on completing needed engineering and environmental work, compliance with statutory and regulatory requirements, agency and stakeholder support, and available funding. Given its size and complexity, this is truly a Parsons Brinckerhoff project. For those of us working to obtain the environmental approvals and permits needed for this project, this is indeed a once-in-a-life time opportunity.

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Ann L. Koby, AICP, is currently the California High-Speed Rail Program Management Team Environmental Manager, and has over 30 years environmental planning and project management experience on transportation projects throughout the U.S.
Parsons Brinckerhoff has been chosen to lead the California High-Speed Rail Program Management Team (PMT), which provides the daily management of the California High Speed Rail Project. The challenge has been how to coordinate and manage a large number of separate, concurrent activities for various parts of the system covering over 800 route miles. The work of the PMT includes the development of project controls, design and engineering criteria, system specifications, environmental methodologies, working with the Federal Railroad Administration (FRA) on safety and compliance issues, as well as working with the state and federal resource agencies to successfully obtain environmental clearances and permits. In addition, the PMT provides direct management and oversight of projects at the local level.

In this respect, the PMT is divided into an Engineering Management Team (EMT) and the more locally focused Regional Management Team(s) (RMT). While the former group focuses on the technical aspects of the project at a programmatic level, the latter teams are tasked with the implementation of these same technical parameters locally. Under the direction of Regional Managers, who in turn are supported by their Regional Engineers, the eight (8) geographically distinct Regional Management Teams are responsible for providing engineering oversight, environmental review, and overall management of the respective local Regional Consultant (RC) teams, which are staffed by other firms.

The RC teams have the responsibility of developing 15% preliminary engineering in support of the project-level Environmental Impact Report/Environmental Impact Statement (EIR/EIS) documents. The RC organizations are also tasked with delivering 30% engineering documents that will then be the basis for the issuance of design-build procurement packages throughout the state. As such, Parsons Brinckerhoff has the responsibility for establishing system level requirements and standards that ensure quality and consistency amongst all the RC’s preparing the environmental documents and preliminary engineering designs for the various sections.

**The Challenges**

In addition to managing the design consultants, the Regional Management Teams have an internal role as interface between disciplines within the PMT to ensure
criteria are met and applied consistently within the geographic section, as well as between adjacent sections. This system approach to design is particularly necessary for those elements that cross section boundaries, such as rail tracks, train control/ signaling and traction power, and is especially evident in a section such as San Francisco to San Jose, where high-speed rail service is planned in a corridor with an existing commuter rail. This situation emphasizes the need for coordination between the RMT, EMT, and other disciplines to develop specific shared-use criteria to potentially accommodate both services. Such approach requires a focused direction and guidance from the PMT.

But not all work occurs in the office. A significant portion of the RMT activities involve extensive coordination efforts with local jurisdictions, members of the public, elected officials, and other organizations to educate and promote the delivery of high speed rail to their communities. It is no easy feat to maintain the objective integrity of the state and federal environmental processes, ensure the consistent implementation of program-wide technical standards, and address local concerns. In addition, with readily available public access to a myriad of online documents and blogs about high speed rail, from friends and foes alike, the educational and outreach process has been challenging. As commonly heard amongst outreach team members, there are days when this effort feels more like a roller coaster than a high-speed ride.

Aside from sporadic – and sometimes sustained – local but vocal opposition to this state-wide project, many other questions and concerns abound from the greater communities. Some questions are easy to answer, for example: “How will you ensure that high-speed trains do not crash with motor vehicles or run over people crossing the tracks?” “Will passengers need to use seat belts?” “How will this project stimulate the California economy?” Other questions may appear border on the absurd: “Since the trains will be travelling so fast, how will we ensure that the trains’ `air field` does not carry debris or other pollutants behind it throughout the state?” “Will the sound or vibration of the passing trains prevent cows in nearby farms from producing milk?” Yet other questions, while valid, are more difficult to answer without potentially compromising the California Environmental Quality Act (CEQA)/ National Environmental Policy Act (NEPA) mandates: “If my home loan is under water and you take my land, will you compensate me for the entire value of the loan or simply compensate me at market value?” “How ‘loud’ will the trains be from my home, exactly?”

Figure 2 – Exhibit board that generally compares sound from high-speed trains to other sources

Figure 3 – Exhibit board for potential San Jose Diridon Station design concepts
To help answer some of these questions and explain to the public the technical and construction challenges inherent in a project of this complexity, we supplement public meetings with visuals, graphics, and 3D models to better convey our message. For example, we complemented exhibits of design concepts (see Figure 3) with wooden models that physically represent the station footprint and other local adjacent facilities (see Figure 4) so that the public has a better perspective of an HSR station and alignment options in San Jose. This went a long way in explaining the design options as well as highlighting the potential impacts on the City’s future development plans. Outreach efforts are of great importance in helping to forge strong and trusting relationships with the communities and to engage them so local input is ensured (see Figures 5 and 6).

Conclusion
With the California High Speed Train Project currently being the largest public infrastructure project in the country, we recognize beyond the evident technical issues that perception matters deeply and widely. Although recent polls by the Authority indicate that the project appears to enjoy support from the greater public in California, we have drawn deep from the PMT and RC pool of talent and creativity to address local public concerns. We continue to work closely with local agency staff, elected officials, the public, and our client, the California High Speed Rail Authority, to shape, communicate, and implement solutions that address local issues but still maintain program and project criteria. As such, we achieve success incrementally but unremittingly. Whether coordinating internally, bridging the understanding between the design consultants and the PMT’s technical staff, discussing technical solutions with local city engineers, or gearing up for the next public information meeting, we strive to uphold the vision of bringing true high-speed train service to California and the United States of America.

Moises Gutierrez, Supervising Engineer, originally joined Parsons Brinckerhoff in 2001 to work on the Tasman East and Vasona light rail extension projects for the Valley Transportation Authority (VTA) in San Jose, California. He joined the HSR project in 2009 as Regional Engineer for the San Jose-Merced segment.

Johnny Kuo, Supervising Engineer, has been part of Parsons Brinckerhoff since 2003. He is the Regional Engineer for the San Francisco-San Jose section. Prior to his involvement with the HSR project, he managed highway projects and led the civil/highway group in the San Francisco office.
Florida’s Miami to Orlando High-Speed Rail Study

By George Walton, Orlando, FL, 1-407-587-7800, walton@pbworld.com

“I look forward to Florida building high-speed rail. I will be able to take Jerry, Elaine, George, and Kramer to the Orlando theme parks without spending too much time with them. Even though Jerry gave me a Cadillac, the 4-hour drive would be too much. A 2½-hour train ride is so much better.”

Morty Seinfeld
Del Boca Vista Tenant Board President

The Miami to Orlando corridor is considered one of the best high-speed rail (HSR) markets in the United States. The termini for this study are in place with significant investment to accommodate HSR service at the Miami Intermodal Center and the Orlando International Airport. Considering factors such as geography, demographics, growth management and environmental preservation, Florida stands ready to deliver the United States’ first true high-speed rail system with planned speeds between 186 and 220 miles per hour.

The Miami to Orlando corridor presents a great opportunity to connect major tourist and business centers. Parsons Brinckerhoff (PB) was selected to lead the effort.

After getting started on the initial work activities, the study was stopped. As part of the 2011 elections, Florida went through an executive leadership change. With a new administration in Tallahassee, many priorities changed, including high-speed rail. Governor Rick Scott chose to not accept federal dollars for the Tampa to Orlando portion of Florida’s high-speed rail system.

This article describes what our study would have been and how it was part of a statewide vision. As with many projects of this size, complexity and controversy, the debate will continue. Many, including the author, hope that one day the study will be revived and lead towards implementing a world class high-speed rail system that Florida (and the US) will be proud of.

Our Study

The Florida Department of Transportation (FDOT) selected Parsons Brinckerhoff (PB) to complete preliminary engineering and environmental analyses to identify a HSR alignment from Miami to Orlando, and to obtain a Record of Decision (ROD) from the Federal Railroad Administration (FRA).

Florida has a long history of HSR planning. Thankfully, St. Augustine’s Fountain of Youth has allowed us to stay young through all the studies. Starting with the 1974 Cross Florida Study, continuing through the 1980s with the Florida HSR Commission Study, then the late 1990’s Florida Overland eXpress (FOX) Study, to the 2000 Florida DOT Coast to Coast Study, and eventually the 2004 Florida HSR Authority Study, Florida has been actively preparing for HSR.

The Miami-Orlando HSR corridor is approximately 235 miles long. The system would connect the Orlando International Airport, which is the proposed terminus of the Tampa-Orlando HSR segment, with the Miami Intermodal Center at the Miami International Airport. A limited number of stations would be provided between these two termini. Substantial prior environmental and engineering work has been undertaken, including initial engineering and environmental review of candidate alignments. However, in the interim, many changes have occurred that require substantial validation and reanalysis. In addition, the Miami-Orlando HSR corridor would be seamlessly integrated into the Tampa-Orlando HSR segment in order to create a single HSR system.
The train, signal, control and information technologies, facility locations, and design criteria for the two corridors must be fully interoperable. This proves challenging as the operating characteristics between Tampa and Orlando are quite different than those between Miami and Orlando.

The HSR system would not utilize at-grade crossings but would be fully grade-separated. In addition, the HSR system would use existing public right of way to minimize community and environmental impacts, as much as possible. The project would be developed to ensure that the HSR system is located as a separate facility from any road systems on which it may be co-located.

The study’s objective was to undertake the necessary environmental and engineering work to prepare the Miami-Orlando HSR Corridor for construction and integration into Florida’s HSR system. This work required undertaking Preliminary Engineering, completing the National Environmental Policy Act (NEPA) process, and developing the Service Development Plan (SDP). At all stages of this work, FDOT was committed to an extensive and inclusive public involvement and outreach program that maximizes public input into the environmental and alignment decisions and provides the transparency necessary for public support.

Several corridor alternatives would be studied for suitability to accommodate the Miami-Orlando-HSR system. Two of these corridors generally follow the alignments of the Ronald Reagan Turnpike (Turnpike) and Interstate 95 (I-95). This project would build on these primary concepts. To avoid the implication that either route is fully aligned with I-95 or the Turnpike, the nomenclature of Inland (Turnpike) and Coastal...
The study would have been developed in three phases which are aligned with three annual and consecutive planning grant cycles.

Phase 1 of the project, which was estimated to take approximately 13 months to complete, included:
- Initiation of the NEPA process, from scoping through selection of the recommended corridors, for which detailed data collection and analysis would be conducted in Phase 2
- Extensive public outreach regarding the NEPA process and the project
- Conceptual engineering sufficient to guide the review and analysis of potential corridor alignments, station and facility sites, environmental and operating issues, and technology selection
- Development of a Draft SDP sufficient to support the initial NEPA and engineering work, including preliminary ridership data, service attributes, trip time analyses, and business case requirements

Phase 2 of the project, which was estimated to take approximately 11 months to complete, was to include:
- Continuation of the NEPA process through data collection and selection of the Preferred Corridor Alignment
- Completion of Preliminary Engineering (about 90% production)
- Completion of the Draft Final SDP, including final ridership data, service plans, and financial data
- Preparation of the Draft Environmental Impact Statement (DEIS) and submission to the FRA
- Continuation of the public outreach efforts; completion of Public Hearings and compilation and reconciliation of comments.

Phase 3 of the project, which was estimated to take approximately eight months to complete, was to include:
- Preparation of the FEIS and submission to the FRA, along with all supporting documentation, for the issuance of the ROD
- Continuation of other public outreach efforts
- Finalization of Preliminary Engineering (100% production), including production of all plans, specifications, and documentation
- Completion of the SDP sufficient to support Florida Rail Enterprise’s (FRE) and FDOT’s plan to procure final design and construction of the HSR project

System Connection to Tampa
Florida’s HSR Vision connects Tampa, Orlando and Miami. The first project planned to be implemented was between Tampa and Orlando. Planned to be located predominantly in the I-4 median, passengers would connect to high-speed trains at stations in Tampa, Lakeland, Walt Disney World resorts, International Drive, and Orlando International Airport.

The project was proposed to be constructed incrementally. FDOT discussed several strategies including one option to release the project as “Early Works” and a Design, Build, Operate, Maintain and Finance (DBOM&F) package. Later versions combined these work efforts as one package. The project stopped before a final delivery plan was determined.

The “Early Works” projects option would have allowed FDOT to start preliminary construction on a fast-track basis, while creating an unobstructed corridor in which HSR construction by the DBOM&F contractor could occur. The early works contracts were planned to include:
- I-4 Median Preparation Project
- State Road 559 Interchange Project
- County Road 557 Interchange Project
- FLHSR Maintenance Facility Site Preparation
- Westbound I-4 Realignment between State Road 417 and Osceola Parkway

Under this delivery plan, FDOT would have sought a concession agreement to design, build, finance, operate and maintain the system. While this initially will only be for the Tampa to Orlando segment, the winning team will have the first right of refusal for implementing the Miami to Orlando segment.

George Walton is a transportation planner with 26 years of experience. He has worked on numerous multi-modal studies. He was recently appointed as the Orlando Area Manager.

A **Service Development Plan (SDP)** is a plan for developing high-speed intercity passenger rail service, either initiating new service or improving existing service (e.g., adding train frequencies and/or reducing trip times). They are typically broken down into distinct phases and/or geographic sections of service improvement. The form of an SDP is up to the applicant and may draw from and include reports and documents prepared for other purposes. An SDP or equivalent covers three general topics:

1. **Rationale** (including purpose and need)
2. Service/operating plan and prioritized capital plan, and
3. Implementation plan (including project management approach, stakeholder agreements and financial plan)
The Benefits of Integrating Linear Scheduling with Gantt Chart Scheduling

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On large linear construction programs, with constrained and incremental funding, it is quite common for implementation decisions to be made based on an integrated assessment of what can be built with the incremental funding, and how these components can be integrated with existing facilities. Showing this in a Gantt chart can be problematic. Consider the example of the California High-Speed Rail Program. With initial funding constrained, only a portion of the Program could be built as the first project. The decision had to be made on how much of the rail line could be built and completed on time with the initial funding. The Gantt chart could identify the schedule to complete the work and the estimate could break down the cost of the various components, but it could not give a complete view of what was being built, where it was being built and the time frame.

Gantt charts (see Figure 1 below) are a common technique for representing the phases and activities of a project work breakdown structure (WBS), so they are understood by a wide audience. They have been in use since the early 1900s. The critical path method (CPM) is best reflected in a Gantt chart, which has been widely employed by the engineering and construction industry. Those projects which deal with repetitive horizontal construction, such as highways, pipeline and rail projects, can find these tools to be missing a key component - distance. This is particularly true when integrating the project features, location and timing.

The solution is to use a scheduling technique known as Linear Scheduling Method (LSM). It is known by several other names, including time-chainage diagram, line-of-balance scheduling and time and distance scheduling.

For the California High-Speed Rail Program, the linear scheduling method has been used to provide an essential view of the information missing from the Gantt chart. Linear scheduling combines the time and distance into a single graph. In Figure 2 below, distance (mileage) is on the X-axis and time is on the Y-axis. This simple graphic takes the output of the schedule and displays it vertically and adds the type and location of elements being constructed. The elements’ height represents the length of time needed to construct them.

This method provides a graphical way to relate the physical location of each construction element and its timing. This improves management decision-making by allowing for effective package planning, avoiding interferences in the field. It also enables management to see clearly which physical elements are on the critical path. For the High-Speed Rail Program, these diagrams were used to show the various development alternatives and budget restraints. Additional graphical information can also be linearly placed to reflect the locations of critical right-of-way acquisition, stations and utility conflicts, as well as tie-ins to existing rail lines. This facilitates effective management decision-making in selecting the best alternative and is best portrayed in a linear planning tool.

The linear scheduling diagram focuses on the
The pre-construction phase of the work since the pre-construction phase (design, environmental, permitting and right-of-way acquisition) generally applies to the entire project, regardless of distance. The Gantt chart below (Figure 3) was used to reflect the detail of the pre-construction activities. This information was combined with the linear scheduling diagram above (Figure 2) to provide a complete picture of the project, enhancing management’s ability to make effective procurement decisions.

The linear scheduling diagram (Figure 2) condenses location and time-specific information along with additional reference information in a single chart. Each diagram represents an alternative alignment. Starting at the bottom, above the key, the individual segment’s limits are defined (Segment ML, F2, H and A2/P/C1). Above, along the X-axis is the distance (in miles) from the start of the alternative alignment on the left. In this example, it reflects a total of 76 miles. The duration of the pre-construction activities (along the Y-axis) take place during the three year period in solid white, from 2010 through 2012. In this white band, the additional reference information is shown, including the cost for the alternative, the critical NOD/ROD (Notice of Determination / Record of Decision) milestone date (Nov 2011), the general locations of towns and stations, and tie-in locations to existing railroads. The earliest Notice-To-Proceed (NTP) for construction in this example project is January 2013, where the grid squares start. The diamonds at the bottom of the grid indicate the locations of utility impacts. Those underneath the viaducts are the most critical.

The varying shades of horizontal bands represent the areas of at-grade civil work. The civil work completion in 2015 is considerably sooner than the major structural construction elements, which aren’t complete until early 2017. That means the areas of at-grade civil work have extra time available. The elements that take the longest to build are the viaducts. Based on their length (miles), it was determined that viaducts ML and D could be constructed using a different method of production, making them more efficient than the shorter viaducts A, B and C. As a result of the linear progression, viaducts ML and D are shown with a sloped finish, meaning they will be completed from left to right in the time frame shown. The light gray color underneath the dark gray viaducts represents the critical right-of-way acquisitions. The viaducts, being the longest to build, need to have their
parcels cleared first. This enables management to know in which order the specific parcels need to be acquired. This information, along with the critical utility impacts, can be ascertained from neither the Gantt chart schedule, nor the estimate. The linear scheduling diagram makes this information clear. Small bridges and overpasses are also shown, all with earliest possible starts. The last construction element represented is the track installation and final adjustment. The nearly-horizontal lines are sloped up from left to right at a slight angle. This represents the way the track will be installed and its production rate. In this example it stopped just short of Viaduct D.

This linear scheduling diagram provides a clear picture for making alternative selection and packaging decisions. Management was presented with three alternative alignments, this example being one of them. It is easy to see which areas the rail would span and how it would tie-in to the existing track, a Federal requirement for independent utility. Comparing the costs of the alternative to see how much can be built for the available money and the possible political ramifications of each choice is a benefit of linear scheduling. From this presentation the decision was made to select Alternative 1. Furthermore, packaging decisions were made based on congruent locations and construction elements. In addition, the program management team now knows which areas will require critical right-of-way acquisitions and utility relocations to allow an early start for those activities.

In summary, alone the Gantt chart schedule does not provide the clarity required for this linear rail program. The use of the linear scheduling diagram combined with the Gantt chart tool provides management with a complete picture of the options, choices and challenges to assist in making effective decisions. That is the goal of all project controls tools.

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